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Final report

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Acronyms

ACCESS-S	Australian Community Climate and Earth-System Simulator
ACIAR	Australian Centre for International Agricultural Research
AIP	Agricultural innovation platform
ANU	Australian National University
APEP	Australia-Papua New Guinea Economic Partnership
APR	Anglo-Pacific Research
BOM	Bureau of Meteorology
CBO	Community-based organisation
CCDA	Climate Change Development Authority
CDWAI	Community Development Workers Association Inc.
CIC	Coffee Industry Corporation
COVID-19	Coronavirus disease 2019
CREWS	Climate Risk Early Warning System
CSA	Climate smart agriculture
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAL	Department of Agriculture and Livestock
DFAT	Department of Foreign Affairs and Trade
EHP	Eastern Highlands Province
ENB	East New Britain
EOPR	End of project review
FFT	Family farms team
FGD	Focus group discussions
FPDA	Fresh Produce Development Agency
FRI	National Forest Research Institute
IDM	Individual Deprivation Measure
KII	Key informant interviews
LP	Linear programming

M&E	Monitoring and evaluation
MAFT	Mission Aviation Fellowship Technologies
MDF	Market Development Facility
MTR	Mid-term review
NARI	National Agricultural Research Institute
NGO	Non-government organisation
NPK	Nitrogen, phosphorus, and potassium
NWS	National Weather Service
OLR	Outgoing longwave radiation
PAR	Participatory action research
PAW	Plant available soil water
PGK	Papua New Guinea Kina
PLB	Potato late blight disease
PNG	Papua New Guinea
PT	Pathogen tested
RMM	Rainfall management matrix
SARDI	South Australian Research and Development Institute
SCF	Seasonal climate forecast
SCFA	Seasonal climate forecast advisory
SCFG	Seasonal climate focus group
SFA	Seasonal farm advisory
SMS	Short message service
SNA	Social network analysis
SWCEM	Space-based Weather and Climate Extremes Monitoring
UNITECH	University of Technology
UoG	University of Goroka
UTAUT	User Acceptance and Use of Technology
WMO	World Meteorology Organization

1 Acknowledgments

The project team sincerely appreciates everyone who contributed to the success of this project. We are especially grateful to Dr. Shaun Lisson for his invaluable role in the early stages, including his significant contributions to the field trial design and the rainfall management matrix. We also extend our thanks to Dr. Peter Hayman and Dr. Geoff Kuehne for their support in adapting the WonderBean to the Papua New Guinea context. Our gratitude goes to our mid-term and end of project reviewers—Dr. Mike Bourke, Dr. Miok Komolong, Ms. Jessica Raneri, and Dr. Veronica Bue—for their insightful feedback. We also acknowledge the Australian Bureau of Meteorology for their support of the National Weather Service. Most importantly, we thank all the farmers who participated in our activities, shared their experiences, and provided valuable feedback on the farm trials and seasonal farm advisories. Their involvement was essential to the project's success.

2 Executive summary

Climate variability plays a significant role in Papua New Guinea's (PNG) food security due to the country's heavy reliance on subsistence agriculture and traditional farming practices. Evidence shows that climate variability is disrupting traditional farming calendars and indigenous knowledge systems, reducing community resilience. In response to these challenges, this project sought to facilitate the use of scientific and indigenous seasonal climate forecast (SCF) information to underpin important food production decisions of farming communities in PNG. SCF information has been a useful tool to help adapt to and prepare for climate variability. However, farmers often do not use it due to the complexity of the information. To address this challenge, the project team utilised best practices from climate smart agriculture (CSA) initiatives to bring together different stakeholders to co-produce SCF products that are useful and relevant to farmers in PNG. The collaborative process strengthened institutional ties between government agencies and research institutions in the country which could have lasting influence in future projects and services.

The project team successfully developed SCF products that informed farmers' management practices. For nearly eighteen months, the National Agricultural Research Institute (NARI), with support from the Australian National University (ANU) and the National Weather Service (NWS), delivered seasonal farm advisories (SFAs) via SMS to farmers in the Eastern Highlands Province (EHP). The SFAs were based on SCF advisories (SCFAs) developed by the NWS, and a Rainfall Management Matrix (RMM) developed by NARI and project partners. These outputs provided **timely, localised, and relevant forecast information** as well as best farm management practices informed by indigenous knowledge, farm trial results, publications, and expert advice.

The SFA and SCFA have been shared with a range of stakeholders, including farmers, PNG government agencies, extensions officers, and non-government organisations (NGOs). SFA recipients have said that the SFAs have been useful to informing and introducing more confidence into their decisions. Farmers said they adjusted their planting and harvesting schedules in accordance with the advice provided in the SFA, resulting in increased yields and avoided crop losses. Due to this, farmers reported that they now produce vegetables to sell on the market. Meanwhile, extension officers used the SFAs to advise farmers on the best time to plant their crops and management practices to improve their yield, resulting in the successful introduction of a new crop variety. Feedback from SFA recipients was overwhelmingly positive with a strong demand that it is continued and expanded in the future.

The project team also developed communication outputs to help stakeholders better understand SCF information, probabilities, and its impact on agriculture. University of Goroka (UoG) adapted "WonderCrop," an excel-based engagement tool about probabilities, into a community game. Farmers enjoyed the game and the resulting discussion around forecasts and farming adaptation practices. UoG also created a suite of videos to share with communities that discuss indigenous practices, the usefulness of SCF information, and adaptive farming practices. Meanwhile, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) developed a bio-economic modelling tool to spur discussion around SCF and agriculture among policymakers, researchers, and extension officers. These materials will still be used after the project to raise awareness and support discussions about climate change adaptation and the utility of SCF information on farms beyond EHP.

The SFA provides a useful 'proof of concept' that PNG stakeholders can use to scale out to other provinces, whereas individual outputs can be used and adapted for other projects. While significant work has gone into the development and initial extension of the SFA, there is scope to verify practice change and validate the value derived from this process to provide additional support to introduce a similar service in other provinces in PNG. Local partners would benefit from additional capacity and resources, including a partnership with a local telecommunication provider, to continue delivering and expanding the service.

3 Background

Agriculture in PNG is heavily impacted by climate change, threatening food security and stability in the country (Allen and Bourke, 2009). Over 82% of the population remains reliant on crop production for subsistence and income (Bourke and Vlassak, 2004). Confronted with uncertainty about forthcoming seasonal conditions, farmers typically fall back on historical practice based on a ‘normal’ season. Substantial divergence (e.g. drought or excessive rainfall) away from these ‘normal’ rainfall conditions expose farmers to production risk.

Effective management of climate variability, such as drought and heat stress, has proven to mitigate the impacts of climate change and even increase farm productivity (Berhane, 2018). The provision and uptake of SCF information has been identified as facilitating adaptation to seasonal climate variability; however, its introduction and use in rural community food production decisions is seen as challenging due to the complex nature of the information. Farmers, especially those in low- and medium-income countries, typically do not have access to climate risk management strategies since most information is not contextualised for them (Alexander et al., 2020). Climate researchers often focus on the scientific content rather than its social relevance and understandability. There is a need to address this gap and identify a method to effectively translate climate information in a way that is useful and understood by end-users at the farm-level (Alexander et al., 2020).

To be most effective, climate information needs to be ***co-designed*** by different stakeholders, including climate scientists, local expert forecasters, agricultural extension officers***, and farmers.*** This often leads to improved collaboration, sharpened knowledge and skills, and higher critical thinking and problem-solving abilities (Khatri-Chetri et al., 2017). Around the world, CSA initiatives have been rolled out to systematise the co-production process and engagement. CSA has been promoted to increase productivity, improve resilience to climate variability and change and, where feasible, reduce greenhouse gas emission in farming systems globally. CSA is unique, by comparison, to other agricultural development approaches because it is outcome oriented, explicitly considers synergies and trade-offs among food and environment objectives, and promotes solutions relevant to specific times and places. The success of these initiatives has been dependent on culturally appropriate interactions with communities and targeted technological transfers to communities and extension providers. In many cases, these CSA initiatives have resulted in improvements in rural livelihoods and the engagement of women in agricultural decision-making (World Bank Group et al., 2015). To achieve these results, elements from a range of CSA projects were tested to ensure they are appropriate and effective in PNG.

In rural communities of PNG, there are low rates of numeracy and literacy. Both men and women are actively involved in agricultural systems but play different roles (Allen, 2009). These social and gendered influences make it extremely challenging to successfully transfer seasonal climate technologies to rural communities to support agricultural production (Caffery & Hill, 2018). Cognisant of these challenges, the project team conducted a full review of CSA initiatives and established field trials to address questions and demonstrate the value of SCF information, incorporated with indigenous knowledge, to local farming communities.

Project approach

This project took a “learn-by-doing” approach, through field days and training. It was designed to incorporate adaptive management and utilised regular monitoring and evaluation (M&E) and reflection exercises to ensure effective co-design among project partners. The project also undertook an internal survey activity to determine if partner’s understanding of the project aims, objectives, and deliverables was uniform. This activity highlighted considerable divergence in understanding that had to be addressed ahead of project implementation. The project also adopted a case study community engagement strategy, varied learning activities with different segments of the community, and conducted experiments within communities and at research stations. A strong co-design ethos was established for this project to ensure that communities have ownership of the learning outcomes.

This project was designed to continually revisit the initial assumptions and modify activities for continued relevance. The integration of scientific and indigenous knowledge occurred via aggregation of information from surveys, Agricultural Innovation Platforms (AIPs), and field trial activities. As of 7 February 2025, 467 farmers in EHP were receiving SFAs via SMS. It is estimated that these CSA initiatives have reached an estimated total of 700 farmers.

Project team

To successfully implement the project, the team was composed of a range of stakeholders with different expertise, including agronomy, communication, and climate science. The project team was led by ANU and composed of representatives from CSIRO, Sustineo, NARI, NWS, UoG***, and Fresh Produce Development Agency (FPDA)***. The project originally involved the Department of Agriculture and Livestock (DAL), Climate Change Development Authority (CCDA), and Phloem3. However, DAL and CCDA eventually withdrew from the project due to lack of capacity to service the project and in the case of Phloem 3, life-threatening illness. The Australian-PNG Economic Partnership (APEP), which was added as a project partner in variation 5, did not formally join the project team as it wanted to explore avenues to formally fund specific aspects of the project from internal funds. Whilst APEP has received a proposal from the project team, the endorsement and resourcing of this project remains at the proposal stage. The funds allocated to these organisations were redirected towards other partners to increase community engagement, post coronavirus (COVID-19).

Project variations

The project has gone through several changes due to the outcomes of the project's mid-term review (MTR), reduction to the number of partners (as outlined above), and the impact of the COVID-19. The pandemic curtailed project team meetings, field trial establishment, and community engagement activities. To adapt to the situation, the project team relocated initial field trials to NARI research stations instead of conducting them within target communities. While this approach allowed trials to continue, it hindered farmer engagement, as participants had to travel to these locations. Efforts to enhance community engagement have occurred in the last two years of the project by additional activities undertaken by UoG, NARI, and FPDA.

During the project, there were limited data and capacity to undertake farm trials at Morobe and East New Britain (ENB) as originally planned due to staffing changes and limited farmer engagement. However, there was significant momentum in EHP due to the community outreach of three partners—NARI Aiyura, UoG, and FPDA—who were all based in the province. Moreover, EHP had rainfall data from the last 70 years which was useful in validating and refining NWS forecasts for the province. As a result, the project team, in consultation with ACIAR, decided to focus its efforts in EHP where there was more capacity among project partners and interest from the communities. By focusing on a single province, the project team was able to optimise its resources to understand how SCF information should be shared and communicated to communities. The outcome is a consultative and collaborative process that can guide further expansions into other provinces once additional resources have been secured.

NWS also took the lead in broader-government engagement in Port Moresby, a role initially earmarked for DAL and CCDA. Lastly, in response to the advice provided by the MTR reviewers, the project team decided to focus on refining the SCF outputs and messaging rather than pursuing a full-scale dissemination of SFA. Other activity-level changes were made in response to the changes above and on-going learnings from project implementation.

The project has undergone five formal variations which are listed below.

- Variation 1 – Adjusted activities in response to delays caused by COVID-19

- Variation 2 – Revised project activities
- Variation 3 – Extended the project by nine months and provided an additional $42,000
- Variation 4 – Removed DAL and CCDA as project partners
- Variation 5 – Extended the project by six months and provided an additional $166,723

Project impact amplification

This project leveraged funding from the Department of Foreign Affairs and Trade (DFAT) to determine the most appropriate SCF to utilise in the project and assess the availability of existing operational weather information. The funding also supported the training of NARI and FPDA staff to undertake the social network analysis (SNA) survey and supported the purchase of tablets upon which the survey results were recorded.

The project also leveraged capacities within Australia's Bureau of Meteorology (BOM) through a negotiated extension of the Australian operational SCF to include PNG, and the extraction of high resolution SCF information for EHP, Morobe, and ENB provinces. This, as well as the provision of a range of forecast products, was made possible by members of the project team and leveraged engagement occurring through the PNG Climate Risk Early Warning System (CREWS) project. The CREWS team also provided ongoing support and training to the NWS staff working on this project.

Lastly, the project adapted two SCF products developed for other contexts. First, the project team worked with Dr Peter Hayman, Principal Scientist in Climate Applications at South Australia Research and Development Institute (SARDI), to create a version of 'WonderBean' appropriate for PNG entitled, 'WonderCrop'. It is a game to help users better understand probability and the utility of SCF in agriculture. This adaptation process is further explained later in the report. Second, the project team included Dr Uday Nidumolu from CSIRO to develop a bio-economic model that integrates SCF for PNG. Dr Nidumolu had previously developed similar tools for India and Bangladesh (Nidumolu et al., 2016; Nidumolu et al., 2022).

4 Objectives

Within the broader development goal of sustaining and, where possible, improving the food security of Pacific smallholders and their communities, the primary aim of this project is to support the enhancement of existing agricultural production through the provision of seasonal climate information in a form that will allow rural communities to respond to unfolding seasonal climatic conditions. It aims to facilitate the use of scientific and indigenous seasonal climate information in PNG farming communities to underpin important food production decisions.

The project originally had three key objectives:

1. To incorporate scientific and indigenous seasonal climate information into farming practices to improve the climate resilience of PNG food production.
2. To demonstrate the potential value of integrating scientific and indigenous knowledge to improve food production outcomes for rural communities via field trial activities, gaming theory, and modelling.
3. To provide Government, Industry and NGOs access to the SCF and SFA information and disseminate knowledge products to farming communities across case study locations in PNG.

During the end of project review (EOPR), the reviewers pointed out that these objectives did not capture the changes in the project that occurred in response to feedback and suggestions from the MTR conducted in 2022. Specifically, the MTR reviewers suggested that "future engagement with local communities should be viewed as a mechanism to gain feedback from rural producers rather than an outreach exercise." Therefore, community engagement was focused on refining the outputs of the project and ensuring that the messaging and delivery methods were suitable for rural farmers. In the 2022 Annual Report, the team added the following end of project outcomes: creation of an SFA, enhanced capacity to understand local climate information, and adjustment of farm practices in line with agronomic guidelines supplied via the SFA. These have been rephrased into the following objective:

4. PNG farmers better understand the value of SCF information and how to use it to support their farm management decisions.

To achieve these objectives, the project activities were divided into five components listed below.

- Component One – Understanding the knowledge landscape
    - The project team sought to understand how climate and weather information is accessed, shared and utilised in the case study regions to ensure that extension and communications activities are effectively tailored.
- Component Two – Establishing field trials
    - The field trials were co-designed with project partners and case study communities to demonstrate the value of using SCF information to manage farm practice.
- Component Three –SFA design
    - The SFA translated the SCF into a form that supports changes to farm management. The SFA was developed in consultation with project partners and considered survey results and community feedback.
- Component Four – Communication and extension
    - The roll-out of the SFA and other related information as generated by the project was undertaken with communities, church groups, web-based information, radio, SMS and government roundtables. This encapsulates most of the project's community engagement.
- Component Five – Economic modelling and value demonstration

- The team sought to demonstrate the additional value of SCF information through a bio-economic modelling platform and farmer field days. This model has been developed using PNG baseline information on commodity prices, labour costs, farm inputs etc. and has been used to show the result of seasonal conditions.

To demonstrate the connection between the activities under these components and the objectives, the project team has created a simple theory of change. This was developed in response to feedback from the EOPR.

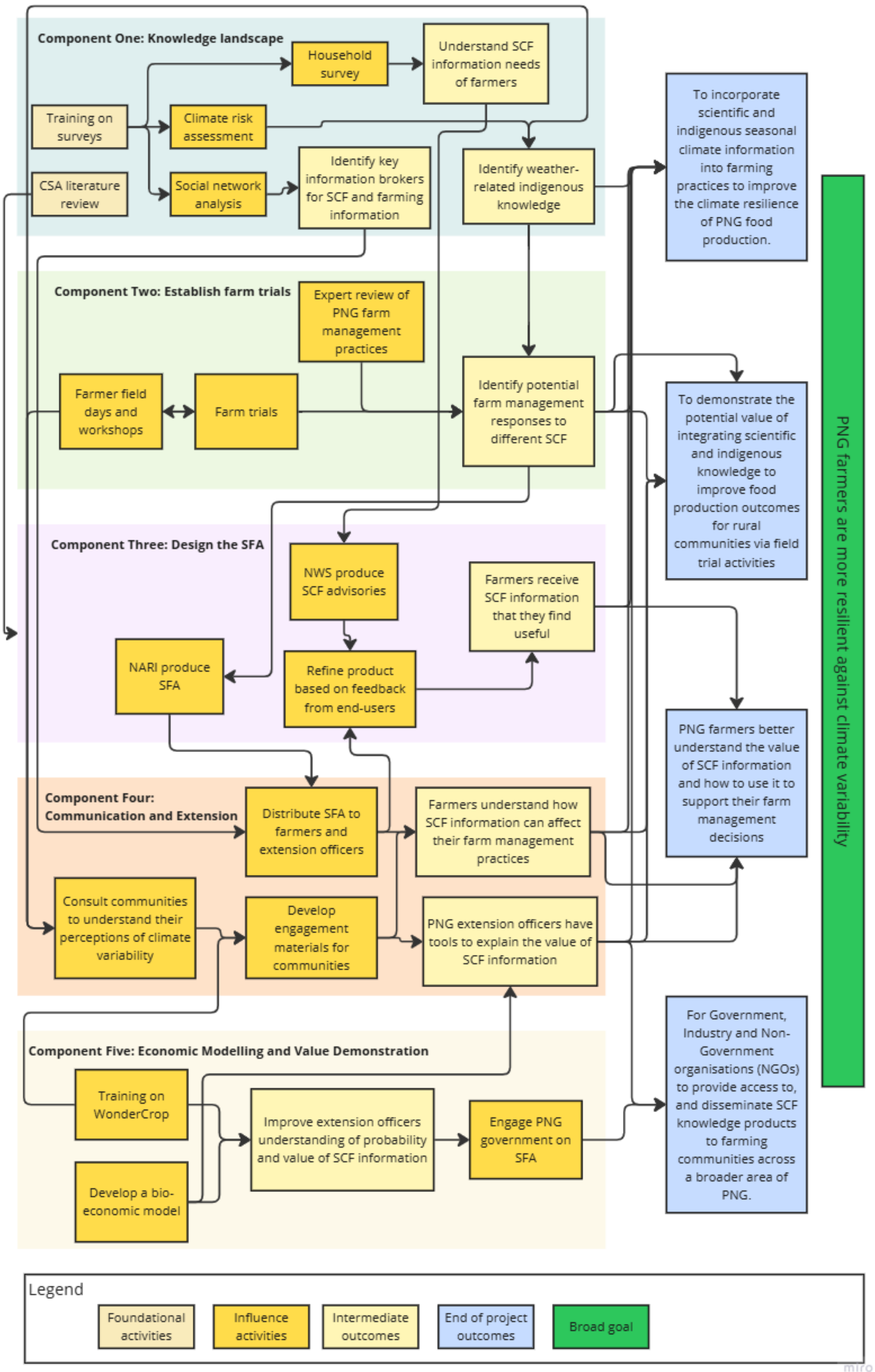


Figure 1 Theory of Change

5 Methodology

To achieve the objectives outlined in Chapter 4, the project adopted an interdisciplinary and co-designed research strategy that established the building blocks for an accessible and scalable climate information service (e.g. SFA). The building blocks have been as follows:

1. a review of existing CSA programs around the world to frame activities undertaken during the project and to pinpoint elements that could be applied to the PNG context;
2. SNA and household surveys to establish a baseline of climate information requirements and channels for dissemination;
3. field trials to determine the impacts of different management practices and demonstrate the value of SCF information; and
4. dissemination strategy for the SFA knowledge products applying the lessons learned through the SNA and household surveys.

Each of these components required specific research methodologies and activities to achieve planned outputs in each of the components and the overall project objectives. The methodologies adopted for these activities are explained in the following sub-sections and are discussed according to the five components presented in Chapter 4.

This project took a "learn-by-doing" approach, through field days and training. It also had adaptive management built in, including regular M&E and reflection exercises. The case study communities played a central role in determining the sorts of learning activities that were produced and made available, as well as the experiments undertaken as part of the field trials. The project's approach to M&E is also discussed in this chapter.

Case study sites

Five trial sites were established in NARI research stations at Aiyura (EHP), Lae (Morobe) and Keravat (ENB). The rationale for selecting these locations is that they provide the ability to examine the role of CSA initiatives:

- across different climatic zones;
- across both subsistence (EHP and Morobe) and commercial farming systems (ENB);
- in parallel with existing extension activities;
- in proximity to major NARI centres; and
- in proximity to other agricultural service providers.

5.1 Methodologies to understanding the knowledge landscape

In the first component of the project, the team aimed to deepen its understanding of the PNG context. This centred on collecting information to guide the design of SCF products and determine the most effective distribution strategies to maximise reach despite limited resources. This was complemented by a global review of CSA initiatives to identify best practices applicable to PNG. Additionally, the team explored farmers' perceptions of climate risk and their mitigation strategies, while also documenting indigenous practices that could contribute to building more climate-resilient farms.

5.1.1 Social network analysis

For the SNA, 1,284 respondents were engaged through data collection activities, conducted across two iterations of fieldwork, in October 2018 (Morobe and EHP) and October 2019 (ENB). However, only 650 respondents exchanged information, and were therefore included in the network analysis.

Within each province, the study area was identified in consultation with NARI. Within each study area, the village locations were randomly identified before being confirmed as appropriate in consultation with NARI. At the village level, survey teams, composed of local Papua New Guinean researchers from NARI and Anglo-Pacific Research (APR), followed a stratified random sampling approach to respondent identification, while also following sampling quotas to ensure a representative spread of the population by gender and age (18–25, 26–40, 41+ years) in target areas. The survey targeted participants who identified as farmers, were over the age of 18 years old, engaged in cropping-based agriculture, and who resided in the study area. In all surveys conducted, female interviewers interviewed female respondents, and male interviewers interviewed males. All data were collected using the Akvo tablet-based data collection platform, and respondents provided informed consent prior to participation.

Table 1 Breakdown of SNA survey respondents

Province	Area	Women	Men	Collection period
Eastern Highlands	Asaro Valley and Bena Region	143	107	October 2018
Morobe	Markham Valley	96	104	October 2018
East New Britain	Gazelle and Kokopo Districts	124	76	October 2019
Total		363	287	

To analyse the data, chi-square tests were run and Cramer's V calculated to identify relationships and their strength between the gender, province, age, education, occupation, and religion – social characteristics that might influence the network. To examine the flow of weather and climate information amongst survey respondents, network maps were constructed, in which individual survey respondents and organisations were two node types and information flow was the directed edge. Node attributes included gender, province, and barriers. The analysis was structured at an overall level, which aggregated findings across all three provinces, and disaggregated by gender to explore the differences between women and men.

Analysis and visualization were carried out in R Studio. To better understand the information sharing networks and how they vary based on gender, the team first calculated the network level centralization and density, which provide measures of network cohesiveness. Then the team identified which nodes were influential in the information sharing network, calculating node level outdegree and betweenness centrality. All calculations were made using the 'igraph' package (Csárdi & Nepusz, 2006) and normalized for two-mode networks based on Borgatti and Everett (1997). Node-level out-degree centralities were re-calculated considering the weight of ties based on the usefulness of information using the 'tnet' package (Opsahl, 2009). This was carried out in networks disaggregated by gender and province. To examine the relationship between barriers and the information networks, the team calculated the frequencies with which each barrier was identified, disaggregated by gender, and ran Pearson's Chi-squared tests. The team then redrew each network including nodes associated only with a specific perceived barrier. Centrality scores for the organisational nodes were recalculated and compared against the whole network.

5.1.2 Baseline household survey

The baseline household survey was divided into two parts: a household level survey and an individual level survey. The surveys and its translation into Tok Pisin were a collaborative process among all partners.

For the household level survey, a man and woman from each household were surveyed together and were asked questions about their household. Typically, it was a husband and wife who participated in the household level survey, but when this was not possible, any two adults of the opposite gender who could answer questions about the household were surveyed. The same man and woman were then surveyed separately as part of the individual level survey. They were asked the same set of questions but answered them separately. To the extent possible, the individual level survey was conducted privately, away from the other members of the household.

Overall, 171 respondents and 192 households were engaged through data collection activities, conducted across two iterations of fieldwork, in December 2020 (Morobe and EHP) and February 2021 (ENB). The survey was developed to draw out key design considerations for SCF in terms of timing, content, and use of information. Because participants could provide multiple responses to some of the survey questions, the data was reformatted as binary response variables.

Table 2 Background information on household survey respondents

Province	Area	Household survey	Individual survey	Collection period
		No. of households	No. of respondents	
Eastern Highlands	Bena Valley, Asaro Valley, Aiyura	30	51	December 2020
Morobe	Markham Valley, Situm Area	32	61	December 2020
East New Britain	Kerevat area (Inland Baining, Napapar #5 LLG)	30	60	February 2021

Within each province, a list of households participating in the project were provided by NARI and FPDA who are the key organisations responsible for farmer engagement in the project case study sites. From this participant list, the fieldwork team aimed to survey 30 households in each province. The quota of 30 households was designed to be made up of 25 households participating in the project and five households not in the project. This sampling approach allows for some limited comparison between farmers in the project with those in the same community but not in the project, to better understand what impact the project is having. The households not in the project were identified randomly but met the requirements of being engaged in crop-based agriculture and from the same villages as farmers in the project.

Due to some difficulties locating 25 households in the project in each province, the quota was not able to be met in Morobe province. Instead, 16 households in the project and 16 households not in the project were surveyed.

Table 3 Individual survey respondents by age group and gender

Age	Female		Male		Total	
	No.	%	No.	%	No.	%
16-25	16	19.8%	12	13.3%	28	16.4%
26-40	44	54.3%	45	50.0%	89	52.0%
41+	21	25.9%	33	36.7%	54	31.6%
Total	**81**	**100.0%**	**90**	**100.0%**	**171**	**100.0%**

In the first instance, the team used descriptive measures and statistics to understand how information needs were distributed across groups. Chi-Square analyses (with contingency tables) were carried out using the “gmodels” package (Warnes et al., 2005), to identify whether differences in the clustering variables existed based on the gender of farmers or their geographic locations. Cluster analysis provided a useful method to examine the intersection and groups of multiple variables simultaneously. The variables related to timing, types, and uses of information were used to examine how climate and weather information could be bundled to form discrete information products. To delineate particular profiles of information users, the team performed kmedoids cluster analysis using the “cluster” package (Maechler et al., 2021). Gower distance was used in the computation of pairwise dissimilarities. The number of clusters (k = 5) was determined using the silhouette method, an internal validation approach that compares silhouette measures indicating similarity of a data point to its own cluster compared to other clusters, for different numbers of clusters.

Once clusters were defined, the dominant information needs for each were summarized and described. Individual respondents were assigned a cluster number based on the fit of their responses. To better understand what characteristics could influence cluster membership, the team used chi-square analyses between cluster number and socio-demographic variables. The team also included perceived challenges to accessing and using information in the analysis to highlight potential barriers to rolling out the different cluster information products. All visualizations were created using ggplot2 (Wickham, 2016).

5.1.3 CSA literature review

To inform the SCF design process, the project team conducted a literature review on CSA implementation globally, to identify common successful elements for implementation in PNG. This undertaking involved reviewing case studies of the approaches to integrate scientific and traditional weather and climate information, package the information in accessible formats for end users, and build extension and communication services for dissemination. A total of 27 case studies were reviewed, the majority of which were in Africa (n=18), then Asia (n=6) and Latin America (n=3). Several different models for platforms to engage communities in CSA were considered, which share many of the same principles, drawing together a network of actors, institutions, and technologies, and promoting knowledge development and diffusion.

5.1.4 Interviews

The project conducted several focus group discussions (FGDs) throughout the project. These were useful opportunities to better understand farmers' needs, capture their indigenous knowledge, and receive their feedback on project outputs and activities.

As part of a climate risk assessment, twenty-one interviews were conducted by seven FPDA staff members. The interviews were conducted on 19 and 20 May 2020 at Mohuveto #1, Unggai-Bena district, and Kuka Village, Daulo district, in EHP. The purpose of the interviews was to explore the smallholder farmers' experience and understanding of growing food, and the decisions that they make in response to changes in the weather. A structured survey was delivered to the interviewees, and the results were compiled by CSIRO.

NARI and FPDA staff also conducted seven FGDs across the case study sites to better understand some responses to the baseline survey around their cropping calendar. This information was used to inform the design and delivery of the SFA.

5.2 Methodologies to design farm trials

The second component focused on establishing field trials to address agronomic management questions raised by the local farming communities and to demonstrate the value of using seasonal climate information to adjust farm management decisions. Although they were originally proposed to be established within communities, the NARI teams established them within their research stations due to travel and engagement restrictions related to COVID-19. The field results contributed to the creation of an RMM which would become a key document for the creation of SFAs.

FPDA, NARI, and DAL project staff held workshops to finalise the field trial designs. The workshops were complemented by farm visits in Asaro and Bena near Goroka, and a village in the Markham Valley near Lae. Participants identified the most important annual crops in each of the three project regions (Lae, ENB, and EHP) and current and typical management practices for each crop. The final step involved workshopping potential ways in which current management might be influenced by access to a 1 to 3-month rainfall forecast.

In recognition of the short trial timeframe (2 seasons) and limited trial resources (i.e. labour, land area, machinery) trial crop selection was restricted to a maximum of two annual crops. It was decided that the initial field trials would primarily focus on how SCF can be used to inform irrigation and fertiliser management, both separately and in combination.

When selecting the type and settings of treatment variables for each of the field trials, the following considerations were made:

- The production impact, costs (i.e. labour and financial), and risk of employing SCF in farmer decision making should differ across the management variables and ideally the focus should be on variables that maximise return while limiting cost and risk to the farmer.
- The proposed trial sites vary in terms of available land area, staffing (i.e. experience and number) and farm equipment availability (e.g. access to tractors). In light of these factors, it was necessary to vary the scale/scope of trials across the sites and seasons.
- As a start, treatments of all field trials managed across all sites were based on all possible combinations of the following management settings:
    - Irrigation: 1) Rainfed or 2) Irrigated (simple, bucket based). The timing of irrigation was based on a cumulative rainfall deficit measurement.
    - Fertilisation: Depending on the crop, up to 5 fertiliser treatments including: 1) Nil, 2) Basal only, 3) Basal plus 1 top-dress, 4)-5) Basal plus 2-3 top-dress applications. The range of total applied fertiliser across the 4-5 treatments has been selected to cover the 'typical' or recommended rate as well as an above-recommended rate of application.
    - Variety: A separate bulb onion variety and potato variety x disease control trials were also conducted in NARI managed field trials in Aiyura, Bena and Goroka in the EHP sites.

The second phase of trials needed closer engagement with farmers and greater integration with the emerging rainfall forecast products and the SFA design process. As such, the focus of the second and succeeding phases of field trials shifted to lower intensity, on-farm trials to facilitate and enhance direct farmer engagement and extension. These compared crop performance under current management during a typical growing season (i.e. average rainfall) to performance under several different responses to actual rainfall forecasts. The selection of treatments was also improved to demonstrate the connection of climate forecasts and selected interventions. More information about the community engagement aspect of the trials is provided in section 5.4.1.

5.2.1 FPDA on-farm demonstration trials

FPDA conducted and managed three types of on-farm demonstration trials as part of this project.

The first set were sweet potato trials on two separate farms in Asaro and a single bulb onion trial in Bena. Each trial was comprised of three adjacent plots (un-replicated):

1. Management of the first plot was based on current/typical best practice. The plot was rainfed with little or no fertiliser applied basally. All other management were as per current standard practice.
2. In the second plot we introduced a series (up to 4) of fertiliser topdressing events with the number and timing informed in real time by the SCF (dry = less, wet = more). This plot represented a farm with no access to irrigation. All other management were as per plot one.
3. The third plot was managed in the same way as plot two but with the addition of simple (i.e. bucket application to individual plants) demand irrigation, the timing and frequency

will be informed by the SCF (dry = more, wet = less). This plot represents a farm with access to irrigation.

Plot 1	Plot 2	Plot 3
Current/typical management	Current/typical management **+ Incremental topdressing (SCF informed)**	Current/typical management + Incremental topdressing (SCF informed) **+ Demand irrigation (SCF informed)**

Figure 2 Farm trial design

A second trial was established to investigate and demonstrate selected management responses to SCF information. The trials built on the findings from the first set of trials and considered feedback from various farmer engagement activities, including:

- The inclusion of standalone nutrition and irrigation treatments, in addition to combined nutrition/irrigation treatments;
- The sweet potato trial was established using pathogen tested (PT) plant material in response to the poor performance of non-PT material in the first trial;
- Consideration of organic nutrient sources (e.g. chicken manure and/or compost) in addition to conventional inorganic fertiliser types.

A third trial on sweet potato was conducted at Asaro to investigate and demonstrate potential management practices that are sensitive and in response to SCF information. The trial was designed based on the feedback collected from the second on-farm trial. The sweet potato trials were based on the findings and certain climate sensitive management practices employed such as:

- The use of simple bucket irrigation when rainfall drops below the average rainfall;
- Standalone organic and inorganic fertiliser application, incorporation of fertiliser (inorganic/organic) with irrigation and standalone irrigation treatment;
- Organic fertiliser (compost) was used because farmers prefer organic fertilisers that are cheap and readily available therefore will use compost;
- The sweet potato cuttings from Gimani PT variety were used because it outperformed the local and/or indigenous variety in yield and vegetative performance.

5.2.2 NARI research trials

Small plot replicated trials were conducted at each of the three NARI sites to measure and demonstrate the potential production and quality impact of irrigation and fertiliser management settings based on the SCF. Each site focused on two crops identified in the workshops: Irish potato and bulb onion at Aiyura; taro and sweet potato at Lae; and taro and sweet potato at Kerevat. Taro, casava, and sweet potato are the major staple root and tuber crops throughout PNG (Bourke et al., 2009). While Irish potato and bulb onion were considered as the high priority horticultural cash crops of economic and food security importance to majority of farmers in the highlands region (Bourke et al., 2009,Okrupa, et al, 2019).

Treatments were based on all possible combinations of the following management settings:

- *Irrigation*: 1) Rainfed or 2) Irrigated (simple, bucket based). The timing of irrigation was based on a cumulative rainfall deficit measurement.
- *Fertilisation*: Depending on the crop, up to 5 fertiliser treatments including: 1) Nil, 2) Basal only, 3) Basal plus 1 top-dress, 4)-5) Basal plus 2-3 top-dress applications. The range of total applied fertiliser across the 4-5 treatments was selected to cover the 'typical' or recommended rate as well as an above-recommended rate of application.

This combination of treatment settings captures a range of responses in 'dry', 'average', and 'wet' years. The SCF information was used to retrospectively identify the season type and the resultant production response if the SFA had been followed.

At the request of local staff at Aiyura, it was also decided to include separate bulb onion variety and potato variety X disease control trials at that site. These trials provided useful insights for this project as well as broader benefit to the local farming community.

Data collection from each trial was intensive and included regular in-crop growth, morphology, and development observations as well as destructive harvests at key developmental stages for biomass monitoring over time. The final harvest included measurement of partitioned biomass (oven dry and fresh weights), yield, and quality.

The actual implementation of the field trial protocols in all case study regions started in 2020. Prior to the establishment of these on station trials, soil sampling was carried out with Dr. Shaun Lisson followed by sourcing of farm inputs, land preparation, field marking, drainage construction, ploughing, nursery construction, and seed sowing etc. through to actual planting and management of the field trials. The crop growth was monitored, and data was collected, analysed, and reported according to the established research protocol. The report of the yield was also converted into the economic outputs on per treatment basis using partial budget analysis. The farm management variables that did well at on station trials were identified and taken to farmers participatory field demonstrations sites.

5.2.3 Rainfall Management Matrix (RMM)

The on-farm trials were designed to capture performance difference between management variables under different rainfall scenarios and make a comparative assessment and recommendations on management variables that do well under a given rainfall forecast. The challenge for the NARI research team was to translate a probabilistic forecast into a specific farm management response. This was achieved through categorising the forecasts of 'below,' 'average,' and 'above average' further down into five specific rainfall scenarios: (1) Good season or optimal, (2) Dry season, (3) Wet season, (4) Dry start and wet finish, and (5) Wet start and dry finish rainfall conditions (Table 4). These measurements are compared against historical data around cumulative rainfall around that given season.

Table 4 Seasonal rainfall scenario characteristics

Seasonal rainfall scenario	Common name	Characteristics
Optimal rainfall throughout	Good Season	Regular, low intensity rainfall that maintain plant available soil water (PAW) in excess of crop demand but below field capacity. No delays in establishment or impaired growth from either soil water deficit or water logging. Potential for elevated weed and pest pressure.

Lower than optimal rainfall throughout	Dry Season	Extended periods of inadequate rainfall resulting in delayed establishment, PAW below crop demand (i.e. deficit) resulting in periods of growth stress. Reduced potential for weed and pest pressure.
Higher than optimal rainfall throughout	Wet Season	Extended periods of excessive rainfall that exceed soil PAW capacity with the potential for run-off, erosion, nutrient leaching beyond the root zone and water logging stress. Increased potential for weed and pest pressure.
Lower than optimal rainfall early	Dry start and Wet finish	Below optimal rainfall through the pre-plant and early crop establishment period followed by above optimal rainfall through to harvest.
Higher than optimal rainfall	Wet Start and Dry finish	Above optimal rainfall through the pre-plant and early crop establishment period followed by below optimal rainfall through to harvest.

NARI interpreted and synthesised the forecast information and integrated it with historical weather information sources such as the Aiyura research station's 79 years of historical rainfall data (Dom, unpublished) and PNG's weather and climate pattern (McAlpine et al, 1983). Hence, after replicating the trials over two to three cropping seasons, the best performing treatments under the given rainfall scenarios were taken to farmers field in Bena, Ifiyufa, and Asaro to compare against their best practices using small plots replicated trials in 2022. Combinations of these on station and on farm trials provided useful insights for the project team to develop the RMM. The process to create the RMM also included incorporating local indigenous knowledge, getting feedback from farmers, reviewing related publications, and consolidating the information in a workshop with agriculture experts. RMM information was developed for each of the provinces, but the project mainly focused on the RMM for EHP.

5.3 Methodologies to develop seasonal climate forecast (SCF) products

The third component focused on creating SCF products, particularly the SCFA from NWS and the SFA from NARI. These products are the main outputs needed to achieve the project's objectives. The SCF products were co-created by NWS, NARI, and ANU following a co-design process. The process involved interviews with farmers and extension officers to refine the products and messaging as well as an intensive 3-day workshop to create consensus messaging.

5.3.1 Seasonal climate forecast advisories (SCFA)

The SCFA was produced by NWS and was informed by the information collected from the baseline household survey and climate risk assessment. It provided an array of seasonal climate outlook on a monthly basis, including outlooks up to two to five months. NWS drew on the Australian Community Climate and Earth-System Simulator – Seasonal (ACCESS-S) dynamic climate model and satellite remote sensing to provide these forecasts. The SCFA provided two outlooks: rainfall probabilistic forecasts and drought indicator forecasts. The template undergone several versions as NWS received feedback from NARI and other extension service providers. This is further discussed in 7.1.3.

5.3.2 Seasonal farm advisories (SFA)

The design process of the SFA followed the action research approach proposed by Kemmis and McTaggart (1988) that utilises a spiral of self-reflective cycles where the team first planned, acted, and observed, then reflected on the progress to revise the plan if necessary. ANU, NARI, and NWS worked together to develop and refine the SFA.

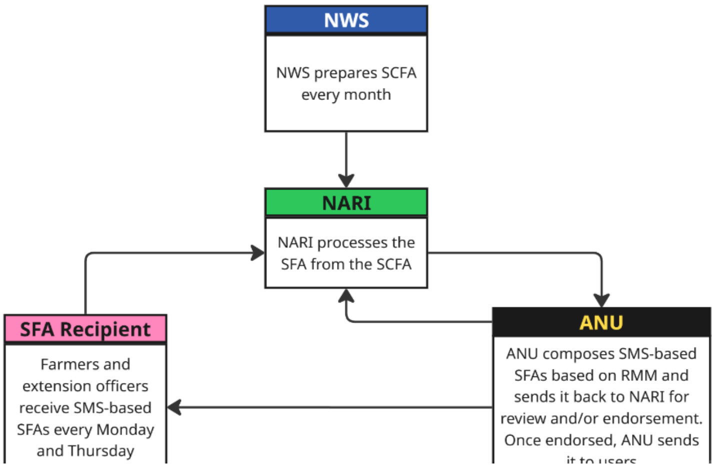


Figure 3 Process workflow of SFA generation and delivery

The SFAs are produced by NARI and delivered via a SMS system managed by ANU. NARI and ANU work together to interpret the SCFA and RMM to create the SFA. There are two types of messages: alerts and advice. Alert messages provide the weather forecast for the next three to five months period. They also serve as an alert or early warning message where needed. Meanwhile, advice messages are follow-up information derived from the RMM.

Table 5 Sample alert message

English	Tok Pisin
Rainfall in EHP shows above rainfall scenario from Jan, Feb and March which will add weed and pest pressure, water-logging stress and soil erosion.	Ol save man bilong ren na san I tok aut olsem bai igat moa rein lon namba one mun igo lo namba tu na tri mun bilon yia 2024

Table 6 Sample advice messages (in Tok Pisin)

(1) Klinim bus lo abarusim resis namel lo bus na kaikai long lait bilong san, na gris bilong graun
(2) Sekim gaden wanwan taim long rausim binating nogut long gaden
(3) Long taim bilong ren, kaikai olsem poteto save kisim bagarap hariap long sik nogut. Planim E2 poteto na sevim mani long marisin

As part of his master's program at ANU, Sibjan Chaulagain conducted a systematic literature review to examine how SMS technology has been used in other countries to deliver climate advisories to farmers. Based on these findings, an action research approach was applied to develop an SMS platform and co-create SMS-based SFAs. This process helped identify technical, administrative, and logistical challenges in implementing the technology and improved the co-creation process. To assess user acceptance, a paper-based and online survey was conducted, with responses analysed using the User Acceptance and Use of Technology (UTAUT) Framework. A two-month trial involved sending climate advisories via SMS to 83 farmers and extension officers. A follow-up survey, co-designed with NARI and FPDA and reviewed by local experts, gathered insights on behavioural intention towards SMS adoption. Additionally, structured interviews explored stakeholder readiness and challenges in scaling up SMS technology in PNG.

SFAs were disseminated to selected farmer and extension officer subscribers every Monday and Thursday under the sender ID, SFA_PNG. Messaging began on 28 September 2023 and continued until 2 May 2024. These resumed on 17 June 2024 and continued until 30 March 2025. Messages were sent in both English and Tok Pisin.

5.4 Methodologies to communicate and engage with communities

This component focused on methods to engage farmers and communities. It was essential to capture indigenous knowledge and receive feedback on the outputs and farm trials since a key objective of this project was to ensure farmers understood SCF and applied it in their decision-making. It also served to inform farmers about SCF and how it can be used to support their farming decisions. This supported the uptake and refinement of the SFA.

5.4.1 Farmer field days and workshops

The group took an AIP approach to engage with farmers. Farmer extension activities involved site visits by local farmer representatives and farm leaders (both male and female). The first visit was used as an opportunity to explain the project objectives and the field trial layout as well as to introduce the ideas of seasonal forecasts, farm advisories (getting some feedback on possible content), and irrigation and nutrient management options on farm. Follow-up farmer visits occurred around crop maturity and involved the same cohort of farmers to highlight which treatment/s performed best and compare them with current practice plots. NARI and FPDA facilitated these visits and interviewed participants through one-on-one interviews, FGD, and workshops to get their feedback.

In Morobe, the Family Farms Team (FFT) approach was introduced and helped by formalising the interaction with a more holistic approach. The farmers actively contributed their experience, including traditional knowledge, and this helped in introducing the SCF. This approach contributed a gender sensitive research process. It became apparent that maintaining farmer engagement was challenging due to a range of other community activities and delays in providing the first SFA. Whilst some decline in participants' interest was experienced, the FFT groundwork provided a good basis for later introduction and pretesting of the SFA.

In Aiyura, the NARI team decided not to take farmers to the on-station field trial activities at planting and during the harvest. Instead, NARI Aiyura established participatory trials with farmers. An initial engagement activity was undertaken with lead farmers in the selected farming communities in EHP. Awareness of the ACIAR CSA Project, sourcing and delivering of farm inputs, irrigation set up, field marking, planting, and farmers engagement to differentiate farm management variables were conducted at Ifiyufa for Irish potato farmers and Bena for Bulb onion farmers. Through this, NARI focused on identifying the farmers' best practices and climate risks associated with their current best practices, followed by combining their current best farming practices with the improved practices derived from on-station field trials results.

5.4.2 Videos and seasonal calendar

To develop the content of the video communication materials, UoG was guided by Participatory Action Research (PAR) principles to enhance climate communication. In line with the objective of this project, co-learning was employed as a research approach to facilitate climate communication with farmers, research scientists, and extension agents. The participatory process also recognises and builds upon local knowledge on natural resource management and integrates scientific knowledge to improve household food security and farmer livelihoods in beneficiary communities.

The following research tools were used to implement planned activities:

1. Participatory video production – UoG facilitated the development of videos including farmer diaries in which farmers were re-skilled to develop/direct their own videos to share experiences gained through the project. The process to develop a video is just as important as the video produced. Therefore, UoG followed a set procedure to engage in developing community-based films.

Stage 1: Pre-production

- Getting to know communities and selecting participants for the camera training in consultation with the lead farmer.
- Gathering background information and reviewing existing practices relating to food security.
- Assessing farmer knowledge, attitudes, and practices to mitigate climate change and how the community addresses food and nutritional security. Information was also gathered on income generation activities from their gardens.
- Assessing needs and constraints of community in regard to food and nutritional security.

Stage 2: Production

- Training workshops on camera operation through small group learning. Farmers give free, prior, and informed consent before they begin working on their stories and produce their films. This also applies to documenting farmer stories with UoG team directing the film.
- Developing the story on community adaptation practices
- Developing & editing the videos directed by the farmers/researchers

Stage 3: Post-production

- Screening films with farmers in their communities, usually in haus pikas or other community areas like churches.
- Gain peoples' understanding of content of the film.
- Further editing is done if necessary.

Stage 4: Distribution to partners, government, NGOs, and mass media including TV stations and screening in beneficiary communities. In addition, distribution of videos on flash drives or SD cards in communities.

- For wider circulation, community screening & TV is planned well beyond the current project life to improve information access by beneficiary communities and stakeholders.

2. Seasonal calendar – This farmer engagement technique was used to incorporate indigenous ecological knowledge and scientific knowledge for farmers to develop their stories for the self-directed videos. Seasonal calendars are useful for traditional climate education and awareness and as a conversation starter for climate change discussions.

The participatory research approach employed by UoG contributed to co-learning by stakeholders (FPDA, NARI, NWS, UoG, and farmers).

5.5 Methodologies to demonstrate value of SCF

Beyond the SFAs, the project sought to demonstrate the value of SCF. These were supported by workshops and farmer field days explained in section 5.4.1. as well as meetings with government officials, agencies, and donors led by ANU and NWS. The CSIRO project team also worked with NARI, ANU, and FPDA to develop a bio-economic model that could be used as a discussion tool around SCF and profit. The model is based on similar work CSIRO has done in India and Bangladesh (Nidumolu et al., 2016; Nidumolu et al., 2022).

5.5.1 Bio-economic model

The modelling framework consists of (i) model inputs (SCF probabilities/scenarios, labour and crop input costs, selling prices of crop products); (ii) linear programming (LP) with the main components consisting of objective function, constraints and activities, and (iii) model outputs (scenarios). SCF from several sources can be integrated with the model. The LP model uses the forecasts as weights when optimising for crop choice. The model is centred on the SCF (3 classes of season type) which influence the crop type (9 crop types). This combination of season types x crop types drives the crop choice model. Various inputs such as labour, fertiliser, fungicides, pesticides, and machinery use contribute to costs while sale of crops (yield × prices) result in revenue. The model optimises for profit based on a set of resource constraints. The model in its current form is at a village scale (although the model has been developed to be scale-independent i.e. it can scale from plot to village to a province as long as the data is adjusted as per scale) i.e. the profit of the whole village is optimised subject to available resources at village scale. This implies that the individual objectives of different farmers and farm specific constraints are not considered explicitly. The model was developed at a village scale with an aim to engage with a larger farming community. Since we do not allow for exchange of resources i.e., there is no land and labour exchange between farmers, optimising at the village level approximates optimisation of an average farm. In case of large variation of available resources between farms, optimisation at farm level (or a group of farms based on a typology) would be more appropriate to model explicitly farm specific constraints.

The LP model (Figure 4) was used to maximise expected gross margins and optimally allocate available farm resources to current and alternative agricultural activities accounting for resource availability and constraints. A number of scenarios were developed through this process to examine changes in resource constraints or cropping activities. The model helps to assess ‘what if?’ scenarios, which are based on quantified input–output relations for current crop production activities with the formulation of constraints as mathematical functions (Nidumolu et al., 2011).

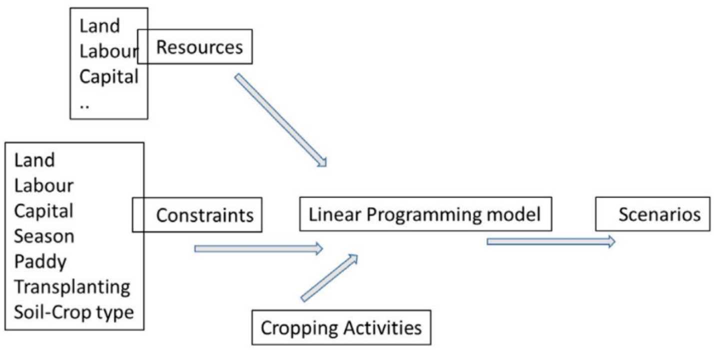


Figure 4 Modelling framework

The general mathematical formulation of the LP model is:

$$max\left\{Z = \sum_{i,k} w_k \cdot gm_{ik} \cdot x_i \right\} \qquad (1)$$

Subject to:

$$\sum_{i,k} w_k \cdot a_{i,j,k} \cdot x_i \leq \sum_{k} w_k \cdot b_{jk} \qquad \forall j \qquad (2)$$

$$x_i \geq 0 \qquad \forall i \qquad (3)$$

where Z is the total expected gross margin, x_i is the optimal level (ha) of activity i (defined as the area of a crop grown on specific soil type), w_k is the weight (probability of state of climate based on SCF classes) of k (i.e. 'drier, 'near average, 'wetter'…), $a_{i,j,k}$ is the input-output coefficient of constraint j corresponding to activity i in state of climate k, b_{jk} is the right hand side of constraint j in state of climate k and gm_{ik} is the gross margin per ha of activity i in state of climate k. The gross margin is defined as expected revenues from sales of agricultural crop products minus variable costs including hired labour, seeds, machinery, fertilisers, pesticides and fungicides. To include the probabilities of a forecast for the three different seasons in the model, a weighting method was used. In this method, all objective functions for each season type are combined into a single objective function. A weighing factor, representing the probability of a specific season type, is given to each objective before all objectives are added. Subsequently, an efficient set is generated through parametric variation of weights, as first introduced by Zadeh (1963).

Objective function

The key objective of the case study farming community is maximising gross margin using the resources available and with a set of cropping activities. Constraints imposed in the model are based on the resources available. These include land and labour: (a) Land allocated to various crops cannot exceed total land available and (b) labour required cannot exceed labour available.

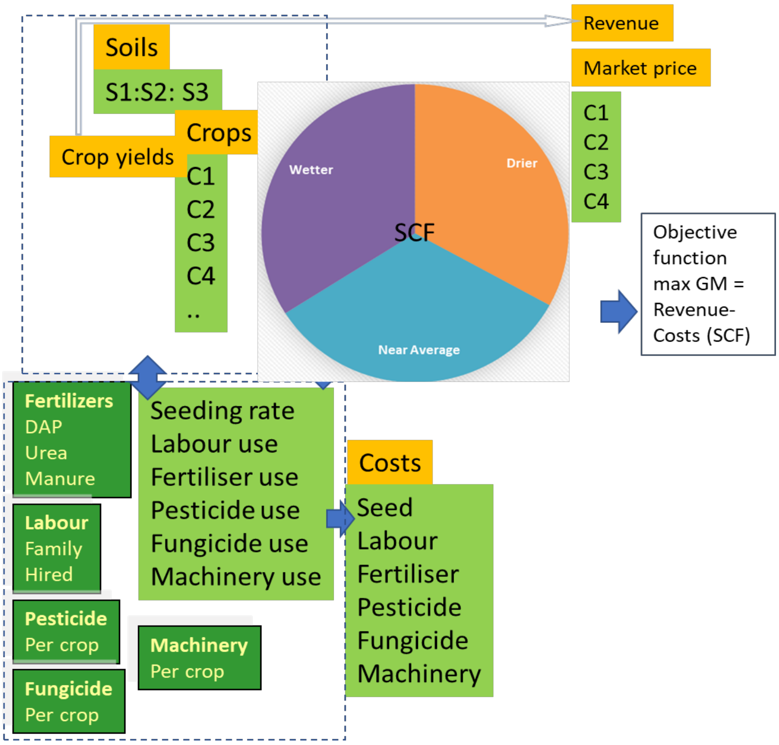


Figure 5 Modelling framework

SCFs ('drier, 'near average, 'wetter) and all objective functions for each climate type are combined into a single objective function. A weighting factor, representing the probability of a specific climate type, is given to each objective before all objectives are added. Subsequently, the efficient set is generated through parametric variation of weights. Labour requirements per crop per season are included as labour person days for the growing season per hectare. While cost of family labour is not included in the model calculations, it is costed per person per day.

Data

Data on the technical coefficients used in the model were gathered from the local farming community and expert knowledge from extension service and researchers. These include crop types, soil types, yields, input prices, and costs and use of inputs such as fertiliser, pesticide, fungicide and labour. This information was collected and validated by Dr Mike Bourke and was made available in 2023. Forecast data includes the probabilities for five season classes viz. ‘drier, ‘near average’, ‘wetter’. Available land at village level was determined per soil type i.e. black soils (40 ha), red soils (16 ha), and sandy soils (80 ha). The total agricultural area of the village is set as 100ha which can be changed to reflect any village case study as this model is at a village scale. In terms of labour availability, it is currently set as 50 but can be changed as required. Labour requirements per crop per ha and per season type have been gathered from expert opinion. Price of hired labour was set at PGK 25/person/day. Market prices for different crops were gathered from expert opinion and market reports. Costs of pesticide, fungicide, implements and seed per crop type were gathered from the experts and various published reports. The usages of different fertilisers, pesticides, and fungicides are determined for each crop type and season type. Seeding rate is calculated as kg/ha and costed in PGK/kg. Crop yield has been gathered from expert knowledge and published reports. Yield (kg/ha) is specified per crop by season type. The model results include:

- Crop areas,
- Variable costs, revenue and profit at village scale,
- Input (labour, machinery, fertilisers, pesticides, and fungicides use), and
- Expected gross margin for the village (the objective function value).

The full information around the data sources can be found in Appendix 11.4.

5.6 Monitoring and Evaluation Framework

M&E of this project was managed by Sustineo. The M&E approach considered project governance, project performance, and impact evaluation. Outputs included partner health checks; activity, output indicators, and annual M&E report; and outcome indicators, impact narratives, final M&E report, and case studies. A copy of the final M&E report can be found in the appendices.

Sustineo’s findings are derived from a combination of quantitative and qualitative data collected through a variety of methods and sources, as outlined below:

- **Key informant interviews (KIIs)**: Conducted between June and November 2024 with representatives from project partner organisations. These interviews provided qualitative data and in-depth insights into the learnings and reflections of project partners.
- **Event and SNA reports**: Prepared by NARI and FPDA, who were responsible for delivering extension services to community farmer participants. These reports, including findings from the SNA, offered feedback on effective knowledge-sharing methods.
- **Group interviews**: Facilitated by local partners delivering extension activities to community farmer participants.
- **Surveys**: Included a baseline household survey, a climate risk assessment developed by CSIRO, and a project partner health check survey implemented in 2021, 2022, and 2023. These surveys supported adaptive management and informed activity development.
- **Field trials**: Data from field sites managed by local partners, including visitor attendance records, provided insights into farmer engagement levels.
- **Audio-visual materials**: Content from farmer videos produced by UoG captured learnings from farmers' perspectives.
- **Meeting notes and attendance records**: Included minutes from project partner engagements and SFA workshops conducted in May 2023 and June 2024. These documents tracked activity implementation and progress towards achieving project objectives.
- **Workplans**: Regularly developed and updated by project partners to guide and document project activities.

This diverse range of methods and data sources ensured a comprehensive understanding of the project's outcomes, challenges, and lessons learned.

UoG also conducted an evaluation of its video materials. The videos were shown across seven rural communities, including six that served as project study sites and one that is beyond the scope of the project. These communities are Gabsongkeg (Morobe), Vunapit (Napapar 3), Bitagunan (Napapar 5) in ENB, and Kuka and Lakomiufa in the EHP, and Yabob Village (Madang). At each site, videos were screened to local farmer groups, after which participants were invited to complete structured questionnaires. These instruments were designed to capture demographic characteristics and gauge participants' comprehension, perceptions, and intentions to apply CSA techniques showcased in the videos. The questionnaires also helped assess how effectively the video medium communicated key CSA messages, particularly among farmers with varying levels of formal education and literacy.

The data collected by UoG was provided in a spreadsheet. For the purposes of this report, the raw data was cleaned and systematically coded. Farmer responses were categorised based on themes aligned with the project's three key objectives: (1) integrating scientific and indigenous seasonal climate information to strengthen resilience in food production, (2) demonstrating the added value of combining knowledge systems through participatory tools and modelling, and (3) improving access to SCF and SFA services for farmers and relevant stakeholders.

Descriptive statistics were applied to summarise general trends across the data, while inferential analysis was carried out using Chi-square tests to determine whether statistically significant relationships existed between demographic variables (such as gender, education, marital status, district (province), and type of video medium used for viewing) and participants' categorical responses. Where significant associations were detected ($p < 0.05$), effect sizes were measured using Cramer's V for variables with more than two categories, or Phi for binary variables. Post-hoc tests were also performed when necessary to explore pairwise differences between categories, particularly for variables like education level and video type. All statistical analyses were conducted using Python, using pandas, scipy, and statsmodels libraries. The results were synthesised to inform this report's conclusions regarding the role of video in strengthening CSA awareness and adoption in rural PNG communities.

6 Achievements against activities and outputs/milestones

The project has successfully developed multiple SCF products to support PNG farmers adapt their agricultural practices based on climate forecasts. These products include a regular SFA delivered via SMS and WhatsApp, the monthly SCFA, a RMM, informational videos, and an adapted ‘WonderCrop’ game. These were made possible by insights from several activities, including the SNA, household survey, CSA literature review, and field trials. In achieving this, the project fulfilled most of its milestones. However, some milestones were not achieved due to challenges from COVID-19, changing government priorities, and resource constraints.

Several activities were ongoing at any point in time as demonstrated below.

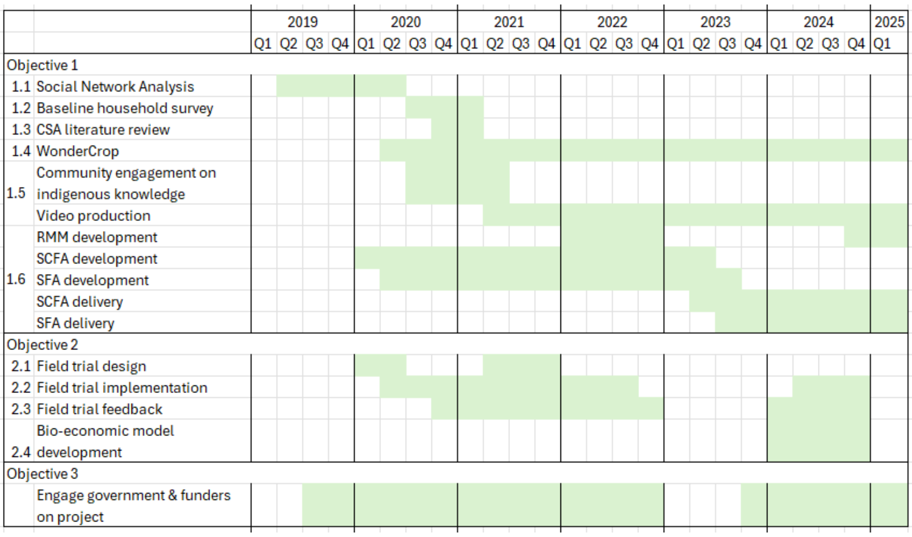


Figure 6 Timeline of activities

Pivot points

Project activities changed throughout the project’s implementation. These include issues out of the team’s control—such as COVID-19, decreased PNG government support—as well as learnings gained from reflection points. A list of these key changes is provided below.

- The project underwent an MTR in 2022. After, the team made some changes based on the feedback, including prioritising the development of the SCF products rather than a full impact evaluation and removing a full end-line survey due to limited resources. UoG also became the designated implementing partner for the ‘WonderCrop’ activity to create a version suitable for farmers.
- COVID-19 impacted the original design of the farm trials since they occurred on research stations instead of within communities, impacting farmer engagement.
- The withdrawal of DAL & CCDA limited the project team’s ability to engage other government agencies, specifically impacting objective 3. In response to this change, NWS became the lead organisation to engage PNG stakeholders.
- There was limited data and capacity at Morobe and ENB. The team decided to focus on EHP which had the most resources and momentum.
- The team sought to engage APEP as part of the MTR recommendations. However, APEP preferred to be a potential funder rather than partner. Talks with APEP began in late 2023 to allow a smooth transition of activities. In 2024, ANU submitted a project proposal to expand the reach and to bring in a local telecommunications company. As of writing this report, APEP has not yet provided a response to the proposal.

6.1 Objective 1: To incorporate scientific and indigenous seasonal climate information into farming practices to improve the climate resilience of PNG food production.

The first objective is focused on integrating scientific and indigenous knowledge to support crop resilience against climate variability. The activities sought to gather information, learn from other projects, adapt information to the PNG context, and integrate learnings into a SCF product. Except for the endline survey, all planned outputs were developed.

Activity 1.A Understand agricultural information requirements and information flows within field areas through a SNA

PNG is composed of several remote communities with limited digital uptake and road infrastructure. This makes spreading seasonal climate information challenging. Therefore, the team sought to understand how climate information was already shared to capitalise on existing networks. The project team conducted SNA activities in EHP, ENB, and Morobe. The SNA revealed how seasonal climate information is shared among rural communities and government agencies; identified the most critical times of year for this information; and highlighted key disseminators and suitable farming strategies for different seasonal conditions. It also compared how information networks may differ between male and female farmers across the three provinces. This activity benefited from initial funding from DFAT.

Table 7 Activity 1.A Understand agricultural information requirements and information flows within field areas through a SNA

No.	Activity	Outputs/ milestones	Completion date	Comments
1.2	Develop and finalise the design of the SNA survey	Baseline SNA survey questionnaire	Apr 2019	The activity was supported by funding from DFAT.
1.3	Translate the SNA survey into Tok Pisin and test the translation process and outputs.	Tok Pisin version of the SNA and household surveys	Apr 2019	The activity was supported by funding form DFAT.
1.5	Initiate SNA analysis in all three case study regions	SNA survey analysis completed.	July 2019 Feb 2020	SNA activities in EHP and Morobe have been supported by DFAT.
1.9	Incorporate both SNA and household surveys into the AKVO software for use on tablets.	Tablet versions of the surveys are available for use.	Dec 2020	Completed
1.10	Undertake survey training sessions in PNG.	NARI, DAL, and FPDA staff trained	Aug 2019	22 individuals trained
1.15	Analyse the surveys and extract the information pertaining to knowledge requirements, timing, and format for SCF factsheet development. Translate analysis into Tok Pisin.	SNA survey analysis completed by Sustineo. Briefing notes on results developed and disseminated.	May 2020	SNA survey analysis was completed in May 2020. Its findings were published in 2022. Briefing notes and project updates we made available on the NARI, FPDA, and ANU websites.

Activity 1.B Conduct household surveys to inform the development of SCF products

The Baseline Household Survey was implemented by Sustineo, APR, and NARI in ENB, EHP, and Morobe. The survey, originally designed to assess project impacts, was expanded following MTR feedback to also explore regional crop patterns, land use, and gender roles in farming. Ultimately, the survey reinforced the understanding that most farmers would like more information about climate, weather, and farm management, but there are also several barriers to access and use.

Table 8 Activity 1.B Conduct household surveys to inform the development of SCF products

No.	Activity	Outputs/ milestones	Completion date	Comments
1.4	Develop the rapid appraisal household survey	Household survey developed and available	July 2020	The activity was supported by funding from DFAT. APR & NARI collected the data.
1.8	Translate the household survey into Tok Pisin and test the process and outputs.	Tok Pisin version of the household surveys available	Dec 2020	Completed
1.15	Analyse the surveys pertaining to knowledge requirements, timing, and format for SCF factsheet development. Translate the analysis results into Tok Pisin	Household survey analysis and findings collated in a summary report Briefing notes on results developed and disseminated.	Feb 2021	Household survey analysis completed February 2021. Briefing notes and project updates we made available on the NARI, FPDA, and ANU websites.
1.27	An end line survey will be undertaken to obtain feedback on the SFA	End line survey completed	N/A	Due to the high costs, the MTR recommended not doing an endline. Instead, NARI conducted a rapid perceptions survey in March 2025.
1.28	Analyse the endline survey to examine opportunities to improve	End line survey analysis completed	N/A	Since the endline survey did not occur, there is no report. The rapid perceptions survey results are found in the final report.

Activity 1.C Review CSA literature and identify learnings suitable for PNG

The project team conducted a literature review of CSA initiatives across the globe and identified potential elements suitable for PNG. This involved reviewing case studies of the approaches to integrate scientific and traditional weather and climate information, package the information in accessible formats for end users, and build extension and communication services for dissemination. The review emphasised initiatives that combined scientific and indigenous knowledge and adopted engendered approaches to SCF extension activities were most successful. From this global literature review and discussions with the project working group, a general process and set of design principles were developed for the SCF outputs.

Table 9 Activity 1.C Review CSA literature and identify learnings suitable for PNG

No.	Activity	Outputs/ milestones	Completion date	Comments
1.6	Complete a comprehensive literature review of CSA implementation globally and identify common successful elements for implementation in PNG.	A report outlining the findings of the literature review and recommendations for PNG.	Feb 2021	The report was used as the evidence base to produce an implementation guide
1.7	Establish a working group to work through the results from the CSA review, SNA, and household surveys as well as AIP activities when completed.	Working group established.	Mar 2021	Working group participants were enthusiastic to engage in the review of results. The working group was representative and knowledgeable about the farming activities in the case study sites.

Activity 1.D Engage farmers with the 'WonderCrop' tool to increase understanding of probabilities

Dr Peter Hayman developed a participatory engagement tool, 'Wonderbean,' to help individuals understand the risks associated with making agronomic decisions using a rainfall forecast. The name was changed to 'WonderCrop' to be more relevant in the PNG context. Officers from NARI, FPDA, and UoG were trained on the tool and used it to engage farmers in the community. UoG developed a dart board game and tested it with farmers.

Table 10 Activity 1.D Engage farmers with the 'WonderCrop' tool to increase understanding of probabilities

No.	Activity	Outputs/ milestones	Completion date	Comments
1.11	Train NARI staff to undertake the 'WonderCrop' extension activity as part of AIP interactions.	'WonderCrop' training completed with NARI staff	Feb 2020	Completed
1.21	Expand the training and extensions material associated with WonderCrop to include Tok Pisin translation relevant for communities.	UoG training on 'WonderCrop' 'WonderCrop' training material completed by UOG.	May 2023 Mar 2025	Activity added in response to feedback form MTR Dartboard version of the game completed
1.22	UoG, NARI, and FPDA staff deliver extension materials associated with 'WonderCrop' at each of the case study sites.	UoG developed a dartboard version of the WonderCrop game and tested it in communities	Mar 2025	Activity added in response to feedback form MTR Dartboard version of the game completed and tested

Activity 1.E Engage communities to understand their perceptions of climate change and capture their indigenous farming practices

The project used videos and local language materials to spark climate change discussions, document farmers' best practices and indigenous knowledge, and capture their experiences through field trials and interviews, with all content refined based on community feedback. In May 2020, CSIRO and FPDA interviewed 21 smallholder farmers in EHP to understand their farming practices and weather-related decisions. Findings showed that farmers were confused by increasing weather variability, especially excessive rain. However, their ability to recall past weather events was limited, with memory fading for earlier years.

Table 11 Activity 1.E Engage communities to understand their perceptions of climate change and capture their indigenous farming practices

No.	Activity	Outputs/ milestones	Completion date	Comments
1.13	Begin the development of video communication material through case study visits.	12 videos produced	Jun 2021	12 videos were produced, covering climate change, project activities, and indigenous knowledge
1.14	Initiate the AIP process at the case study locations to capture the indigenous seasonal knowledge regarding agriculture. Undertake the 'WonderCrop' activity with communities.	Farmer field days	Initiated in Aug 2020	Two field days in EHP, 1 in Morobe and 1 in ENB. Estimated participation was 186 for EHP, 45 for Morobe, and 37 for ENB.
1.18	Synthesise the information from the AIPs regarding indigenous seasonal knowledge regarding agricultural production.	NARI has recorded indigenous knowledge	2024	Information has been captured in videos by UoG and PowerPoint presentation by NARI.
1.16	Finalise development of the video material.	Community screening	Mar 2025	12 videos completed as of March 2025.

1.23	Assess the effectiveness of the video material with rural communities.	Assessment report	Mar 2025	Community screening delivered and feedback collected

Activity 1.F Develop SCF products beneficial for farmers in the field sites

Informed by the findings in previous activities, the project team developed three SCF products: RMM, SCFA, and SFA. The RMM was developed to link rainfall forecast information to potential on-farm management responses. It presents potential on-farm responses for nine management variables to different combinations of five month-long rainfall forecast information. The RMM has been translated into Tok Pisin and collated into a book.

Meanwhile, a SCF focus group was established to assess the forecasting capabilities of NWS and develop draft SCFA and SCF products. It involved representatives from NARI, NWS, ANU, and BoM. Workshops were held which had served as a preliminary step to determine the content and format of the SCFA. The discussion reviewed past techniques and products, necessary information, regional customisation, stakeholder involvement, and preferred formats for SCFAs, leading to the development of a draft SCFA template.

Through the CREWS-PNG project, NWS has provided regular SCFA to support NARI's development of SFA. The SCFA provided forecast and other climate information relevant to agriculture. ANU supported NWS and NARI throughout this process and facilitates the delivery of the SFA. The SFA is also sent to farmers through a WhatsApp group.

Table 12 Activity 1.F Develop SCF products beneficial for farmers in the field sites

No.	Activity	Outputs/ milestones	Completion date	Comments
1.17	Establish a seasonal forecast focus group (SCFG) with NWS, BoM, and the Asia Pacific Climate Centre to see how developmental SCF products for PNG could be accessed and used.	SCFG established	May 2020	SCFG, including BOM, NWS, and DFAT, established in May 2020. Agreement and training established for receipt of Australian SCF information. Assessment report completed in May 2020 and reported in Annual report.
1.20	Assess whether the level of forecast skill and service provision in weather services in PNG is commensurate with the lead time needed to address the farm management decisions identified in the CSA review, surveys, and AIP activities.	Assessment report	Dec 2022	NWS forecast products supported by BoM
1.24	Expert working group established to develop a contingency table of recommended action associated with different season types and different crops.	Crop contingency table completed and reviewed by two external experts.	Jan 2023	A working group was deemed infeasible in the timeframe, so two experts were consulted on the form and content of the RMM. This feedback was provided and integrated in the RMM.
1.25	Working group to complete analysis of the results from the CSA review, SNA, and household surveys as well as AIP activities to develop a draft SCF advisory. Draft SCF	A draft version of the SCF advisory designed and circulated to the project partners and communities to test its effectiveness and interest in PNG.	May 2023	Draft SCFA developed in May 2023 and tested with project partners and stakeholders.

	information factsheet in both English and Tok Pisin.			
2.6	Produce hardcopy and electronic version of the SCFA product.	Advisory available for circulation.	Jun 2023	16 editions of the SCFA have been produced. These have been made available online. Hardcopies were distributed to key government agencies and CBOs for their feedback.

6.2 Objective 2: To demonstrate the potential value of integrating scientific and indigenous knowledge to improve food production outcomes for rural communities via field trial activities

To encourage farmers to adopt new practices proposed in the SFA, the project team established field trials to display the potential outcomes of adopting new farming practices. Findings from these trials informed the design and content of the RMM which is central to the creation of SFAs. The project team decided to bring the field trail component of this project forward into 2020 as both travel and community engagement were not possible under COVID-19 restrictions. This objective had three main activities: design, implementation, and feedback.

Although not captured in the activity tables, the project team also developed a bio-economic model to support discussions around SCF in agriculture. CSIRO led the creation of the model with consultations from ANU, NARI, and FPDA. Bioeconomic farm models have been used to optimise farm production planning decisions and enable explorations of “what-if” questions at farm level (Janssen and van Ittersum, 2007). Such a framework could be used as discussion-support tool to design production plans and agricultural management decisions.

Activity 2.1 Field trial design

FPDA, NARI, and DAL-based project staff attended workshops held in Goroka and Lae respectively on 10 and 14 February 2020 with the primary aim of discussing the design of project field trials for the 2020 and 2021 seasons. The workshops were complemented by farm visits at Asaro and Bena near Goroka, and a village in the Markham Valley near Lae. Participants were asked to identify the most important annual crops in each project region and current and typical management practices. The final step involved workshopping potential ways in which current management might be influenced by access to a rainfall forecast.

Table 13 Field trial design

No.	Activity	Outputs/ milestones	Completion date	Comments
2.1	Through the initial AIP activities identify a set of management decisions (heuristics) that both male and female farmers would be willing to modify using information from the SCFA. Determine if heuristics used by men and women are fundamentally different. Through the AIPs also establish how farmers would modify heuristics in order to inform the design of the field trials.	A priority list of community heuristics established for case study sites reflecting both male and female farmer input. The report contained a list of management decisions common to all five sites as well as decisions specific to each site. Second trial is designed based on farmer feedback	2021	The household SNA and baseline surveys identified farm management decisions that could be influenced by information from SCF. Field trials have demonstrated a selection of these heuristics to communities, and the communities have provided feedback on ease of implementation, willingness to adopt, and the impact on crop productivity.

2.2	Through the working group, determine a priority set of heuristics to formally test in conjunction with the SCF advisory information. Circulate the priority list back to the AIPs to seek feedback.	Consensus list of heuristics determined by the working group. Modification made to the list based on AIP feedback.	May 2021	Field trials have demonstrated a selection of these heuristics to communities, who have provided feedback on ease of implementation, willingness to adopt, and the impact on crop productivity.
2.3	Examine how the heuristics and other forms of indigenous knowledge (i.e. derived via AIPs and surveys) can be effectively drawn together to inform the content of the SCF advisory.	Consensus list of heuristics and indigenous knowledge compiled by the working group.	Dec 2021	Farmer feedback field trials included opportunities to include indigenous knowledge in the SFA and future field trials.
2.5	Design field trials at the three NARI research stations in collaboration with NARI, DAL, and FPDA that highlight the priority list of heuristics and how they would be modified using the SCF advisory.	Field trial designs completed, and project team management plan established.	2020	The first set of field trials were designed and carried out by FPDA and NARI in all three provinces.
2.7	Develop a field trial protocol that will be applied at each research station to establish how crop production will be monitored and measured. This protocol will include a baseline crop rotation, a treatment rotation, and monitoring protocol.	Field trial protocol established.	July 2020	Complete

Activity 2.2. Field trial implementation

Replicated trials were conducted at each of the three NARI research station sites for crops identified in the workshops: Irish potato and bulb onion at Aiyura (May to October 2020; June 2020 to November 2021); taro and sweet potato at Lae (June to October 2020); and sweet potato at Kerevat (October 2020 to March 2021). Eight possible combinations of fertiliser and irrigation treatments were replicated across four blocks, which accounted for site variability. Management options also accounted for different resource availability.

FPDA conducted duplicate trials in early October 2020 in Asaro for PT and non-PT seeds of the Gimani variety of sweet potato. The fertilised plots (Plots 2 and 3) received three split applications of NPK fertiliser, and the control plot received no fertiliser. In Plot 3, irrigation was applied for the first month after planting. In Bena, two varieties of bulb onion (Malbec and Gladallan Brown) were transplanted from the nursery in late January 2021. All plots (including the control) received a fertiliser application in early March 2021. Plots 2 and 3 received an additional topdressing one month later in early April. While irrigation commenced after transplanting, supply constraints restricted the amount of water applied to the irrigated plots during dry periods. High rainfall totals around harvest time forced an early harvest and under-cover drying of harvested bulbs. FPDA conducted three additional sweet potato trials in 2022 and 2024.

Table 14 Field trial implementation

No.	Activity	Outputs/ milestones	Completion date	Comments
2.4	Align the operational SCF data outputs based on	Prioritisation of heuristics based on	2024	The literature review was used to develop an

	activity 1.20 with the heuristics to determine which can be effectively addressed on a routine basis.	comparison against existing SCF data outputs.		implementation guide and a draft template for the SCFA. SCFA data outputs are available for use and are part of the SFA design.
2.11	Harvested data from community-based field trials and research stations analysed to develop information regarding the value of using seasonal climate information.	Data collated from all field trials	Jan 2025	Results from the field trial were collated and shared with ANU in January 2025. Technical reports are available from NARI and FPDA but have not been published as standalone documents

Activity 2.3 Field trial community feedback and learnings

Both FPDA and NARI held farmer field day events, which served as both a demonstration and an opportunity for feedback. 1,012 farmers visited the NARI and FPDA field trial sites from 2019 to 2024. The farmer field days included a presentation and short training on climate forecasts and a short training on its application to agricultural decision-making. Farmers were also taught how to collect rainfall data using a rain gauge. They also included taste tests of field trial produced crops to learn about crop quality.

Farmers generally agreed they preferred to use fertiliser for sweet potato farming, because of the enhanced yields. However, fertilisers are considered too expensive, and continuous use is seen to have negative impacts on the soil. Organic fertilisers, such as compost or chicken manure, were suggested as an alternative. From the bulb onion field day, farmers noted traditional signals for making management decisions. For instance, looking at the life cycle of an orycite beetle can help predict the onset of dry periods or seasons. Meanwhile, farmers could see the potential benefit from simple irrigation in dry seasons, especially for enabling planting at the most profitable/favourable time of the year. However, they wanted to see further irrigation trials as a standalone treatment without extra fertiliser.

In response to feedback from farmers, the focus of the second and third phases of field trials shifted to lower intensity, on-farm trials to compare crop performance under current management during a typical growing season (i.e. average rainfall) and performance under several different responses to actual rainfall forecasts.

Table 15 Field trial community feedback and learnings

No.	Activity	Outputs/ milestones	Completion date	Comments
2.8	Male and female farmers from the case study sites transported to the field trial sites shortly after planting and just before harvesting (Field trial one).	Farmers visit field trial site post planting and pre-harvest	2020	6 field visits occurred in 2020 (EHP, Morobe, and). No field days were conducted in 2021 due to COVID-19 restrictions. 10 field visits were conducted in 2022 (EHP and Morobe) 6 field visits were conducted in 2023 (EHP). 14 FPDA farm visits Estimated that 221 male farmers and 249 female farmers attended these field visits.
2.9	Male and female farmers from the case study sites transported to the field trial sites shortly after planting and just before harvesting (Field trial two).	Farmers visit field trial site post planting and pre-harvest	2022	
2.12	AIPs will be presented with trial results (i.e. yields and profitability) from the second field trial to allow male and female farmers to determine if production is sufficient for their own	AIPs will have shared the results from the second field trial and provided feedback for the second field trial.	Mar 2024	

	consumption, cash sales, and customary obligations. Feedback from the AIPs will be used to redesign the second-year trial.			
2.13	Based on the yields and other metrics from trials, determine how heuristics could be further developed to link the flexible decision-making with climate knowledge.	New heuristics established for PNG farmers	Mar 2025	Standalone RMM's have been developed for each of the three provinces, but insufficient testing has been undertaken on Morobe and ENB RMMs.
2.14	Based on the field trial results direct extension and training with each of the AIPs in the implementation of the new heuristics into community-based food production activities.	New heuristics established for PNG farmers	Sep 2023	Delivery of RMM, SMS, and WhatsApp messaging has occurred for EHP only. New heuristics are delivered to farmers through SMS advisories and WhatsApp platform in relation to forecast for the season.

6.3 Objective 3: For Government, Industry and Non-Government organisations (NGOs) to provide access to and disseminate SCF knowledge products to farming communities across a broader area of PNG.

Under the third objective, the project team sought to expand the reach of SCF products by engaging with different stakeholders, including government, industry, and NGOs. Early on, the project team established a connection with the CREWS-PNG team to raise awareness regarding the ACIAR project and to seek additional partnerships. Through this connection, the team, led by NWS, managed to secure localised forecast information for the five case study locations. Meanwhile, survey results generated a great deal of interest from other government agencies, such as the Disaster Risk Reduction Group, the Coffee Industry Corporation (CIC), and the Cocoa Board.

In response to feedback from the MTR, the team engaged APEP, formerly Market Development Facility (MDF), to improve the project's community engagement and dissemination capacity. However, APEP decided against joining the ACIAR project and requested the team to submit a proposal so it could fund an extension of the project. ANU submitted a proposal to APEP in July 2024, which included a budget from Digicel. However, there has been no update at time of writing whether APEP will fund an extension of the project.

The team also supported CCDA and UNDP's negotiations on a SMART Climate or 'Strengthening Multi-sectoral Adaptation Responses Through Climate-related information,' proposal. However, it was unsuccessful.

To raise awareness about the project, the team has given several presentations in PNG. Team members also presented at the 2024 Pacific Small-Island Developing States Conference in Nadi, Fiji, 2024 AusAID Conference in Canberra, Australia, and 2025 Pacific Research Symposium in Tonga. The project received significant interest from other Pacific states and donors active in the region.

Table 16 Objective 3 activities and achievements

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	Based on the results of SNA, AIPs trials and videos, undertake extension activities with DFAT post	8 meetings with DFAT post	2019-2021	Completed

	and other Government agencies to broaden the impact.	2 meetings with the Forum on Disaster Risk Management 4 meetings with senior DAL officials 11 meetings with CCDA staff 5 meetings with CREWS-PNG team		
3.2	Assist CCDA and UNDP negotiations to develop a proposal for the SMART Climate Initiative.	Project team contributed to proposal	2021	The project team provided input into the drafting of the SMART proposal. Unfortunately, the proposal was not successful.
3.3	Engage APEP to broaden out the extension of the SFA to Church Groups in Lae and via National Radio. Explore options for extension of the SFA a major phone carrier in PNG.	Meeting with Digicel and APEP held	Jun 2024	APEP facilitated discussions with Digicel (telecom), GSMA (non-profit promoting telecoms), radio, and church groups.
3.4	Work with Digicel to develop a viable subsidised or user pays model to continue the service	Digicel budget received	Jul 2024	Proposal to expand the activities with APEP-funding was submitted
3.5	Present a recommendation report to PNG government to seek ongoing funding and expand the SFA service		Feb 2025	ANU has met APEP and submitted a proposal for their consideration in July 2024. The proposal is still under consideration.

6.4 Objective 4 – Farmers understand and adopt SCF information into their farm management decisions

After the MTR, the project team decided to focus on developing the SCF products and ensuring that they were easily understood and used by farmers. This is captured in the iterative nature of the SCF products and the numerous opportunities for feedback that have resulted in improvements across the products. Although there are no specific activities identified towards this objective, farmer feedback has shown that the farmers find the SFA useful, most especially the alert messages, and have used it to inform their on-farm decisions. NARI conducted a rapid perceptions survey at the end of the project to capture farmers' feedback. Of the 467 SFA recipients, 87 responded to the survey. Survey results show generally positive feedback from the farmers. The success of the SFA is expounded upon in the following chapters.

7 Key results and discussion

This project enhanced the climate resilience of farmers in PNG by providing SCF information and related farm advice in a timely, relevant, and accessible way to support farmers' decision-making. It followed a transdisciplinary approach, involving climate scientists, agronomists, communication experts, social scientists, and farmers themselves. Various components and outputs were developed to help farmers understand and integrate SCF information into their planning. First, the project undertook three surveys to understand the farmers' information needs, information networks, and perceptions about climate change. These findings—combined with a review of CSA interventions and relevant agronomic literature as well as field trial results—created a series of SCF and farming outputs that formed the basis for the SFA. The RMM, a novel framework of combining indigenous and scientific knowledge, is used in conjunction with the SCFA, a monthly forecast, to develop SFAs that are delivered to farmers via SMS. Continuous feedback was crucial throughout the process. The project team actively engaged stakeholders—including farmers, extension officers, churches, community-based organisations (CBOs), and project partners—to refine and improve the project's outputs and support the adoption of new technology and farm management practices through farmer field days, interviews, and FGDs. This collaborative, supportive, and reflective approach was key to its success.

Due to the complexity of the research, project activities were divided into five components to guide their implementation. The components and their relevant activities are listed below:

- Component One – Understanding the knowledge landscape
    - Social network analysis
    - Household survey
    - CSA literature review
    - Climate risk assessment
- Component Two – Establishing field trials
    - Field trials
    - RMM development
- Component Three – SFA design
    - SCFA design process
    - SCFA distribution to project partners
    - SFA design process
- Component Four – Communication and extension
    - SFA distribution and feedback
    - WonderCrop
    - Videos
- Component Five – Economic modelling and value demonstration
    - Farmer field days and workshops
    - Bio-economic model

While the outputs are discussed separately, it is important to understand that they are all connected to ultimately support the creation, delivery, and uptake of the SFA. To communicate SCF information in a manner relevant to farmers, the project team produced the RMM, SCFAs, and SFAs. These were informed by the results of the SNA and household surveys, indigenous knowledge, the field trials, and scientific expertise. Figure 7 is a visual schematic of how these outputs are connected. These were all supported by community engagement activities led by NARI, FPDA, and UoG. Meanwhile, community engagement activities helped increase the awareness of climate change and understanding of SCF while supporting the uptake of the SFAs.

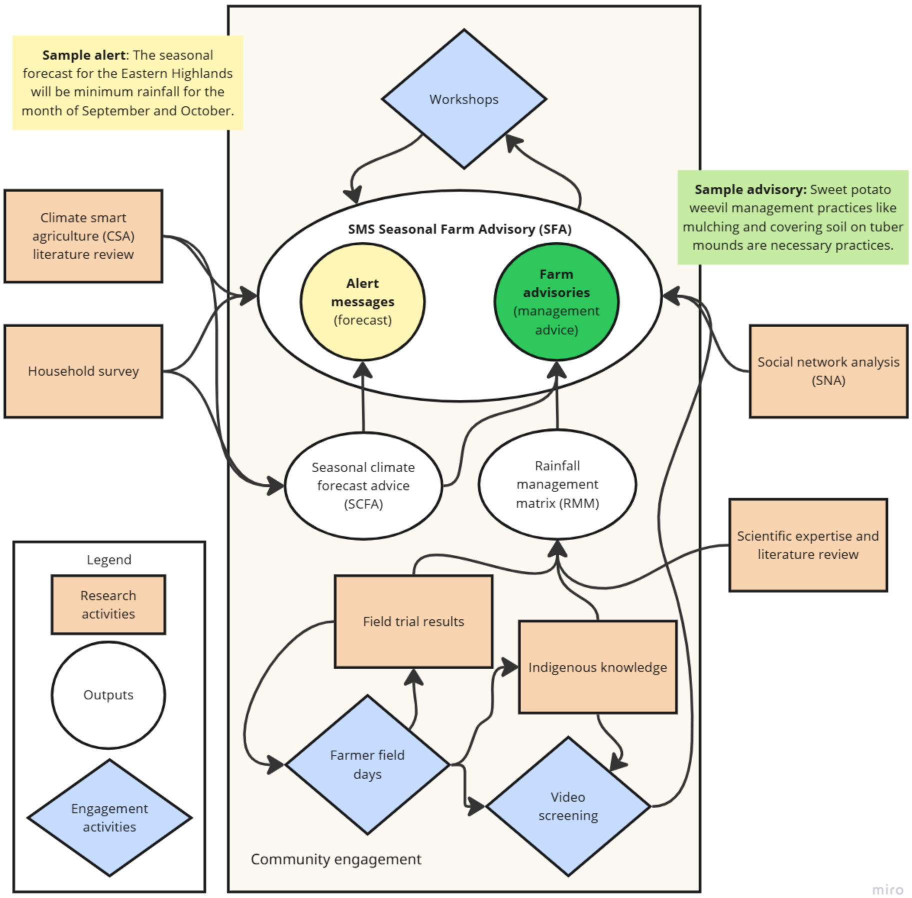


Figure 7 Link between outputs

7.1 Component 1 – Understanding the knowledge landscape

The first set of activities laid the foundational work of the project. Through these activities, the team understood how to implement a CSA initiative in the PNG context. The outputs of these activities answer several questions:

- What should the team consider and/or adopt to ensure a successful CSA project in PNG? (CSA literature review)
- What do farmers think of climate change? (Climate risk assessment)
- What SCF information do farmers need? When do they need it? (Household survey)
- Who are they key knowledge brokers of information? (SNA)
- What indigenous SCF information do farmers possess? (Engagement activities)

7.1.1 What should the team consider and/or adopt to ensure a successful CSA project in PNG? (CSA literature review)

Through background literature and partner consultations, the CSA review identified three challenges facing the development and dissemination of CSA information: 1) participation of multiple and diverse stakeholders; 2) targeting specific, often marginal populations; and 3) pursuing the most appropriate formats and communication channels for effective climate information services. The lessons from the review can be synthesised under two main stages: the development of climate information services, and how to communicate and scale up this information. In the development stage, it is important to involve stakeholders with varied but complementary experience, employ participatory processes to facilitate co-design, integrate traditional and local knowledge with scientific forecasts, and build local capacity for collecting and interpreting weather data. In terms of communication, bundling different types of information (including crop calendars and historical weather data), using a variety of channels (e.g. oral, visual/demonstration, and print), and building on existing social networks and company relationships can ensure that information is widely accessible. Notably, particular measures might be necessary to ensure that information is available to women, youth, and remote communities.

From this global literature review, a general process and set of design principles was developed for the PNG context, which reflected the lessons and themes drawn from the case studies. The translation of climate information into on-ground action requires three essential components: relevance (including social, cultural, and gender), credibility (the perceived technical quality of the information) and legitimacy (the perceived suitability of the process by which the information is co-designed and generated).

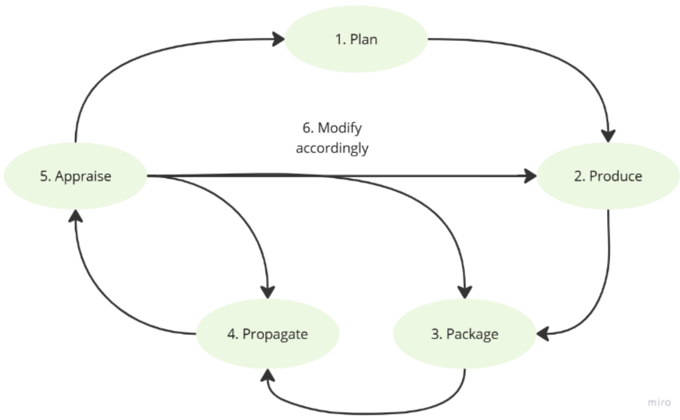


Figure 8 Adaptive development and dissemination process

These lessons were presented as an Implementation Protocol that outlined six stages of an adaptive process for developing and disseminating climate information services, in particular SCFs and climate agro-advisories. The guide is designed to be reassessed and adapted in consultation with stakeholders to enhance its effectiveness over time. The six key are stages:

- **Plan** – establishing structures, identifying stakeholders, and defining roles;
- **Produce** – generating climate forecasts and advisories through co-design;
- **Package** – ensuring the information is accessible and tailored to different users;
- **Propagate** – implementing dissemination strategies suited to the region and stakeholders;
- **Appraise** – continuously evaluating and improving the process; and
- **Modify** – returning to different stages as needed.

7.1.2 What do farmers think of climate change? (Climate risk assessment)

In May 2020, the project team conducted interviews to explore smallholder farmers' experience and understanding of growing food and their decisions in response to changes in the weather. Farmers actively responded to weather conditions and managed their growing crops accordingly. For instance, if they were growing sweet potato and it started to become too wet, they dug drains to reduce the amount of water in the soil. If it was too dry, they watered their crops if they had access to water. They shifted cultivation to a drier or wetter area in response to unfavourable conditions. However, farmers acknowledge that they generally did not make changes in response to a bad year and just waited for conditions to improve.

Farmers ranking of production constraints showed that having planting material was most important. This might refer to their ability to access cuttings of PT varieties. This was followed by land suitability, which might refer to whether the land is available or has enough fertility left to keep growing crops. The third ranked item is availability of labour. This is important because there is no mechanisation or history of use of draft animals. The least important item, fertiliser availability, indicates that the demand for fertiliser is low and uncommon.

The weather is critically important to farmers, who have observed confusing fluctuations resulting in lower yields and/or lower quality crops. Despite these challenges, the assessment found that smallholder farmers do not helplessly standby. They have responded to changing weather conditions by adjusting their daily activities and crop management practices. While they do not make dramatic changes in the crops they grow, they make familiar adjustments more frequently due to less predictable weather and other pressures like land scarcity from a growing population. Indigenous knowledge, traditionally passed orally through generations and reliant on local weather patterns, has become less reliable due to climate variability, affecting normal cropping methods.

7.1.3 What SCF information do farmers need? When do they need it? (Household survey)

Access to seasonal climate information is rarely available to farmers. Available sources are viewed as inconsistent and untrustworthy. However, most farmers do want SCF information and have similar needs in terms of information type and timing. Seasonal rainfall, drought early warning systems, temperature, and rain forecasts were the most important types of information for farmers. However, men and women have distinct information needs. Men primarily want seasonal rainfall and drought information, while women relatively consistently cite seasonal and daily rainfall and daily temperature forecasts. This differs by province as well. In ENB, men cite daily wind information as important, but women favour rainfall and weekly temperature forecasts. Conversely, women in Morobe prefer information in a daily timescale, and those in EHP find rainfall more important than temperature.

The timing differences between gender and provinces are also pronounced. June is the most frequently cited month for receiving information, followed by September and January. September is more important for women, while July and January are for men. In Morobe, June is the most important month to receive information, but September is relatively more important in EHP and ENB for women, while men in ENB and women in Morobe prioritise January.

Uses of climate information also varied by gender. Women more often used weather and climate information to decide when to plant and harvest, while men used it more to choose crops and plan for markets. Both noted the importance of rainfall forecasts to inform land preparation, but this varied by gender and province. The other main divergence of this type was women using information to transplant seedlings in ENB, while men were more likely to do so in the EHP. Weather and climate information guided fertiliser and insecticide application essentially only in the EHP, and primarily for women.

Based on the survey results, the project team created the season types that farmers were most interested in i.e. dry, optimal, wet, wet/dry and dry/wet (Figure 9). Once the season types had been determined the project team established a list of farm-based activities that would occur across the life of the crop. Generalised messaging was developed for the five season types. This messaging was based on agreed activities that would be appropriate for all crops.

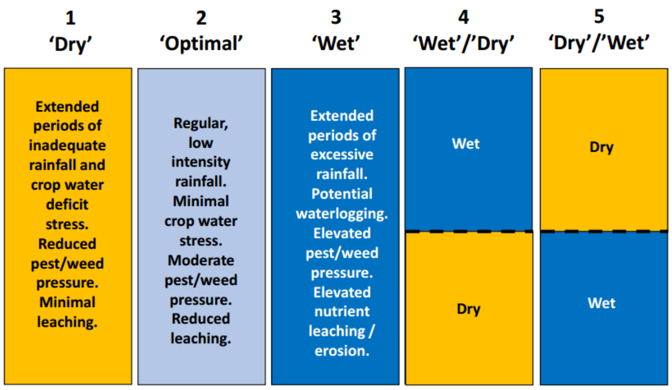


Figure 9 Season type definitions

7.1.4 Who are the key knowledge brokers of information? (SNA)

The SNA results highlight that the church, family, and Wantok (one's tribe or clan) are important and highly trusted sources of information. All groups were consistently central in all regions and acted as avenues to reach smaller community groups, such as farmers or women's groups. These groups also created cliques (sub-networks), meaning that they interact with each other frequently. Government, including NARI extension officers, was a highly trusted source reaching the central groups; however, they were only disseminators of knowledge, not recipients. Overall, farmers were the recipients rather than disseminators of knowledge. Therefore, there are a range of opportunities to reach farmers via different major groups in the community which the SFA delivery capitalised on.

Family and friends play a unique and central role in ENB's information network. Both men and women frequently give information to family and friends, but both genders reported infrequently receiving information from them. The centrality of family and friends in the ENB information network suggests a greater focus on sharing knowledge informally. In EHP and Morobe, men have greater connections with community leaders and formal support institutions such as government. However, they report lower regularity than women in engaging with all groups as part of the broader flow of information. In contrast, in ENB, men report higher regularity than women in engaging with community-based and local groups. This suggests better access and a certain level of trust or respect commanded by men needed to share information with other groups in this region. It is worth noting that women in ENB report stronger engagement with business groups specifically, but they report receiving information from these groups infrequently.

The information sharing networks in ENB seem to be more dispersed than EHP and Morobe, with a greater number of connections between diverse groups. There are also fewer instances reported in ENB of closed-loop sharing of information within a singular group. Though the ENB information network may have more numerous links, these may be more tenuous and signal lower levels of trust within and between certain groups.

There are also gender differences in information needs and networks. One of the key findings from the FGDs is that the seasonal calendars of men and women vary significantly, suggesting different farming roles and likely different information needs. Women also highlighted certain barriers to participating in the project, for example, a woman noted: "Husbands and small kids also discourage us from attending community activities".

Men have greater access to and engagement with media as an information source across all three locations. In ENB, women reported engaging with the media sometimes as a source of information, but male respondents reported stronger and more frequent links between media and other groups in sharing information. Women in ENB have greater connections with community and agriculture and government groups than men do but can very infrequently access or receive information from these or any other sources (except media and observation). Despite reporting higher flow regularity with community and church groups, men also most frequently report sourcing information from media and observation. This highlights the need to consider how gender plays a role in accessing media platforms, and to note the limitations of media in widely sharing climate and weather information.

Women interact with personal networks, CBOs, and formal business, and government groups. This suggests that women are an important and active part of the information network in all surveyed regions. It also suggests that men in ENB play a similarly active role to women, in connecting personal and community networks to share information. While relationships with community groups and leaders was a common connection across all three regions, it is the men who engage more strongly and frequently with this group to share and receive information. Women play an important role in sharing the information they do receive from local and community groups with their family and friends.

7.1.5 What indigenous SCF information do farmers possess? (Community engagement)

Through this project, team members from NARI and UoG have collected various indigenous knowledge that communities use to predict dry and west seasons as well as practices that can help mitigate the impact of climate change. Indigenous knowledge is orally passed down through generations. Some of it depended on local weather patterns which have been impacted by climate variability. Other traditional knowledge draws on practices of observing the sun and moon directions or natural signs like insects burrowing to predict local weather.

Examples are contained in Table 17 collected from the Morobe and ENB provinces.

Table 17 Indigenous wet and dry season indicators

Location	Wet season indicators	Dry season indicators
Huon District, Morobe	Sprouting of young shoot of wild yam called 'offre' Bird sound from white neck Heron locally known as 'Ngarowaneng'	Drying of the leaves of wild yam called 'offre' Bird sounds from 'Gogorob,' aka Hooded Butcher Bird
Nawaeb District, Morobe	Rosewood young shoots from its branch Winds blowing from mountains to the coast Flowering of fruits or nut trees like galip, chestnut	Creek or riverbed drying up Winds blowing from coast to the mountain Rosewood leaves drying up
Gazelle District, East New Britain	Flowering of a tree with creamy white flowers, aka 'Alka' Coastal okari nut producing young shoots/leaves Flowering of mango, orange fruit trees North westerly winds blowing (Tabar) North easterly winds blowing (Labar)	

With the support from NARI, University of Technology (UNITECH), and National Forest Research Institute (FRI), the UoG team documented indigenous farming practices in Morobe province. The Patep community, located in the mountains of Morobe, maintain an irrigation system for taro cultivation built by their ancestors during the pre-European era. The irrigation system channels water from the mountain rivers to their community taro gardens using dugout palms and bamboos as pipes. However, with the emergence of the market economy, the aquatic vegetable watercress has replaced the traditional irrigated taro. The traditional irrigation system has provided a steady supply of water even during droughts. Beyond agriculture, the irrigation system also provides regular water for drinking and household chores. The system is unique to the area and the entire country where irrigation is not commonplace.

Photo 1 Part of Patep irrigation system

The Bugwev community in Buang and Bulolo districts have taught themselves to plant watercress in response to floods that destroyed their coffee gardens in 2015. The community decided to plant watercress after they saw it being carried down the river. They built stone walls to ensure the watercress receives some water but is not overwhelmed.

The community observed that watercress needs a careful balance of water and sun to grow. The community sells the watercress in the markets where they sell, on average, 100 bunches of watercress for 100 kina. Although watercress must be sold the day after harvest before going bad, the community says it is an opportunity to have fast income since it only takes two weeks to harvest. This provides regular income in comparison to other crops.

There are also innovative farmers who have observed the relationship between rainfall and prediction the season. David Kulimbao, a farmer and community leader from Bena, measures rainfall using empty tin cans and a ruler which he says helps him predict whether rain will be light or heavy. He logs his measurements in a notebook. He also measures the water level in the stream with a marked bamboo or with his legs. He says the water level indicates the water level upstream and if a dry season is coming. If the water level is at the ankle level, dry season is near.

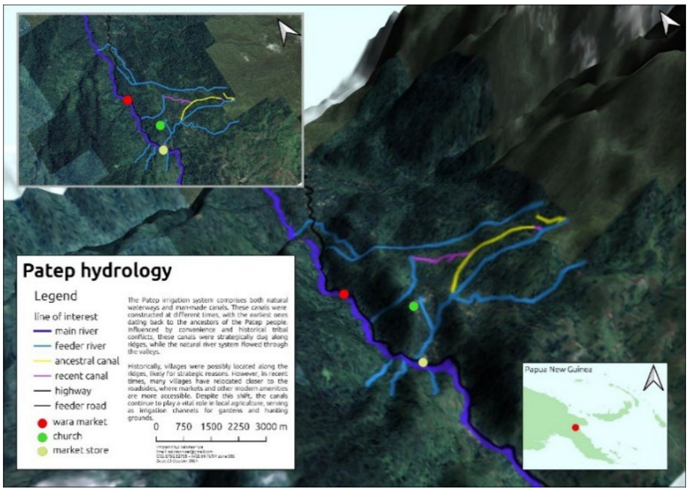


Figure 10 Patep hydrology and irrigation system

7.2 Component 2 – Establishing field trials

In the second component of work, the team established field trials. These trials had two purposes. First, the results were used to populate gaps in the RMM which is discussed at the end of this chapter. Since SCF were not available yet when the trials were ongoing, the team retroactively looked at the seasonal conditions that prevailed and the performance of the management options to see what an appropriate response would be. This information was fed into the RMM. Second, the field trials were opportunities to demonstrate the value of different farm management practices, e.g. irrigation and fertiliser use. The field trials were initially intended to occur within communities. However, due to COVID-19, the team decided to hold most of the trials on research stations. This limited community engagement but ensured the activities could proceed amidst uncertainties. The findings of these field trials are outlined in case studies. The RMM is also discussed at the end of the section since it was partly informed by the results of the field trials.

7.2.1 Field trial results

Case study 1: On station field trial results of Potato Irrigation x Fertiliser application

On station field trials conducted in 2020 and 2021 at Aiyura considered the influences of irrigation, timing and rates of fertiliser applications, and variety selections and fungicide management practices on Irish potato production. The first treatment combination of Irish Potato field trial reported was inflow water management (1) rain fed and (2) bucket irrigation combined with four levels of fertiliser applications. The four levels of fertiliser rates were (1) Nil (0Kg/Ha or control), (2) Basal fertiliser application of 740Kg/Ha, (3) Basal + 1 top dressing fertiliser split application of 1480Kg/Ha, and (4) Basal + 2 top dressing fertiliser split application 2220Kg/Ha. The four levels of fertiliser were combined with two levels of inflow water and were applied at different growth stages on E2 variety. Results of the first on station trial (irrigation x fertiliser applications) indicated that fertiliser levels and time of application had high significant influences on the growth and yield qualities while irrigation had significant influences on the growth and yield qualities parameters assessed. The results from this trial could be taken into farmers' fields with minor adjustments taking into consideration farmers current practices. Basal + 2 top-dressing fertiliser (2220Kg/Ha) were omitted because it was not economical as per the on-station trial results. Thus, the possible treatment combinations taken forward to farmers' fields based were basal and basal + 1 top dressing with or without irrigation depending on the local weather.

Case study 2: On station field trial results of Fungicide x Variety

The second potato trial undertaken in 2020 and 2021 involved four Irish potato varieties E2, Sequoia, Markies, and Santana and tested with and without the recommended fungicide management practices in Aiyura. Results from this second trial indicated that E2 is highly tolerant to potato late blight (PLB) disease and is a very high yielding variety compared to the other three varieties. The E2 variety is also a late maturing variety. Sequoia was found to be highly susceptible to PLB compared to the other two introduced varieties, Markies and Santana. In terms of yield and income, Sequoia variety grown without applying the recommended spray management practices under Aiyura environmental condition put up poor performance while Markies and Santana could produce least without spraying fungicides where as E2 can produce optimum yield without spraying of fungicides.

Case study 3: On station field trials of Bulb onion Irrigation x Fertiliser application trials

Photo 2 Onion harvest from trial

NARI Aiyura also conducted a trial on the effect of inflow water and nutrient management. It revealed that onion responded well to the application of different fertiliser rates. Yields were all higher in plots amended with different fertiliser applications in comparison with the control. Significant results were shown at 70 DAT, while high significant effect on total bulb yields at 100 DAT and maturity. Irrigation effect was shown at maturity. Yield was doubled and then tripled under the irrigation basal + 1 top-dress and irrigation basal only, and irrigation + 2 top-dress treatment at maturity, respectively. Irrigated fertiliser treatments produced higher yields compared to the rainfed fertiliser treatments. Irrigated treatments produced more marketable onions than that of rainfed. Both the main effect of irrigation and sub-effect of fertiliser shows significant and high significant results, respectively, and highly influenced the total bulb fresh weight and dry matter production. The application of basal + 1 top-dress combined with irrigation has increase onion growth and bulb yield. Based on the results, nil fertiliser application was omitted as it was unrealistic since farmers use nutrient options to grow onion. Therefore, the five fertiliser management regimes encompassed the range of current farmer practice, the recommended rate for bulb onion, an above-recommended rate, one event manure application, and two event manure applications—both manure application practice by farmers were use based on the SCF information.

Photo 3 Participants in farmer trials

Case study 4: Sweet potato trial

The sweet potato trial examined ridge planting methods, fertiliser treatments, and farmers' adoption of new practices. Ridge planting was found to be effective, with a 40 cm ridge height and inclined planting angle yielding higher root production, while a 30 cm ridge with horizontal planting produced round swollen roots. Stand-alone NPK (12:12:17) fertiliser resulted in the highest yield benefits, yet many farmers hesitated to invest due to financial constraints and unpredictable weather. Most farmers had access to agricultural information but were slow to adopt innovations. A follow-up trial on inorganic fertiliser solubility is needed to refine recommendations and encourage adoption. Farmers were given management options based on their resources, with compost treatment being affordable but slow to gain acceptance. While the trial was research-oriented, results showed that NPK fertiliser, especially when combined with irrigation, had the highest gross margin, followed by organic compost. For profitability, stand-alone NPK and its combination with irrigation proved most viable, while compost treatment also showed potential for profit.

7.2.2 Farmer feedback

Photo 4 Family participants in an activity

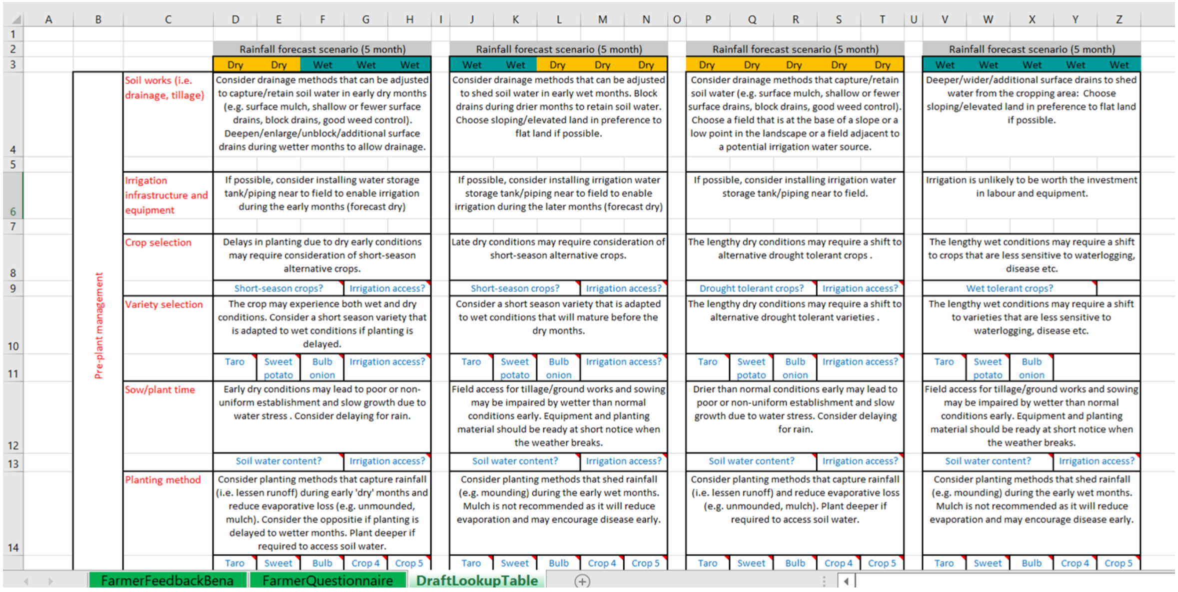
Farmer field days were held in Kuka village (EHP), Momase Regional Centre (Morobe), and Kerevat station (ENB). The participants were a mix of subsistence, semi-commercial, and commercial farmers. Often, the farmers are considered 'lead farmers' since they have a big following of farmers who look up to them and follow their advice. Feedback from the farmers helped design succeeding trials. One of the barriers to overcome was farmers' perceptions that inorganic fertiliser is prohibitively expensive and detrimental to the environment. It was suggested that future trials explore lower cost and more readily available animal manures and composts. Feedback from the field day indicated that farmers could see the potential benefit from simple irrigation in dry seasons, especially for enabling planting at the most profitable/favourable time of the year. They also wanted to see further irrigation trials as a standalone treatment without extra fertiliser. Mention was also made of the potential to modify drainage methods in response to rainfall amount and forecast.

The FFT workshop paved way for opening discussions within communities. The workshop was useful to understand the communities' farming systems, their traditional seasonal calendar, and the farming problems they faced. The community expressed a clear desire to be part of the project after the FFT workshop and was very involved in the FGDs and one-on-one interviews. The act of conducting the workshop was appreciated and contributed to maintaining a high level of trust between the community and the project.

The farmers were impressed by the increased yields in fertiliser and irrigation trials but did not directly see its connection with climate forecasts. However, they said they would be willing to invest in fertiliser and irrigation if they had SFA information. It was a challenge to explain the SCF terms to farmers (e.g. "above average wet" in a dry month). Therefore, it was necessary to invest time and effort in explaining and refining the terms. The field days were also an opportunity to collect indigenous knowledge and better understand how they recognise climate change in their local areas. It was a challenge to explain SCF and adaptive farm management practices when they contradicted indigenous knowledge. Lastly, the field days were a good opportunity to gain feedback on the RMM and SFA.

7.2.3 Rainfall management matrix

The RMM, previously referred to as a contingency table, serves as a comprehensive resource for farm management strategies tailored to various rainfall scenarios and priority crops. Its primary aim is to provide clear, practical recommendations that help mitigate the adverse impacts or leverage the benefits of forecasted seasonal rainfall patterns. The RMM has undergone several stages of development and refinement. The concept was initially drafted by Dr Shaun Lisson and subsequently advanced through a co-design process involving Australian and PNG project team members, drawing on the results from the trials, literature review, and indigenous knowledge. This collaborative phase was crucial for incorporating local scientific knowledge of crops and management practices. The RMM was later reviewed by agricultural scientists Dr Mike Bourke and Dr Miok Komolong, who bring extensive experience from working across PNG. Farmer feedback was also sought to ensure relevance and usability, and the RMM underwent a final review during a team exercise at the 2023 SFA Workshop. As a living document, the RMM has become increasingly rigorous and relevant with each iteration.



		Rainfall forecast scenario (5 month)	Rainfall forecast scenario (5 month)	Rainfall forecast scenario (5 month)	Rainfall forecast scenario (5 month)
		Dry Dry Wet Wet Wet	Wet Wet Dry Dry Dry	Dry Dry Dry Dry Dry	Wet Wet Wet Wet Wet
Pre-plant management	Soil works (i.e. drainage, tillage)	Consider drainage methods that can be adjusted to capture/retain soil water in early dry months (e.g. surface mulch, shallow or fewer surface drains, block drains, good weed control). Deepen/enlarge/unblock/additional surface drains during wetter months to allow drainage.	Consider drainage methods that can be adjusted to shed soil water in early wet months. Block drains during drier months to retain soil water. Choose sloping/elevated land in preference to flat land if possible.	Consider drainage methods that capture/retain soil water (e.g. surface mulch, shallow or fewer surface drains, block drains, good weed control). Choose a field that is at the base of a slope or a low point in the landscape or a field adjacent to a potential irrigation water source.	Deeper/wider/additional surface drains to shed water from the cropping area: Choose sloping/elevated land in preference to flat land if possible.
	Irrigation infrastructure and equipment	If possible, consider installing water storage tank/piping near to field to enable irrigation during the early months (forecast dry)	If possible, consider installing irrigation water storage tank/piping near to field to enable irrigation during the later months (forecast dry)	If possible, consider installing irrigation water storage tank/piping near to field.	Irrigation is unlikely to be worth the investment in labour and equipment.
	Crop selection	Delays in planting due to dry early conditions may require consideration of short-season alternative crops.	Late dry conditions may require consideration of short-season alternative crops.	The lengthy dry conditions may require a shift to alternative drought tolerant crops .	The lengthy wet conditions may require a shift to crops that are less sensitive to waterlogging, disease etc.
		Short-season crops? Irrigation access?	Short-season crops? Irrigation access?	Drought tolerant crops? Irrigation access?	Wet tolerant crops?
	Variety selection	The crop may experience both wet and dry conditions. Consider a short season variety that is adapted to wet conditions if planting is delayed.	Consider a short season variety that is adapted to wet conditions that will mature before the dry months.	The lengthy dry conditions may require a shift to alternative drought tolerant varieties .	The lengthy wet conditions may require a shift to varieties that are less sensitive to waterlogging, disease etc.
		Taro Sweet potato Bulb onion Irrigation access?	Taro Sweet potato Bulb onion Irrigation access?	Taro Sweet potato Bulb onion Irrigation access?	Taro Sweet potato Bulb onion
	Sow/plant time	Early dry conditions may lead to poor or non-uniform establishment and slow growth due to water stress . Consider delaying for rain.	Field access for tillage/ground works and sowing may be impaired by wetter than normal conditions early. Equipment and planting material should be ready at short notice when the weather breaks.	Drier than normal conditions early may lead to poor or non-uniform establishment and slow growth due to water stress. Consider delaying for rain.	Field access for tillage/ground works and sowing may be impaired by wetter than normal conditions early. Equipment and planting material should be ready at short notice when the weather breaks.
		Soil water content? Irrigation access?	Soil water content? Irrigation access?	Soil water content? Irrigation access?	Soil water content? Irrigation access?
	Planting method	Consider planting methods that capture rainfall (i.e. lessen runoff) during early 'dry' months and reduce evaporative loss (e.g. unmounded, mulch). Consider the oppositie if planting is delayed to wetter months. Plant deeper if required to access soil water.	Consider planting methods that shed rainfall (e.g. mounding) during the early wet months. Mulch is not recommended as it will reduce evaporation and may encourage disease early.	Consider planting methods that capture rainfall (i.e. lessen runoff) and reduce evaporative loss (e.g. unmounded, mulch). Plant deeper if required to access soil water.	Consider planting methods that shed rainfall (e.g. mounding) during the early wet months. Mulch is not recommended as it will reduce evaporation and may encourage disease early.
		Taro Sweet Bulb Crop 4 Crop 5	Taro Sweet Bulb Crop 4 Crop 5	Taro Sweet Bulb Crop 4 Crop 5	Taro Sweet Bulb Crop 4 Crop 5

FarmerFeedbackBena FarmerQuestionnaire DraftLookupTable

Figure 11 Screenshot of the RMM

The RMM is a ‘look-up’ table containing crop husbandry management practices in land preparation and crop management advice for a range of possible seasonal rainfall scenarios (See Figure 11). The table covers nine significant crop types grown over the three target provinces (EHP, Morobe, and ENB) and is a key element of the project that brings together agronomic, climate, and economic information to help farmers better manage seasonal rainfall variability, uncertainties, or other weather extremes. Key features of the RMM include potential responses for nine crop management variables to different seasonal rainfall scenarios covering the period from site preparation to final harvest as crop specific or as generic advisories. The scenarios cover a spectrum of rainfall conditions ranging from below optimal rainfall throughout the season at the ‘dry’ end, through to above optimal rainfall throughout at the ‘wet’ end. Each scenario is defined in terms of tangible system outcomes including: 1) crop growth stress from water logging or soil water deficit; 2) soil water balance impacts on run-off, deep drainage, nutrient leaching and erosion; and 3) biotic impacts from pests, disease and weeds etc.

Each table follows a consistent structure, addressing five seasonal rainfall scenarios: *Wet*, *Dry*, *Optimum*, and two transitional scenarios, *Wet/Dry* and *Dry/Wet*. These scenarios are expressed in relative terms, such as wetter or drier than the normal or average season, recognising that ‘normal’ conditions vary between locations. For each scenario, the RMM outlines recommendations across seven management variables: land preparation, variety selection, planting, irrigation, nutrition, pest and weed management, and harvesting. This structured approach ensures that the RMM acts as an effective application tool for the SFA, offering targeted, user-friendly guidance to extension workers and farmers.

Despite the huge RMM database, UoG translated the RMM for five crops (taro, bulb onion, peanut, sweet potato, and potato) into Pidgin with the help of some farmers and validation from project team members. The RMM translation forms the basis for the SMS messaging to farmers. A book has been developed.

How is the RMM used for the SFA?

The RMM is used in tandem with the SCFA (produced by NWS), which provide weather information on a three-month time scale, to develop the SFA. Depending on the forecast and the month, the SFA will draw on relevant advice from the RMM to distribute to the farmers. Given the variability of farming contexts and rainfall scenarios, not all RMM recommendations are universally applicable. Project teams play a vital role in advising on the most suitable management strategies, guided by their interpretation of SCF data and local knowledge.

However, the RMM made it easier to decide and train others to provide the SFA service. While it does form the basis of the SFA, the RMM is also useful beyond this project as it provides a framework to integrate indigenous and scientific knowledge across different sectors.

7.3 Component 3 – Designing the SFA

Activities under the third component address the main objective of the project: PNG farmers understand SCF information and use it to support their farm management decisions. The SFA is not intended to replace what farmers currently do, rather it is an additional 'tool' in their management decision 'toolbox'. Indigenous and other local knowledge remain a key determinant of what farmers do.

Building on the learnings from component one, the project team developed SMS-based SFAs to provide farmers SCFs. This required translating complex probabilistic information into simple text that farmers could understand. This section discusses that translation process as well as the thinking behind the delivery of the SFA. These activities generated two outputs: SCFA and SFA. While both outputs have often been referred to as the SFA throughout the project lifetime, the team has separated them to clarify the process and the two outputs.

The creation of the SMS-based messaging was done by consensus between the NWS, NARI, and FPDA. The Tok Pisin messages were often validated against the RMM messages to ensure consistency. The SMS messages were also translated back to English by other NARI staff to ensure that critical information or actions have not been incorrectly translated. This approach was very labour intensive and if this work were to continue and to be scaled to other locations a more automated approach would be required.

7.3.1 Seasonal climate forecast advisories

Where does PNG get its forecasts?

At the early stages of this project, NWS was also part of the CREWS-PNG project with the World Meteorology Organisation (WMO) to develop a drought early warning system. NWS only has thirteen weather stations across PNG, and most are located in the lowland areas, with even fewer having records that extend beyond 20 years. The project team was able to negotiate with CREWS to support the forecast requirements needed for the SCFA by altering the boundaries of the Australian operational SCF system to include PNG. With assistance and training from BOM, NWS was able to create prototype products that provide forecasts at different time scales and provide other information such as rainfall measurements and drought hazards.

One of the caveats associated with the SCF information is an assessment of accuracy of the SCF information. In Australia the SCF information is validated against over 1200 rainfall observations. Given the limited number of weather stations in PNG, the SCF is only able to be validated against satellite observations of rainfall for a period of 15 years. Given the limited verification of forecast accuracy in PNG, the project team decided that SFA messaging needed to be conservative and contain estimates of cumulative seasonal rainfall for communities accessing this information to determine their responses based on perceived risk.

What is the accuracy of the forecasts?

A validation study was conducted by BOM to evaluate the WMO’s Space-based Weather and Climate Extremes Monitoring (SWCEM) Demonstration Project precipitation products over PNG. The products evaluated were based on remotely-sensed precipitation, vegetation health, soil moisture, and outgoing longwave radiation (OLR) data. The satellite precipitation estimates of the Climate Prediction Centre/National Oceanic and Atmospheric Administration’s morphing technique and Japan Aerospace Exploration Agency’s Global Satellite Mapping of Precipitation were assessed on a monthly timescale over an 18-year period from 2001 to 2018. Station data along with the ERA5 reanalysis were used as the reference datasets for assessment purposes. In addition, a case study was performed to investigate how well the SWCEM precipitation products characterised drought in PNG associated with the 2015–2016 El Niño.

Overall statistics from the validation study suggest that although there remains significant variability between satellite and ERA5 rainfall data in remote areas, this difference is much less at locations where rain gauges exist. The case study illustrates that the Vegetation Health Index, OLR anomaly, and the Standardized Precipitation Index were able to reliably capture the spatial and temporal aspects of the severe 2015–2016 El Niño-induced drought in PNG.

This study is novel as modern-day satellite-derived products have not been evaluated over PNG before. A focus on their value in monitoring drought can bring great value in mitigating the impact of future droughts.

It is concluded that these satellite-derived precipitation products could be recommended for operational use for drought detection and rainfall monitoring in PNG, and that even a modest increase in ground-based observations will increase the accuracy of satellite-derived observations remotely. (Chua et al. 2020) This validation study was critical as it gave the project team the confidence and the motivation to use the satellite-based products developed by BOM and PNGNWS for the SCFA.

What are the challenges with the forecasts?

One of the key challenges with the forecasts was to differentiate between deterministic and probabilistic forecasts. The key difference lied in how to address uncertainty in the forecast. Deterministic forecasts provide a single, 'best guess' outcome, while probabilistic forecasts offer a range of possible outcomes with associated probabilities, acknowledging the inherent uncertainty in predictions.

The other equally important challenge was for users to understand probability forecasts. Probability forecasts provide a range of possible outcome with associated probabilities and to decide amongst the range of possible outcomes requires adequate knowledge in dealing with probability and how to meaningfully interpret them.

In terms of assessing the skills of the forecasts, NWS required a few ground-based observation against the satellite-derived observations remotely. For EHP, NWS was fortunate to have two ground-based stations that were used to validate the forecast. Unfortunately, this cannot be said for other provinces as there is only one station or no stations at all.

What are seasonal climate forecast advisories?

SCFAs were specialised monthly seasonal climate outlooks for the agricultural sector developed by NWS. It was first produced and disseminated on 6 June 2023 and was specially designed to incorporate the needs of agriculture stakeholders, particularly in EHP. It was intended to help agricultural extension officers, such as the project team from NARI, develop more targeted advice to the farmers they support. The content of the SCFA has been co-designed by project team members and fine-tuned based on feedback from stakeholders across the three provinces. The SCFA was not designed to be shared with farmers directly. Instead, it was intended for agricultural extension officers and other institutionalised information brokers identified in the SNA, including the NARI team that develops the SFA.

The findings from component one revealed that for the SFA to be accessible and utilised it needed to be localised and shared with a wider range of localised and community-based groups to ensure women have the same level of access as men. In February 2020, staff from ANU, CSIRO, and Phloem 3 visited Goroka and Lae to discuss the SCF information needs with FPDA, NARI, and DAL staff. Based on the presentation of a range of different forecast products and after a discussion of what these meant and how to communicate them, the participants agreed on the following:

- The SCFA should be developed using the tercile probability forecast products and include the accuracy/skill estimates.
- Temperature forecasts had limited accuracy and were not of interest.
- The SCFA should include national and regionalised SCF information so recipients can get a sense of what is happening outside their region.
- The SCFA should include weekly, one month, and three-month forecast of rainfall in a broader information product.
- The SCFA should include a 6-month forecast at the beginning of the year and middle of the year to prepare farmers for potential drought conditions or the risk of below long-term mean rainfall.

With the requests in mind, NWS designed the first iteration of the SCFA (Figure 12) and developed regionalised SCFAs for EHP, ENB, and Morobe. They were first shared to the team in June 2023.

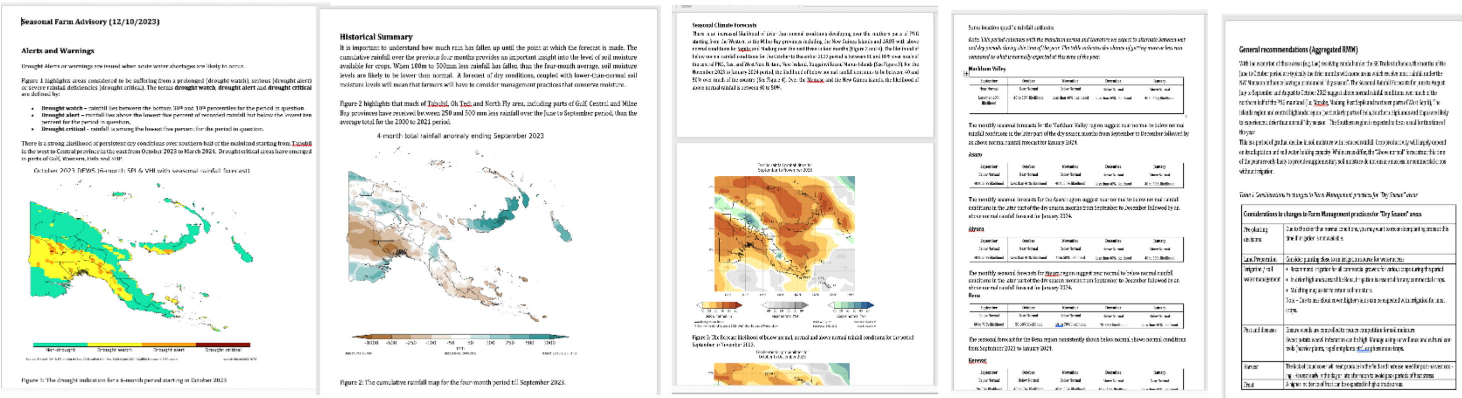


Figure 12 First version of the SCFA

The project team from NARI regularly provided feedback to NWS to improve the SCFA. The team also reached out to other stakeholders—such as DAL extension officers, churches, provincial governments, universities, and CBOs—to improve the readability and messaging of the SCFA. The team observed that it initially took stakeholders sometime to read, understand, and process all the information in the SCFA. Some of the feedback included:

- Appreciated the SCFA document. Seen as a vital tool for farmer extension activities.
- Need to include weather information on wind as ENB is prone to the traditional winds (Labur is North Westerly-dry and Taubar is South Easterly-wet).
- Weather forecast information needs to be further scaled down with easy-to-understand English.
- Installation of automated weather stations in each district in ENB will form basis of useful information to plan in agriculture.
- Expressed interest to share with his taro and sweet potato farmers in Markham.
- Would prefer the SCFA to be location specific and crop specific.
- Valuable to farmers for planning, particularly with reference to time of planting experiences with delayed onset of rains.
- Suggest the map on the SCFA document to have provincial and district borders for easy reference.
- Preferred to have an SCFA document for Morobe Province excluding the other provinces.

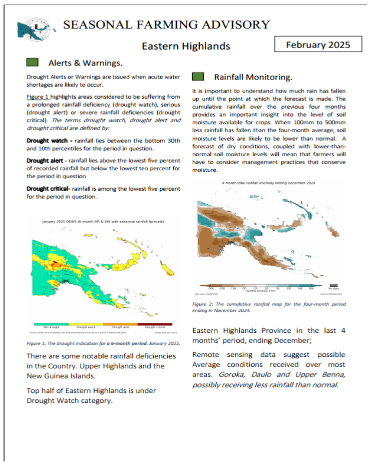
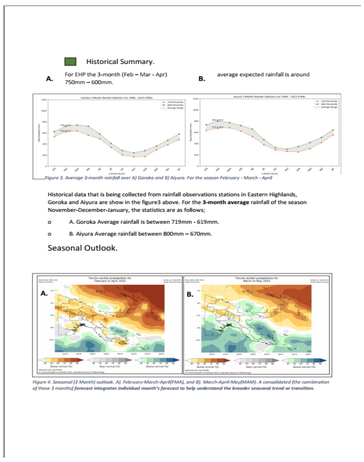
The team accommodated as much feedback as possible. Some adjustments NWS made to the SCFA over time include:

- NWS first provided 5-month forecasts. These have been changed to 3-month forecasts based on the feedback of farmers.

- Made the SCFA more visually appealing and made the messages shorter and clearer.
- Had the drought alerts at a 6-month timescale to make it more relevant to farmers.
- Made the historical summary location-specific.
- Modified the seasonal outlook maps so that it was at the provincial level.
- Revised the monthly seasonal probabilities to make it more easily understood and redesigned the maps to include colours based on probability.

The SCFA template went through four iterations. The latest version was finalised in December 2024. It had five pages that contain tailored information relevant for the agriculture sector of the specific province. The information contained in these pages are outlined in Table 18.

Table 18 Contents of the SCFA

Page #	Contents	Sample page
1	<u>Alerts</u> • Drought Alerts on a 6-month timescale. • Highlights areas considered to be suffering from a prolonged rainfall deficiency. <u>Rainfall Monitoring</u> • Cumulative rainfall for the last four months compared to normal. Provides an important insight into the level of soil moisture available for crops.	 SEASONAL FARMING ADVISORY Eastern Highlands February 2025 Alerts & Warnings. Drought Alerts or Warnings are issued when acute water shortages are likely to occur. Figure 1 highlights areas considered to be suffering from a prolonged rainfall deficiency (drought watch), serious (drought alert) or severe rainfall deficiencies (drought critical). *The terms drought watch, drought alert and drought critical are defined by:* **Drought watch -** rainfall lies between the bottom 30th and 10th percentiles for the period in question. **Drought alert** - rainfall lies above the lowest five percent of recorded rainfall but below the lowest ten percent for the period in question **Drought critical-** rainfall is among the lowest five percent for the period in question. *Figure 1: The drought indication for a **6-month period.** January 2025.* There are some notable rainfall deficiencies in the Country. Upper Highlands and the New Guinea Islands. Top half of Eastern Highlands is under Drought Watch category. Rainfall Monitoring. It is important to understand how much rain has fallen up until the point at which the forecast is made. The cumulative rainfall over the previous four months provides an important insight into the level of soil moisture available for crops. When 100mm to 500mm less rainfall has fallen than the four-month average, soil moisture levels are likely to be lower than normal. A forecast of dry conditions, coupled with lower-than-normal soil moisture levels will mean that farmers will have to consider management practices that conserve moisture. *Figure 2: The cumulative rainfall map for the four-month period ending in November 2024.* Eastern Highlands Province in the last 4 months' period, ending December; Remote sensing data suggest possible Average conditions received over most areas. *Goroka, Daulo and Upper Benna, possibly receiving less rainfall than normal.*
2	<u>Historical Summary</u> • Observed cumulative rainfall for three months. For EHP, 2 rainfall stations are used, Aiyura and Goroka. This provides insight to what is considered Normal rainfall amounts for a 3-month season. <u>Seasonal Outlook</u> • Based on a 3-month forecast from the BOM Climate Model, ACCESS-S. • Provides a guide to the probability of the rainfall to be above normal, below normal or normal for the season.	 Historical Summary. A. For EHP the 3-month (Feb – Mar - Apr) 750mm – 600mm. B. average expected rainfall is around *Figure 3. Average 3-month rainfall over A) Goroka and B) Aiyura. For the season February - March - April* Historical data that is being collected from rainfall observations stations in Eastern Highlands, Goroka and Aiyura are show in the figure3 above. For the **3-month average** rainfall of the season November-December-January, the statistics are as follows; o A. Goroka Average rainfall is between 719mm - 619mm. o B. Aiyura Average rainfall between 800mm – 670mm. Seasonal Outlook. *Figure 4. Seasonal (3 Month) outlook. A). February-March-April(FMA), and B). March-April-May(MAM). A consolidated (the combination of these 3 months) **forecast integrates individual month's forecast to help understand the broader seasonal trend or transition.***
3-4	<u>Monthly Probability Forecasts</u>	

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Focuses on the province. Overlays the districts and extract the rainfall probability on average for a district.
Forecast data is from ACCESS-S and presented at the 3-month lead time although monthly information is often contained in the text

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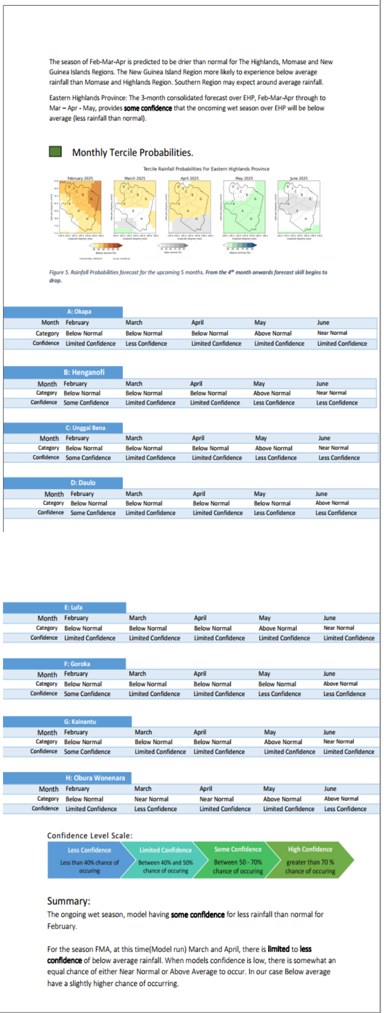
The season of Feb-Mar-Apr is predicted to be drier than normal for The Highlands, Momase and New Guinea Islands Regions. The New Guinea Island Region more likely to experience below average rainfall than Momase and Highlands Region. Southern Region may expect around average rainfall.
Eastern Highlands Province: The 3-month consolidated forecast over EHP, Feb-Mar-Apr through to Mar – Apr - May, provides some confidence that the oncoming wet season over EHP will be below average (less rainfall than normal).
Monthly Tercile Probabilities.

Figure 5. Rainfall Probabilities forecast for the upcoming 5 months. From the 4th month onwards forecast skill begins to drop.
<table>
<tr><th colspan="6">A: Okapa</th></tr>
<tr><td>Month</td><td>February</td><td>March</td><td>April</td><td>May</td><td>June</td></tr>
<tr><td>Category</td><td>Below Normal</td><td>Below Normal</td><td>Below Normal</td><td>Above Normal</td><td>Near Normal</td></tr>
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<tr><td>Month</td><td>February</td><td>March</td><td>April</td><td>May</td><td>June</td></tr>
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<tr><th colspan="6">C: Unggai Bena</th></tr>
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<tr><td>Category</td><td>Below Normal</td><td>Below Normal</td><td>Below Normal</td><td>Above Normal</td><td>Near Normal</td></tr>
<tr><td>Confidence</td><td>Some Confidence</td><td>Limited Confidence</td><td>Limited Confidence</td><td>Less Confidence</td><td>Less Confidence</td></tr>
<tr><th colspan="6">D: Daulo</th></tr>
<tr><td>Month</td><td>February</td><td>March</td><td>April</td><td>May</td><td>June</td></tr>
<tr><td>Category</td><td>Below Normal</td><td>Below Normal</td><td>Below Normal</td><td>Below Normal</td><td>Above Normal</td></tr>
<tr><td>Confidence</td><td>Some Confidence</td><td>Limited Confidence</td><td>Limited Confidence</td><td>Less Confidence</td><td>Less Confidence</td></tr>
<tr><th colspan="6">E: Lufa</th></tr>
<tr><td>Month</td><td>February</td><td>March</td><td>April</td><td>May</td><td>June</td></tr>
<tr><td>Category</td><td>Below Normal</td><td>Below Normal</td><td>Below Normal</td><td>Above Normal</td><td>Near Normal</td></tr>
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<tr><th colspan="6">F: Goroka</th></tr>
<tr><td>Month</td><td>February</td><td>March</td><td>April</td><td>May</td><td>June</td></tr>
<tr><td>Category</td><td>Below Normal</td><td>Below Normal</td><td>Below Normal</td><td>Below Normal</td><td>Above Normal</td></tr>
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<tr><th colspan="6">G: Kainantu</th></tr>
<tr><td>Month</td><td>February</td><td>March</td><td>April</td><td>May</td><td>June</td></tr>
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<tr><th colspan="6">H: Obura Wonenara</th></tr>
<tr><td>Month</td><td>February</td><td>March</td><td>April</td><td>May</td><td>June</td></tr>
<tr><td>Category</td><td>Below Normal</td><td>Near Normal</td><td>Near Normal</td><td>Above Normal</td><td>Above Normal</td></tr>
<tr><td>Confidence</td><td>Limited Confidence</td><td>Less Confidence</td><td>Limited Confidence</td><td>Limited Confidence</td><td>Less Confidence</td></tr>
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Confidence Level Scale:
Less Confidence – Less than 40% chance of occuring
Limited Confidence – Between 40% and 50% chance of occuring
Some Confidence – Between 50 - 70% chance of occuring
High Confidence – greater than 70 % chance of occuring
Summary:
The ongoing wet season, model having some confidence for less rainfall than normal for February.
For the season FMA, at this time(Model run) March and April, there is limited to less confidence of below average rainfall. When models confidence is low, there is somewhat an equal chance of either Near Normal or Above Average to occur. In our case Below average have a slightly higher chance of occurring.
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<u>Monthly Scenario Probabilities</u>

Messaging associated with the possibility of a fixed rainfall amount is also contained in the SCFA. Focus is made on rainfall thresholds where a 75% confidence level exists.

<u>Summary</u>

A summary is then provided expressing the likely scenario for the months and season.

<u>Overall Summary</u>

This now combines all the information into a single digestible message.

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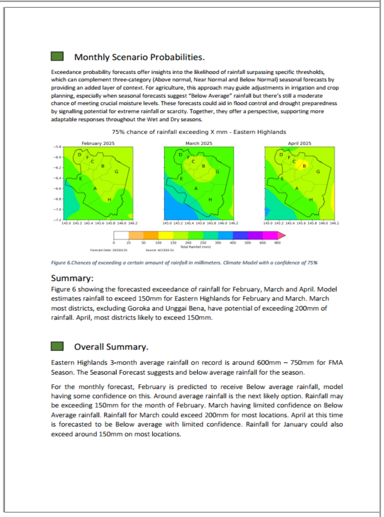
Monthly Scenario Probabilities.
Exceedance probability forecasts offer insights into the likelihood of rainfall surpassing specific thresholds, which can complement three-category (Above normal, Near Normal and Below Normal) seasonal forecasts by providing an added layer of context. For agriculture, this approach may guide adjustments in irrigation and crop planning, especially when seasonal forecasts suggest "Below Average" rainfall but there's still a moderate chance of meeting crucial moisture levels. These forecasts could aid in flood control and drought preparedness by signalling potential for extreme rainfall or scarcity. Together, they offer a perspective, supporting more adaptable responses throughout the Wet and Dry seasons.

Figure 6.Chances of exceeding a certain amount of rainfall in millimeters. Climate Model with a confidence of 75%
Summary:
Figure 6 showing the forecasted exceedance of rainfall for February, March and April. Model estimates rainfall to exceed 150mm for Eastern Highlands for February and March. March most districts, excluding Goroka and Unggai Bena, have potential of exceeding 200mm of rainfall. April, most districts likely to exceed 150mm.
Overall Summary.
Eastern Highlands 3-month average rainfall on record is around 600mm – 750mm for FMA Season. The Seasonal Forecast suggests and below average rainfall for the season.
For the monthly forecast, February is predicted to receive Below average rainfall, model having some confidence on this. Around average rainfall is the next likely option. Rainfall may be exceeding 150mm for the month of February. March having limited confidence on Below Average rainfall. Rainfall for March could exceed 200mm for most locations. April at this time is forecasted to be Below average with limited confidence. Rainfall for January could also exceed around 150mm on most locations.
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How many iterations of the SCFA were there?

A total of four iterations of the SCFA were made:

1. Base Outlook: Original template
   The original template included alerts and warnings, a 6-month drought update with historical summaries, SCF, some location-specific forecast, and a general recommendation.
2. SCFA_v1 April 2024
   A restructure of the basic template, designed to enhance clarity and improve readability.
3. SCFA_v2.8 September 2024
   Introduced new probabilistic tercile maps at the provincial level, along with more district-focused rainfall forecasts.
4. SCFA_v2.9 December 2024
   Added a new rainfall exceedance forecast, providing insights into how much rainfall could exceed the given monthly average.

7.3.2 Seasonal farm advisories

What are seasonal farm advisories?

SFAs refer to the messages farmers received to help inform their on-farm decision-making. There were two types of messages that were delivered either in English or Tok Pisin:

- **Alert messages**: These texts provided SCF updates to farmers. The forecasts were given for the next three months. These texts were sent out once a quarter unless the forecast has changed, wherein another text would be sent with the revised forecast.
- **Farm advisories**: These messages were sent twice a week and drew from the advice provided in the RMM. They provided either generic or crop-specific advice. Due to the character-limitations for SMS, only one short message could be sent. The team sent messages twice a week to cover as many crops as possible. During the project period a total of 84 unique messages were sent, resulting in the consumption of 14,100 SMS credits across all registered users.

Each SMS-based SFA was less than 160 characters to limit the messages to one SMS length. ANU, NARI, and NWS reviewed the advisories to ensure they were clear, concise, and complete. The final agreed SFAs after modifications were scheduled for dissemination on the SMS platform.

Table 19 Sample SFA messages

Alert Messages	Farm Advisories
The seasonal forecast for the Eastern Highlands will be minimum rainfall for the month of September and October	If you are planting crops in sloping surface, construct steps like drains or make potholes to capture topsoil from draining and prevent soil nutrient leaching
Ol saveman bilong ren na san (NWS) I tokaut oslem bai igat mo ren long mun Novemba na Disemba igo inap lo namba tu mun, Februeri bilong yea 2024	Ol gaden kaikai olsem kaukau, potato na raun onion ino save kamap gud long gaden wei wara istap na I wet tumas. Mekim gut baret na planim ol dispela kaikai gut

The SFA was intended to help farmers become more resilient to climate variability. Due to unpredictable weather patterns, traditional knowledge is not as reliable as before. The SFA helped farmers adapt to growing uncertainty and changes. The SFA could be particularly useful ahead of undesirable climate events such as a drought although this did not occur during the SFA delivery period. The messaging and information provided in the SFA were finetuned based on feedback from subscribers.

How are SFAs made?

The co-creation of an SFA involved the collaborative workflow of NWS, NARI, and ANU and with input from FPDA. NWS generated a 3–5-month seasonal forecast for EHP while NARI synthesised and processed the complex SCF information into user tailored forecast information to produce the SFA. The SCFA was examined to see which seasonal conditions prevailed. The seasonal weather conditions were compared with the RMM to create a list of actions to translate into SFAs. The local crop conditions were used to determine which messaging needs to be included in the SFA. For example, if the SCF indicates dry conditions but crops and land preparation have not yet taken place, the messaging from the RMM that covers these activities would be the focus of the SMS messaging. The developed advisories were shared back to NWS and NARI to see if the advisories were clear, concise, and complete. The final agreed SFA was scheduled for dissemination on the SMS platform.

Although the SFAs were created as per the workflow shown in Figure 13, the process was sometimes delayed due to limited staff at NWS and NARI. So, new staff allocation and the periodical team meetings of NARI, NWS, and ANU to co-create SFAs were set-up. The existing EHP seasonal forecast-based content was also observed as being too vague in comparison to the content tailoring result of the systematic review. However, it was noted that the digital climate service was a very new intervention in PNG where stakeholders like NARI, NWS, and CBOs were introduced. Having said that, future research is needed to understand whether this level of content tailoring was enough to cater to user needs. It was also proposed that the seasonal forecast be downscaled to at least the district level and that advisories for different crop varieties and crop growth stages be co-created in the future. Generic advisories were prepared based on the average rainfall conditions of the whole EHP region. This did not guarantee the actual context of local conditions. Scaling down seasonal forecasts to district level or even micro-location needs sufficient weather data and resources that were not available in this project.

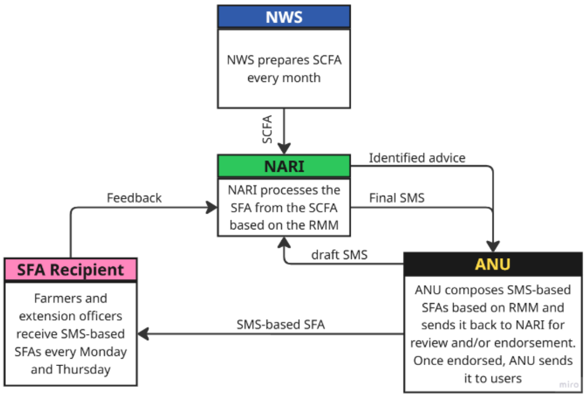

Figure 13 SFA creation process

How are SFAs distributed?

The project team considered the following options to deliver SFAs to farmers:

1. SMS
2. USSD
3. Outbound dial
4. Chatbot
5. Mobile app

The original plan was to disseminate SMS-based SFAs with a commercial carrier in PNG. An online meeting was organised with Digicel to explore a partnership. However, it failed to materialise in time for the project. Without a local telecommunication partner, the project could not pursue options 2 and 3. Meanwhile, options 4 and 5 required internet connectivity. As per GSMA (2022b), the usage of mobile networks in PNG is even lower as mobile cellular subscriptions have reached just 39%, and only 29% of the total population, mostly in cities, is connected to mobile internet. Although mobile subscriptions are also low, the team decided to pursue SMS delivery as it seemed like the best option to reach farmers, noting their remote and often dispersed locations. This reflects the trend in other developing countries disseminating agriculture climate advisories (Yegbemey and Egah, 2021).

To develop the SMS platform, a dedicated domain name, www.sfapng.com, was purchased from Namecheap; a dedicated server was purchased from Digital Ocean; and a SMS Gateway and SMS credits were purchased from Twilio and SMS Bulk. A web-based platform with the domain www.sfapng.com was built in PHP source code to store and disseminate SMS advisories.

The first message was delivered on 28 September 2023. SFAs were disseminated every Monday and Thursday at 7:15 am PNG time through the sender ID SFA_PNG in Tok Pisin and English. There were insufficient resources to divide the SFAs according to crop. And so, the team delivered two messages a week to try to cover as many farm management recommendations as possible. The SFAs continuously went out until 2 May 2024. The team had to pause the SFA delivery service because the first SMS platform, Twilio, changed its pricing structure and prices became prohibitive. The team examined three other SMS platforms and changed to SMS Bulk in early June 2024. The last SFA was delivered on 27 March 2025, alerting all users that the systems would no longer be available. A total number of 11,477 SMS were sent from September 2023 to March 2025.

Although the number of mobile subscriptions is low in PNG, the project team specifically engaged key information brokers—including extension officers, church groups, and CBOs—to amplify the reach of the SFAs. The team has heard from many SFA recipients that they have gone on to share the advice with other farmers through word of mouth or online. Unfortunately, no work has been done to analyse the precise reach of the SFAs.

The NARI Aiyura team also set up a WhatsApp group in May 2024 when the SMS service was suspended. The group has been an excellent avenue for farmers to share their experience using the SFA and provide feedback. The group has shown that there is some potential to explore other delivery mechanisms, such as a chatbot, to more digitally-capable farmers, such as commercial farmers. The WhatsApp group remains active.

What are the challenges of SMS-based SFAs?

There are three main challenges to the current SMS delivery system used for the SFA.

First, there is a gender imbalance with mobile subscription. For every 100 men who own a mobile handset and use mobile internet, only 63 women own a mobile handset (GSMA, 2022b). Therefore, more work needs to be done to ensure women, particularly women information brokers, receive SFAs.

Second, relying on a US-based company to deliver the SMS is costly. Each message costs $0.31 to send. The monthly costs of running the current system for nearly 500 subscribers is $1,300. The cost will only increase if the service is upscaled. Therefore, there is a need to partner with a local telecommunications provider and create a sustainable financial system. Partnering with a local company also opens the possibility of exploring USSD and Outbound dial as a delivery mechanism.

Third, SMS are limited to 160 characters. This means messages must be short and simple. Crafting these messages is difficult. The type of information shared via SMS is also limited since pictures, videos, and audios cannot be shared.

7.4 Component 4 – Communication and extension

A key element of this project is ensuring farmers understand the SCF information and find it valuable. To achieve this, the project sought feedback and insights from farmers and communities at various points of the project. The farmer field days, discussed in section 7.2.2, were essential in fine tuning the farm trials to make them more relevant for farmers. Meanwhile, the activities listed in this section focus on feedback around the SFA, efforts to inform communities about probabilities, and opportunities for farmers to share their knowledge and learn from one another.

7.4.1 SFA Reception

Who receives the SFAs?

The first version of the SFA was delivered to 83 subscribers. Drawing on the SNA, the project team prioritised including key information brokers, such as church and community leaders, to maximise the reach of the SFA. Over time, the number of subscribers grew to 437 due to word of mouth and active workshops by the NARI project team in Aiyura. Although the SFA recipients only represent 0.23% of the reported 200,000 farmers in the province, the SFAs have been spread through word of mouth and other digital methods that are beyond the scope of this project. At certain periods, the subscriber numbers decreased since the project team removed numbers that were repeatedly not able to receive the SMS SFA.

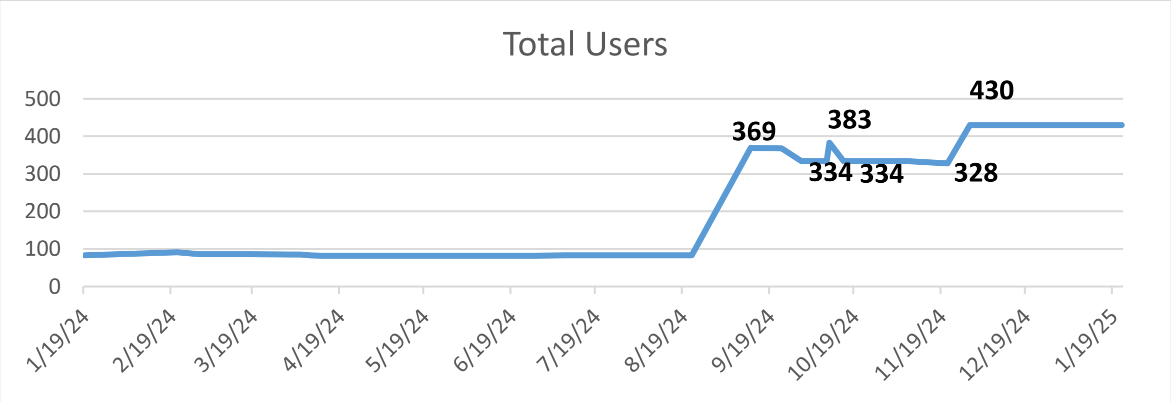

Figure 14 SFA subscribers over time

The subscribers were all located in the EHP and came from eight districts: Goroka, Ungai Bena, Daulo, Henganofi, Lufa, Okapa, Obura-Wonenara, and Kainantu. Among the subscribers, 73% were male and 27% were female, reflecting the gender disparity in mobile ownership. Meanwhile, 86% of subscribers were farmers while the rest were extension officers and church leaders. Among these subscribers are four types of recipients described in Table 20.

Table 20 Profile of SFA subscribers

Lead farmers	Regular farmer	Community and church leaders	Extension officers
Farmers who have access to land that is a hectare and above and produce over 50 bags of crops.	Farmers who are producing crops on less than one hectare	Individuals who are community leaders or representatives or have key roles in the community church.	Government officials who provide advice, tools, and other support to farmers

PNG communities are isolated and have unreliable access to the internet and other communication resources. Illiteracy is also a challenge with only 70% of its adult population considered literate. To address these challenges with limited resources, the project team capitalised on information brokers identified in the SNA. While there have been some anecdotes of farmers not sharing the information, there are also those who have shared the information to over 200 people. Lead farmers and extension officers have been particularly effective in spreading the information delivered in SFAs as they

Case study: Duldul Sustainable Farming Facebook Page

Lovii Komi Guhe, a SFA recipients, said that the SFA "has changed the perception [of farmers] and the way of doing farming". He said the information is vital and useful. Since not everyone receives the SFA, he calls farmers and the rest of the community to share the information. He also shares the SFA on his Facebook page, Duldul Sustainable Farming. His posts are an opportunity to further spread the advice shared by the SFA team and spread awareness about the service so that more people can receive the SMS directly. He also coordinates with the project team to help more farmers get enrolled in the SFA.

already have groups of farmers relying on them for advice and support. For this reason, whilst the SMS has only directly reach 437 users, conservative estimates are that the information has been shared with over 700 farmers in the region.

Incorporating farmers' feedback

The project team consulted farmers throughout the SFA delivery. Early consultation with farmers on degree of 'happiness' with the messaging undertaken by ANU staff members showed that farmers wanted more information about existing cumulative soil moisture conditions. Based on this feedback, SFAs included cumulative soil moisture conditions during the dry SCF in December to March of 2023 and 2024. Further information was included about demand irrigation as well.

The project team collected feedback from SFA recipients two months after it was first delivered. Many users (82.5%) agreed that the SMS they received in English and Pidgin were easy to understand. Meanwhile, 87.5% believed that using the SMS tool has clear benefits. Almost 85% of the SMS users responded that it was possible to share the SMS advisory with others who may not have access to the SFA. Similarly, almost 77% of the users believed that their friends or neighbours might likely use SMS for farming advice because of the participant's willingness to share the information.

When asked, "How does the SFA SMS help in terms of making better farm decisions?" Most farmers said it would improve farm management especially in the face of climate change. Meanwhile, farmers also believed it would help with planting and harvesting planning as well as improving their awareness of weather conditions. Most farmers use the advice that is relevant to the crop they are already familiar with. At this point, we have not heard of any farmer trying a new crop because of the advice. Farmers are also constrained by their own circumstances. Therefore, there is a variety of responses and adaptations of the advice that would need to be captured in any follow up work.

According to the farmers who attended the EOPR, the Alert SFAs—messages that provide SCF—have the most useful information, particularly with commercial farmers who already know the best management practices to adopt. However, semi-commercial farmers and smallholder farmers also benefit from the farm management advice. They said they follow the advice in the SFAs since it comes from NARI, knowledgeable people that they trust. Beyond horticulture farmer, SFA recipients included business owners and aquaculture farmers who used the SFC to inform their decisions.

At the conclusion of the project, the NARI team ran a rapid perceptions survey amongst subscribers to get their feedback after eighteen months of the service running. 87 subscribers from across EHP participated in the survey. The response was overwhelmingly positive with all respondents saying it was easy to understand and 97% saying they would want to continue using the SFA in the future. Farmers mainly used the weather forecasts from the SFAs to guide their farming activities, particularly with drainage management and soil preparation. However, slightly more farmers—98% to 97%—said they use the crop management information the most. Most farmers (82%) said they would be willing to pay for the SFA service with another 16% said they were unsure.

The survey also revealed that SFA recipients were dispersed among different communities. Most had heard about the service from other farmers in their communities and had also accessed the information through word of mouth and social media. 93% of the respondents said they would recommend it to other farmers. This demonstrates how important it is to identify key interlocutors to maximise the reach of the SFA.

Despite the benefits, respondents noted that technological and social barriers exist for spreading the SFA more broadly. First, reliable network coverage and power supply affected their ability to receive the SFA. They were also disappointed by the delivery disruptions in 2024. Low literacy rates are another challenge. There is also a demand for more varied information on livestock management, water conservation, market access, and post-harvest storage.

7.4.2 WonderCrop game

Dr Peter Hayman developed a participatory engagement tool, 'Wonderbean', to help individuals understand the risks associated with making agronomic decisions using a forecast of rainfall. The name of the tool was changed to 'WonderCrop' to be more relevant in the PNG context. Officers from NARI, FPDA, and UoG were trained on the tool and used it to engage farmers in the community. UoG designed a participatory community-focussed activity using dart game version of the WonderCrop game to disseminate information on decision making at farm level.

The WonderCrop exercise was initially designed in response to some advisers and farmers in Australia who made the comment that using uncertain SCF is risky. The first stage of the game shows that risk exists, and everyone is playing a risky game. The second stage is designed to illustrate the value of characterising uncertainty as a probability distribution or risk profile. The third stage, which introduces SCFs, was partly intended to highlight to climate scientists and extension personnel that decision making with a forecast isn't easy because the result is not guaranteed.

Throughout the project, the tool has been refined based on feedback from partners and farmers to suit the PNG context. For example, the tool was adjusted to have large amounts of rainfall to not act as a positive (as it would be in an Australian context) but rather as a negative influence on profit.

Training in the use of the WonderCrop tool included a short presentation explaining how weather is random unless we have weather forecasts, and how weather forecasts are based on revised probabilities. The participants were then exposed to the excel spreadsheet in a directed activity to explore key decision is the area of a farm to plant to a higher return but higher risk crop ('WonderCrop') relative to the area to leave with a lower return but lower risk crop. The tool provides an economic return based on a forecast and choice of how much of the WonderCrop to plant. In the workshop, participants were formed into four groups and then five rounds of WonderCrop were played. The first two rounds were played without any suggestion as to what the weather might be. The third round was for an above normal year, the fourth round for a below normal year and the fifth round for a very much below normal year.

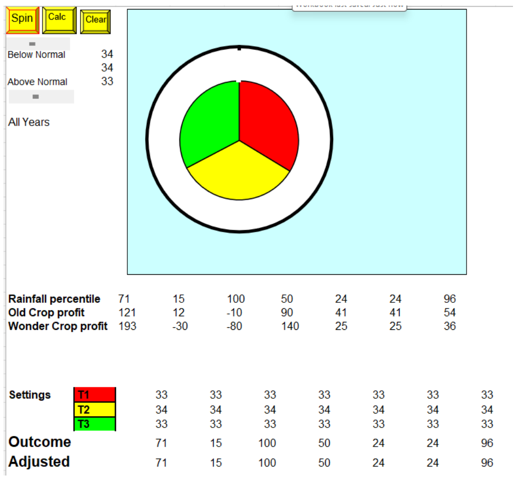

Photo 2 Screenshot of WonderCrop excel

From excel to darts

The WonderCrop game, as an excel file, was perceived to be a difficult concept to grasp, let alone engage farming communities. To address this, UoG translated it into a game. After exploring various options to produce a video, it became apparent that a video would not be an appropriate medium. The content of the video would not be suitable for community understanding and interpretation of climate probabilities. Instead, UoG decided to translate the WonderCrop game into a community entertainment game—darts. The WonderCrop dartboard game was developed in October 2024 as a participatory communication tool to engage farmers, researchers, and extension officers to discuss:

1. Community responses to the introduction of new research technologies released.

2. How research, extension officers, and farmers could integrate indigenous and scientific knowledge when introducing a new technology.
3. The utilisation of participatory methodologies such as the dartboard game addressing seasonal uncertainties and profit margin.

The game is designed to empower communities by leveraging their indigenous knowledge alongside external expertise. The game fosters open discussions, enabling participants to assess a new WonderCrop against a local crop variety. This process aims to strengthen and empower marginalised voices, particularly women, within the community.

Photo 3 Farmers playing dartboard game

The game has several objectives. First, it aims to highlight the importance of participants' experiences and indigenous knowledge in complementing external expertise. Second, it encourages discussions on best management practices to improve food production and resilience against climate-induced risks. Last, it demonstrates how farm profit is influenced by seasonal climate outcomes, crop selection, and land area.

The game requires materials such as large papers, pens, and counters like stones, bottle tops, or seeds. It is designed to be completed in approximately one hour and is divided into three stages. In the first stage, an extension officer introduces the benefits of the WonderCrop (e.g. PT sweet potato) to the farmers. This sets the stage for the subsequent activities by providing essential information about the new crop.

The second stage involves evaluating the WonderCrop using matrix scoring. Participants are divided into small groups of 4-5 people. Each group lists criteria for evaluating the WonderCrop and the local crop, focusing on both positive and negative aspects. They then create a matrix with the WonderCrop and local crop across the top and criteria down the side. Using counters, the groups score each crop based on how well they meet each criterion. This activity encourages participants to discuss and integrate scientific and indigenous climate information when selecting a crop.

During the test trials, the second stage was an opportunity for farmers to express their questions and share their experiences in relation to new crop varieties. It was an activity for collecting information on farmer perspectives on the new technologies released from research. However, the activity does set expectations among farmers about new technologies. Therefore, access to these innovations should be ensured when delivering the game.

The third stage introduces the probability distribution of profit using a WonderCrop dartboard game. Participants remain in their groups from the previous stage. The facilitator explains the rules of the dartboard game, which includes factors such as land area, crop choice, and seasonal climate conditions. The game starts with a score of 301, and each group's score is subtracted from this total. The first group to reach zero wins, representing the highest profit. The scoring systems adopts the way typical dart games are scored in the community. This stage helps participants understand the benefits of choosing the WonderCrop and how its performance depends on the application of best management practices.

This stage was popular among participants since the dartboard was familiar to them. It was a great opportunity to promote gender equity since both men and women could play and play together as well as a learning opportunity about best farm management practices. One farmer group interpreted the dartboard as their land where they plant food crops daily. The dartboard arrow represented the seeds to be planted. Some seeds fell on very good soil and the arrows that did not hit the target were seen as crops that did not grow due to poor soil health.

WonderCrop dartboard to these farmers *‘represented their land and they must look after their land – graun em i laip bilong mipela / ‘the land is our life’/* (Sogomi fresh produce farmer group – Bena).

The WonderCrop dartboard game was trialled for the first time in PNG farming communities in EHP. The game was trialled with three farmer groups in January to March 2025. Total number of participants was 30 farmers—11 female and 19 male. The WonderCrop was a NARI released technology PT Gimane sweet potato while the local crop was the non-PT Gimane. As a debrief farmers were asked to describe one significant lesson learnt from playing WonderCrop from the matrix scoring exercise and the dartboard activity.

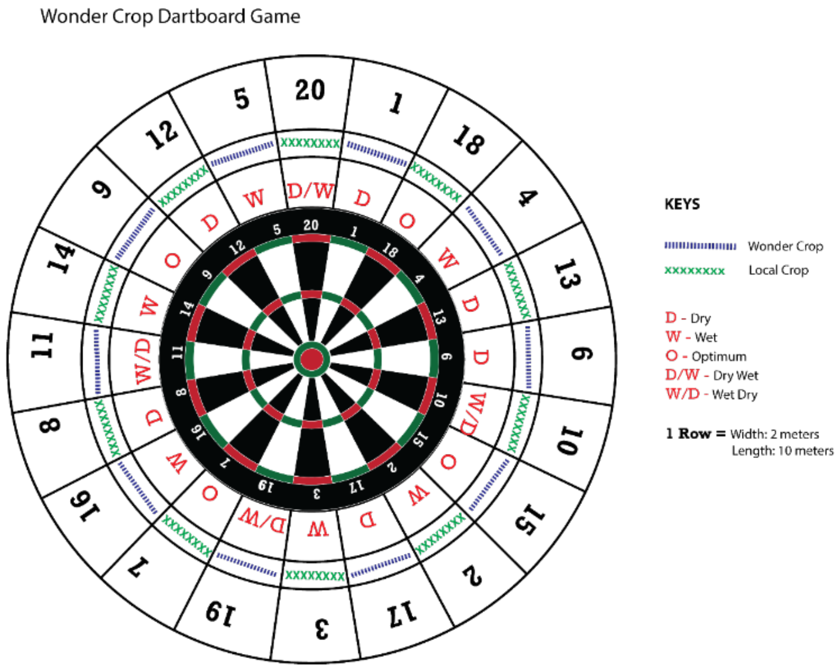

Figure 15 WonderCrop dartboard

During the debriefing, the focus was on integrating scientific and indigenous knowledge specific to the crops. Participants were encouraged to learn from the discussion and respect the knowledge and preferences of others. The debriefing also included an analysis of profit and loss, influenced by seasonal climate information and best management practices. This comprehensive approach ensured that participants gain valuable insights and practical knowledge through the game.

The WonderCrop dartboard game was so popular that a farmer group offered to pay for it to play the game with the farmers in their network. Asked why they would want to buy the WonderCrop dartboard game, they said it made it very easy to learn new management practices to take care of their land. Another reason given was that it was an easier way to understand the different seasonal climate conditions and how these affects farmer decisions on the farm. It made them aware of the importance of obtaining weather information to help in making farm decisions.

7.4.3 Videos

UoG, in particular the Centre for Social and Creative Media (CSCM), produces ‘community videos’. The videos produced are for farmers to use in their farmer networks for farmer- to-farmer learning. One of the major obstacles to reaching out to and working with farmers is trust. Over the last few years, UoG carried out trainings, workshops, and film screenings to build that rapport with farmers, in an effort to better understand how to communicate climate risk to farmers and integrate traditional knowledge and science into best management practices.

Video extension materials can help bridge communication gaps by delivering audiovisual content that is culturally and linguistically tailored for specific communities. These materials make CSA concepts more accessible by visually demonstrating techniques—such as water management—thereby supporting learning through observation. For farmers with low literacy levels, videos can significantly improve comprehension and retention by illustrating real-life applications of CSA methods, including conservation agriculture, agroforestry, and efficient water use.

There were twelve videos (Table 21) produced by UoG for the project. The first two videos, Introduction to Climate Change and Lukautim Graun, were completed in 2020 and used as conversation starters. Discussions from the videos led to developing a program to train farmers on basic camera skills.

UoG began filming the field trials between 2022 to 2024. The video production was dependent on completion of farm trials in the research sites. The field trials in in Goroka covered potatoes, bulb onions, and vegetables while the field trials in Lae focussed on sweet potato and taro. Trials in Kerevat focussed on sweet potato.

Table 21 Summary of UoG videos

Title of the video	Purpose	Comments
Conversation starters		2020
1. Introduction to climate change	Overview of the causes and effect of climate change	
2. *Lukautim graun*	Sustainable agriculture practices – food production and food processing as preparation for severe weather conditions.	
Farmer directed videos	These videos allowed farmers explore how they could integrate indigenous knowledge with science to address climate change impacts.	2021-2022
3. Murphy and Lynetth	Bulb onions – Nursery & irrigation	
4. Benny	Cabbage – Use of homemade plant-based pesticides	
5. Naomi and Ben	Sweet potato – Use of pheromone traps and local knowledge on managing Sweet potato weevil.	
6. Anna and David	A Frame – Sustainable agriculture practice.	
Research site films – Field trials	Film based on farm trials, utilising the rainfall management matrix and the best management practice. Use of indigenous knowledge and science in the applying best management practices.	2023 – 2024
7. CSA Kerevat		
8. CSA Goroka	Lae and Goroka films show that most do not use irrigation.	
9. CSA Lae		
Indigenous knowledge	Patep and Buang videos was to document how some communities have managed their natural resources for agriculture.	
10. Patep Indigenous Irrigation	Patep indigenous irrigation system is more than 100 years practice, still used for food production and now a significant part of the landscape to mitigate climate change.	A paper to be published on the Patep Irrigation system – draft paper under review.
11. Buang irrigation	Buang community use indigenous methods to direct and manage water in their watercress gardens.	
SFA for farmers in EHP	This video gives an overview of the project. It highlights farmer use of the SFA.	

12. SFA	Achievement of the primary focus of the project – documented evidence of the farmers using SFA messages.	2025

Introduction to Climate Change

The first video is an introduction to climate change. It explains the drivers of climate change, such as increased energy use and rising population. It also discusses the effects of climate change, such as rising sea levels and increased occurrences of extreme weather events. Afterwards, the video discusses the impact of climate change on farming.

Lukautim Graun

Lukautim Graun features farmers who discuss indigenous knowledge, community planting practices, innovative approaches to capturing weather information, and climate risk mitigation strategies they have adopted. David Kulimbao, one of the farmers featured, discusses his practice of documenting water levels to help forecast the weather. He uses a tin can and ruler to measure the amount of rainfall and a marked bamboo to measure the water levels in a nearby stream. Meanwhile, another community in the video increased their climate resilience by building an irrigation system to provide and store water near their gardens and by preserving beans that can be used in case of a drought.

Photo 4 Screenshot from Lukautim Graun video

CSA – Goroka

This video features project activities in the Goroka province. It includes interviews with farmers who share their experiences being impacted by climate change, such as decreased yield or destroyed crops, and what they've learned from project activities. As discussed previously, the project set up farm trials to test best management practices under different rainfall conditions. These farm trials were also an opportunity to engage farmers and provide training on best farm management practices. For example, some farmers were hesitant to practice irrigation since it is very labour intensive. However, the trials provided an opportunity for them to see the benefits of irrigation and convinced them to adopt the practice. The video also included some discussion on seasonal forecasts and how farmers would find them useful.

CSA – Morobe

The video presents project activities as well as indigenous knowledge from communities in Morobe. The video showcases various indigenous knowledge possessed by farmers, such as intercropping, planting lemongrass to deter pests, and rose trees as guides to changing seasons. It also features the Patep irrigation systems which was explained in section 7.1.5. However, traditional practices have been affected by climate variability and the farmers acknowledge the need to change. The project set up farm trials to test fertiliser and irrigation management practices. However, the season was really wet, so they no longer applied irrigation. The project team also explained the challenges brought by COVID-19.

CSA – Rabaul

The video focuses on the farming practices and indigenous knowledge of farmers on Rabaul. They do not rely on forecasts from the radio, TV, or newspaper as they have their own methods. For example, they observe the direction of the wind—whether they flow east to west or north to east—or the evening temperatures to predict whether wet or dry season is approaching. They say their forecasts are often different from those reported from official sources. However, they would appreciate if government agencies, like NARI, continue to regularly provide forecasts. Farmers state that they are wary of adopting new farming techniques as they are confident in their own methods and are worried about the effects of chemicals. To address this, NARI planned to set up on-farm trials to compare the results of traditional and scientific management practices. However, this did not occur due to staffing issues after the video was produced.

Seasonal farm advisory

This video provides an overview of the SFA and how it was produced. It discusses the connections between the field trials and the SFA as well as the different partnerships that made it possible. The video also features farmers and extension officers who discuss how they have benefitted from the SFA which is further explained in Chapter 8.

Photo 5 Screenshot from SFA video

Farmer directed videos

In 2021, UoG conducted a workshop with the following objectives:

1. To discuss how to advance communication, understanding, and use of uncertainty of weather warnings and climate risks with the farming community;
2. To advocate the importance of using traditional ecological knowledge and scientific knowledge to help create resilience in agriculture; and
3. To preserve traditional agricultural knowledge as practical knowledge relevant to future agricultural resilience.

Workshop participants watched the first two videos to generate discussion on incorporating indigenous seasonal weather patterns into on-farm management practices. Farmers were then trained on basic video camera skills and storyboard development. This allowed for participants to recognise the importance of integrating traditional ecological knowledge and scientific knowledge in the best management strategies such as land preparation and nutrient management for increased production. The self-directed video was used to document their stories on how they applied this traditional ecological knowledge and scientific knowledge on climate change and seasonal weather patterns. These farmer-directed videos feature their own best practices on a selected crop addressed farm trials. Creating this safe space allowed farmers to be comfortable to tell their stories and have open discussion about how they modify recommended practices based on their own observations and knowledge. The output of the workshop was the four farmer-directed videos. They feature farmers from EHP, namely Anna & David, Berry & Sotie, Murphy & Lyneath, and Naomi & Ben. In the videos, the farmers share

Photo 6 Participants in camera operation workshop

their best farming practices so that other farmers may learn and adopt the relevant practices to their own gardens.

Patep Irrigation

This video captures the irrigation system of the Patep community. The detail of the system is captured in 7.1.5. It features representatives from the community, NARI, and NFI. In the video, the Patep community representatives share how the system has always been part of their community and used natural resources to redirect the water to their gardens. Women representatives share how the system has made other tasks, such as cleaning, easy. Those in the video warn about the impact of climate change and advocate for other communities to create their own irrigation system to protect themselves and future generations.

Buang Watercress

This video features the Bugwev community and their watercress farms. The community had first discovered it when a flood filled their rivers with watercress and ruined their coffee gardens in 2015. After this, they decided to plant watercress by the river. Due to the success of innovative watercress farmers, all 99 households now practice it. The watercress farmers share how difficult it is to grow it and share how they work together to manage the challenges. Their innovative practice to use stones to control the water flow to their watercress is outlined in section 7.1.5. One main challenge is that watercress must be sold immediately. If they are unable to reach the market due to the lack of transportation or bad weather, the harvested watercress rots. They also maintain other seasonal crops like coffee and oranges. The community learned how to plant watercress by themselves, and they are very proud of it.

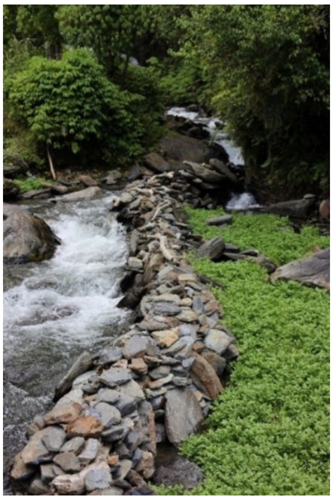

Photo 7 Buang watercress garden

The impact evaluation of the videos through community screening showed increased farmer learning on the best management practices. For example, most farmers in project sites depend on unsustainable pest management practices including using hazardous insecticides. However, important insights into 'safer pesticides' and new farming practices were adopted by farmers upon watching the videos as captured in the questionnaires in line with the M&E protocols. Sufficient data has been generated on the process to develop community-based videos followed by assessments on the benefits. Hence a paper is planned to be written and submitted to a journal for publication.

7.5 Component 5 – Value demonstration

The activities under this component sought to demonstrate the value of SCF information in farming as well as the value of SFAs. Complemented by the activities under Component 4, these activities help support the uptake of integrating SCF information into agricultural planning. Supporting the uptake of innovative approaches is essential to ensuring it is well integrated into established processes and will continue beyond the lifetime of this project. The project team enacted three activities under this component. The first activity, farmer field days, were connected to both Component 2 and Component 4 as it was a way to communicate the field trials with the farmers. However, one of the main impacts of the field trials was providing farmers visible and clear results of adopting certain management practices. CSIRO led the second activity which created a bio-economic model to drive discussions around the impact of SCF on the economic outputs of the crops. This model was designed specifically for research and extension officers, not farmers. Lastly, the project team sought to engage other government agencies to generate visibility and support for the project and sustainment of the SFA.

7.5.1 Farmer field day and workshops

Farmer field days usually occurred at the start and end of a farm trial. The field days were an opportunity for farmers to gain new planting materials as well as improve upon their normal practices. Lead farmers, who guide a greater group of farmers, attended and brought back their new learnings to their group. 1,063 farmers attended these farmer field days and follow-up SFA workshops. As discussed in 7.2.2, these field days were great opportunities for farmers to learn additional farm management practices that would increase their yield and resilience. Some farmers also expressed interest in SCF information. To enhance their abilities, the project distributed rain gauges and thermometers to support the interest of keen farmers from Bena and Ifiyufa.

7.5.2 Bio-economic modelling

Bioeconomic farm models have been used to optimise farm production planning decisions and enable explorations of “what-if” questions at farm level (Janssen and van Ittersum, 2007). Very often these models are deterministic, assuming that all model parameters are known in advance. However, in practice, many critical agricultural decisions depend on climatic conditions which are highly uncertain and not known at the time of decision making. The probabilistic results of SCFs can be used in mathematical programming farm models to account for uncertainty of climate and its consequences on optimal agricultural management decisions. Such a framework could be used as a discussion-support tool with key stakeholders and extension officers to design production plans and agricultural management decisions. The development of scenarios in this way allows stakeholders to establish risk-based responses to different climate events. Meza et al. (2008) recommend the use of bioeconomic optimisation modelling approaches to value SCF “as these approaches are rich enough to incorporate the qualitative knowledge from social science approaches realistically”. Bio-economic modelling approaches also allow for “facilitated social interaction between researchers and farmers” and enable stakeholder partnerships to generate relevance of research and analysis to decision makers (Nelson et al., 2002).

For this project, the bio-economic model was built for extension officers, such as NARI and FPDA officers, to use and discuss different scenarios. The model provides an estimate based on seasonal conditions, input costs, and commodity price about the most appropriate crop to choose and area to plant. This information is currently only available to the NARI and FPDA staff due to the limited SCF validation. Further development of the model would be required to provide a more conservative response to the seasonal conditions.

The model is an attempt to ‘demystify’ the probabilistic nature of SCFs for both researchers and extension officers. The modelling exercise eventuated from the challenge of how to engage researchers, extension officers, and farmers on SCF as a part of portfolio of climate risk management tools in rainfed agriculture. Modelling approaches such as this one could provide ways in which researchers and extension advisors can discuss SCFs with farming communities. It should however be noted that this modelling tool is meant to be a discussion support tool used to describe consequences of different pathways and not prescriptive on what options to take. The development of the model provided an opportunity to build ‘social capital’ on managing climate risk among farming communities.

The model is sensitive to small price changes and caution is needed in selecting the prices and should involve consultation with the farmers and extension services, so the model results are relevant to the region of interest. While the model responds to small changes to prices, farmers are more likely to consider the solutions cautiously and in line with their responsive, ‘lean not jump’ and adaptive risk management. The modelling tool also helps in exploring different price options in a scenario-building exercise and links season and prices to arrive at an optimal solution that would provide additional complexity to the discussion on risk.

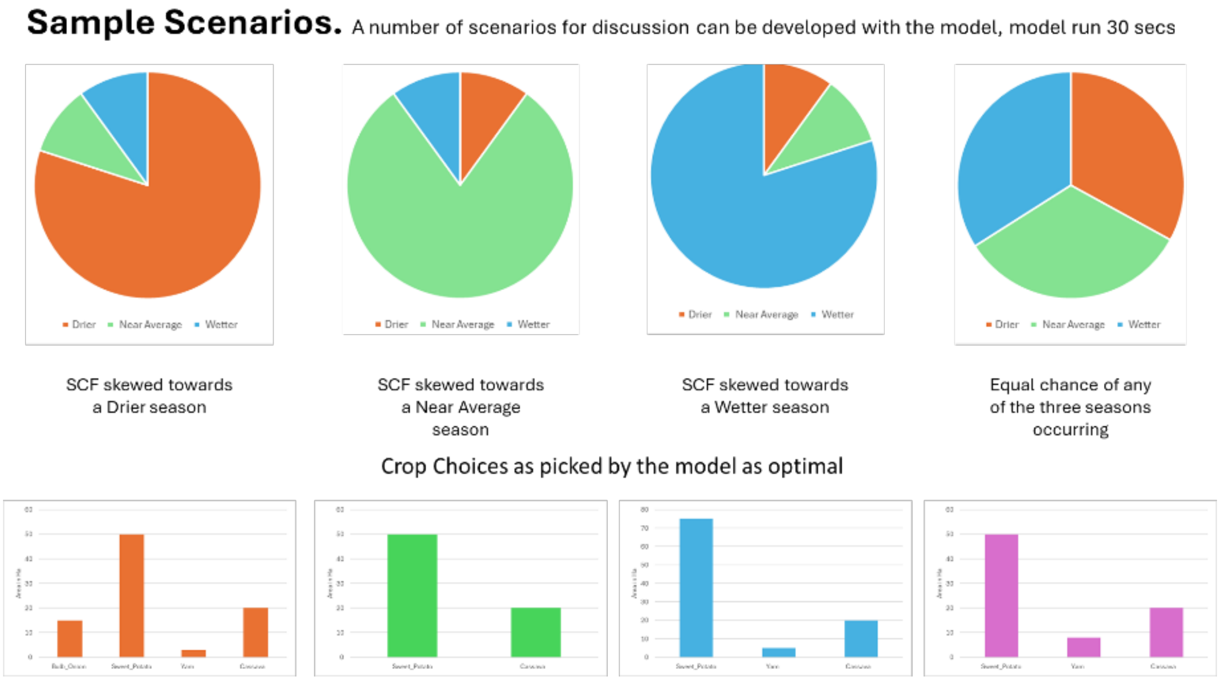

Figure 16 Sample scenarios produced by the model

7.5.3 Results of government engagement

Due to the withdrawal of DAL and CCDA from the project, NWS led the government engagement on behalf of the project team, leveraging partnerships created through the CREWS project that brought together government stakeholders from agriculture, energy, health, and water resources. ANU supported NWS' engagement where possible. NWS also leveraged monthly UNDP-led disaster management team meetings and the national outlook forum to increased visibility of the project. Meanwhile, ANU engaged DFAT at the Australian High Commission in Port Moresby and ACIAR country office to keep them abreast of project developments. NARI and ANU also had the opportunity to present the project to DAL Secretary Dr Sergie Bang who was pleased and supportive of the project's progress and continuation. Although government agencies are supportive of the project and interested in the SFA, more needs to be done, particularly with DAL and CCDA, to secure government buy-in to sustain the SFA beyond donor-funded support.

Agriculture is a very important climate sensitive sector in PNG. Over the years, NWS has supported the establishment of weather stations at key strategic locations nationwide, partnering with NARI and DAL to provide essential data for research aimed at enhancing climate resilience in agriculture, aligned with CSA principles. Unfortunately, many of these stations are no longer operational due to lack of support from the PNG government. One of the immediate and key priority for the government must be to ensure these monitoring stations are fully operational and that agrometeorological research becomes one of the critical pillars for agricultural research in PNG.

Photo 8 NWS and ANU attend 2nd CREWS stakeholder meeting

While NWS engaged with a variety of government agencies, it did not have the same mandate and convening power as CCDA and DAL. This challenged the project's implementation as some research partners required more senior management support to deliver their activities. If DAL had remained on the project, it may have been easier to ensure project activities were implemented as scheduled. Their withdrawal also impacted the sustainability of the SFA service. Although NARI and NWS partners are capable of continuing the service after the project, both organisation require additional resources, including additional staff to handle the servers and delivery of the SFA. If DAL had remained on the project, it would have been easier to plan for its continuation and ensure the relevant agencies had the resources to do so. To avoid a similar situation in the future, the project team could consider creating a governance or advisory body that includes all necessary government agencies so that they may be kept abreast on the progress without having to commit too much.

8 Impacts

For the first time, PNG has operationally available regionalised SCFs that over time will be accessed and utilised by rural communities. This represents a considerable scientific and social development because of this project and the relationships and interactions fostered by the way in which the project was managed and implemented. The project has had significant positive scientific, capacity building, and community impacts. However, they are limited in scope and without the continued support and momentum provided by the project are at risk of being unable to be sustained over time. More needs to be done to ensure these positive impacts are sustained into the future. No formal impact evaluation was conducted as part of the project due to budgetary and time considerations. Instead, a rapid survey was conducted to assess the impact of the SFA.

8.1 Scientific impact

The project made strong progress using innovative scientific methods, centred on two key tools: the RMM and SNA. These resources support future CSA work by providing targeted climate information to farmers. The RMM focused on agronomic research and reviews, while the SNA mapped strategic information networks. Together, they ensured SFAs were accurate, relevant, and well-targeted, with potential use beyond the project.

8.1.1 RMM

The RMM is a key outcome of the project, serving as a critical document in the SFA production process while also extending its usefulness beyond that scope. By integrating indigenous and scientific knowledge into a single resource, the RMM can act as a valuable reference for various projects and advisory services. Additionally, it provides a framework and process for capturing indigenous knowledge, which can be further expanded or adapted. As part of this initiative, the team has developed an RMM for EHP and drafted versions for Morobe and ENB which are maintained by NARI. Future efforts in PNG can build on this foundation, developing RMMs for additional provinces and contributing to a growing database of localised farming management practices. Even the existing RMMs can be easily updated as research progresses and more information is collected. This tool can also be used as a foundation to train and share knowledge across organisations involved in agricultural extension activities.

8.1.2 Social network analysis

The project's SNA findings are a valuable knowledge product with strong potential to inform future activities and broader research, particularly in understanding gender dynamics in PNG. These findings shed light on how men and women differently access and share information, offering critical insights into the social networks that influence communication within communities. This understanding is essential for designing effective adaptation and knowledge transfer projects, especially those aiming to increase farmer adoption of new practices. The SNA approach, if used early in project planning, can help tailor engagement and extension strategies to local contexts. Additionally, the household surveys contributed to a deeper understanding of intra-household roles and decision-making, moving beyond the traditional household-level analysis. This supports the development of climate information and support services better aligned with the needs and realities of different household members.

8.2 Capacity impact

Capacity building was a core component of this project, strengthening stakeholders' ability to use and understand probabilistic forecasting. Enhancing the project team’s capacity was crucial to its success, involving the establishment of institutional partnerships, the expansion of professional networks, and the development of key skills. At the same time, extension officers and farmers have also benefited through their engagement in project activities and use of the SFAs, further supporting knowledge transfer and practical changes on-farm. At the end of the project, NARI conducted a rapid survey of 87 SFA recipients to assess changes in their farming practices due to the SFA. The assessment of the project's impact on farmers is based on anecdotes from the SFA recipients and the rapid survey that collated the farmers' perceptions. More work needs to be done to assess its impact on yield and actual practice.

8.2.1 Institutional partnerships

One of the most significant positive outcomes of the project has been the establishment of new partnerships between institutions and key individuals. All project partners reported forming new connections through their participation, with most indicating these relationships would be valuable for future initiatives beyond the project. Mauro (NARI) established connections with international researchers, enabling the publication of articles and collaboration with Sibjan (ANU) on developing SMS and WhatsApp communication tools. Johannes (NARI) praised ANU for bringing together key PNG stakeholders during the project's inception, fostering collaboration and information sharing.

The FPDA formed a new partnership with UniTech students through the bulb onion field trial and collaborated with UoG and NARI. Lonica (FPDA) anticipates these partnerships will continue in the future. Similarly, UoG partnered with UniTech for the Patep Indigenous Irrigation video since UniTech students had already developed a community profile. This profile addressed climate adaptation needs, such as food security and market access. UoG has also produced a film, social map, and community report, all of which will be shared with the community to support funding applications. UoG also worked with FRI to identify calendar trees and explain the forest's role in water regulation and its importance in climate change mitigation in communities. UoG has also partnered with the Mission Aviation Fellowship Technologies (MAFT) to disseminate CSA videos through its network of remote communities.

Uday Nidumolu (CSIRO) built connections that have enhanced CSIRO's networks in the Pacific, while NWS developed relationships with organisations that improve their understanding of audience perspectives. These collaborations enable NWS to prepare climate information better tailored to specific stakeholder needs. These partnerships highlight the project's role in fostering long-term collaboration, strengthening institutional networks, and enabling continued innovation and information sharing across regions and disciplines.

Photo 9 Project team photo during MTR

8.2.2 Project team capacity

Survey

As part of the project's capacity building and training efforts, Sustineo, ANU, APR, NARI, and FPDA collaborated to develop, implement, and analyse the surveys. This process included the introduction of survey tablets and software, requiring training across partner organisations with 22 PNG staff trained. The survey platform has since been made available to UoG students and NARI staff. As a result, the NARI is capable of conducting their own data collection for surveys such as the rapid perceptions survey.

Improved understanding of climate risk

The project significantly improved the team's understanding of climate risk and its practical impact on farm management. While the concept was initially unfamiliar and not well understood, the activities and training clarified the importance of managing climate risk and vulnerabilities. This realisation fostered a strong commitment to advocate for and share this knowledge, particularly with farmers. The project also enhanced the team's capacity to understand, interpret, and synthesise forecasts into actionable advisories. Moreover, it provided valuable learning opportunities for team members by enabling them to work in new and diverse environments, broadening their skills and experience. Through the development and roll-out of the 'WonderCrop' tool, staff in FPDA, NARI, and UoG have been exposed to probabilities and are now able to discuss these with rural communities. Meanwhile, it was the first time NWS directly engaged with farming communities, helping them better understand and interpret local climate information and use it to support agro-economic decision making.

Capacity building of early-career researchers

The project has been highly effective in building the skills and capacity of junior researchers, staff members, and students. The collaboration with UoG has been particularly impactful, offering students an opportunity to actively participate in the project and gain valuable hands-on experience. Focusing on developing young researchers is vital—not only to build their skills but also to strengthen the long-term sustainability, quality, and resilience of the PNG research community.

Undertaking further training and qualifications to increase skills

A key impact of the project has been inspiring team members to seek further training and qualifications to build their skills. For example, Ruth participated in the Crawford Mentoring Program, upgraded her expertise through the ACIAR Learn Platform, attended a 'de-risk workshop' facilitated by ACIAR, and enrolled in an online project management course with UniTech. Similarly, Lonica, inspired by her exposure to project management during this project, has commenced a Diploma in Project Management at Divine Word University in Madang. These initiatives show the team's strong commitment to ongoing learning, ensuring they are prepared to contribute to future projects and the wider research community.

Integration of new knowledge and skills

The project significantly supported team members' professional growth by expanding their skills and perspectives. For example, Kasis (NWS) gained a deeper understanding of climate communication through a social science lens, enabling him to better tailor meteorological information for communities. Lonica strengthened her project management and M&E capabilities, enhancing her overall project contributions. Lilly (UoG) developed skills in GPS-based social mapping and broadened her professional network through the creation of videos. She believes this experience will help her bridge indigenous knowledge with scientific methods in future work. These examples highlight the project's role in building cross-disciplinary capacity to tackle complex challenges.

Challenges within and across partner organisations

Lonica identified major resourcing and capacity challenges at FPDA, including delays caused by a lack of vehicles and staff being stretched thin with additional duties. While individuals like Lonica and Lance have strengthened their skills through the project, limited support from

FPDA leadership has hindered broader organisational impact. As a result, the knowledge gained remains largely with these individuals rather than being shared across the organisation. This highlights the need for stronger institutional backing and systems to ensure that capacity-building efforts lead to lasting organisational improvements and sustainability.

Project partners frequently faced challenges in attending meetings and activities due to poor internet connectivity and network outages, issues worsened by the COVID-19 pandemic. Limited resources further constrained their ability to engage consistently. Coordination across NARI teams also proved difficult at times, with internal dynamics and resource shortages hindering smooth collaboration. These challenges underscore the need for better infrastructure, stronger coordination mechanisms, and improved resource allocation to support effective teamwork and ensure the success of future initiatives.

8.2.3 Extensions officers' capacity

The SFA has also become an important tool for extension officers. With a stronger understanding of SCF and its agricultural impacts, extension officers can now offer more targeted advice to farmers—covering everything from crop stages to recommended tools and seed types. Many of these officers support hundreds of farmers in their local communities.

Case study: Maureen Kaiento

Maureen Kaiento, a DAL Program Manager in Kainantu District, shares SFAs with farmers who visit her office and has also personally benefited from them. Through the SFAs, she gained knowledge about different crops and seasonal patterns, enhancing her ability to advise farmers. She found the SFA Alert messages particularly useful for crops not covered in the RMM. After initially poor results from distributing rice seeds to 259 farmers, Maureen used SFA Alert insights to guide her advice, leading to improved rice crop performance across her district.

UoG collaborated with the church-based Community Development Workers Association Inc. (CDWAI) in Bena to develop training modules that teach farmers best practices and incorporate climate change information into faith-based messages. The project has also empowered CDWAI to shift its focus toward supporting farmer networks more directly, resulting in notable changes in farming methods within the community.

8.2.4 Farmers increased capacity

Before this project, farmers relied solely on indigenous knowledge passed down through generations, planting without reference to SCF information. However, increasing climate variability has made some of this traditional knowledge less reliable. Without guidance, farmers faced a high risk of crop loss due to drought and extreme weather events. Farmers who participated in the project or received SFAs are now aware of SCF and how to use it in planning their agricultural activities. In a rapid perceptions survey, 97% of respondents reported having made—or intending to make—changes to their farming practices based on the SFAs. They used the forecasts to guide planting and harvesting schedules, manage labour and inputs, and reduce the risk of crop losses from i weather changes. Meanwhile, one farmer working with UoG has notably improved his farming practices using a rain gauge provided by the project, enabling him to track rainfall and advise his farmer groups more effectively.

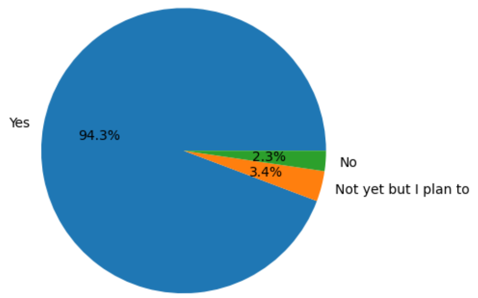

Figure 17 Rapid perception survey respondents who have made or plan to make changes to their farming practices because of the SFA

Case study: Seasonal awareness among farmers

Ben Iseho is a commercial sweet potato farmer from Asaro who supplies customers in Port Moresby and Lae. He participated in FPDA's farm trials and receives the SFAs. He shared that prior to the project, he never knew what kind of season he was in. Now he knows and uses SFAs to help inform his farming decision.

Farmers used to plant sweet potatoes without considering the weather, but now they check forecasts first. If it's expected to be too hot, they avoid planting to protect crop quality. If heavy rain is forecast, they prepare tools and family for the extra labour. Proactive farmers have benefited from tools like rain gauges and thermometers to better understand their local climate. They continue to combine traditional knowledge with SFA information to guide decisions, helping them better plan farming schedules, labour, and input use such as fertiliser.

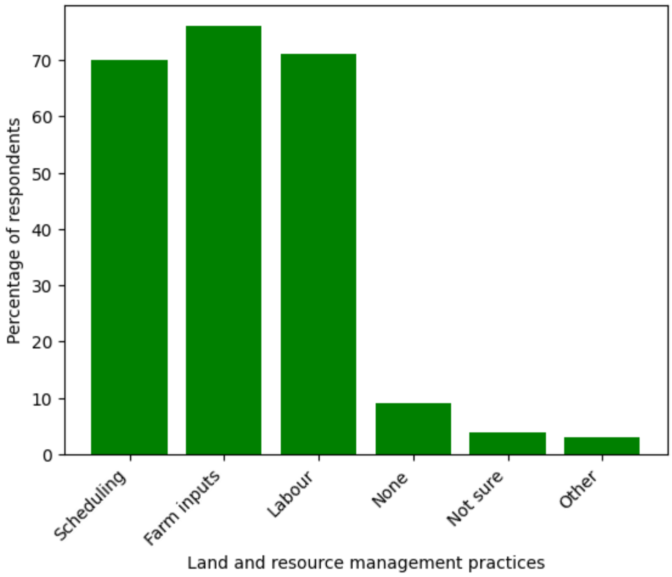

Figure 18 Rapid perception survey: Changes to management practices because of the SFA

The project has provided farmers with valuable opportunities to learn and adopt improved farm management practices, including efficient irrigation and fertiliser application. Many farmers have begun implementing these techniques on their own farms after observing their benefits through on-farm demonstration trials. These trials played a crucial role in demonstrating that the additional labour and investment could yield substantial returns. Furthermore, farmers now feel more confident in making decisions about planting schedules and drought preparedness, thanks to the forecasts and early warning information delivered through the SFA.

While the SFA was initially designed to support crop production, it has also proven valuable to the coffee, livestock, fisheries, and beekeeping sectors. The advisories have been shared through platforms like the Highlands Micro and Small Medium Enterprise Network. In Bena, beekeeper Elizah Sam uses SCFs to decide when to supplement his hives with sugar during dry spells, helping maintain bee populations and prevent migration. In Goroka, Ps Kumson of Kotoni Trout Farm adjusts his water infrastructure based on forecasts—conserving water during dry periods and preventing floods during heavy rains.

Beyond the SFA, farmers deepened their understanding of seasonal climate information and farm management through the participatory WonderCrop dartboard game. The game empowered communities—especially women and marginalised groups—by making complex seasonal science more accessible. During debriefings, key discussions focused on community challenges, the value of indigenous knowledge in interpreting seasonal forecasts, and the importance of local agricultural realities. The game helped farmers grasp climate probabilities and apply best practices to real-world problems. It also played a role in bridging the gap between scientific and Indigenous knowledge.

Some farmers also received training on video recording. This has increased their digital capacities and may lead to more opportunities for them to capture their practices and share them with others. It may also open new opportunities for them beyond farming.

8.3 Community impact

The project achieved meaningful community-level impacts, particularly in EHP due to the rollout of the SFA. It successfully captured and integrated indigenous knowledge, offering long-term value for both the community and sector. However, the project also faced significant challenges, most notably the COVID-19 pandemic, which disrupted planned community engagement, delayed the finalisation of the SFA, and limited farmer participation. While the team adapted by shifting to virtual engagement, resource constraints and a loss of momentum led to some farmers withdrawing, and changes in the farming population made sustained engagement difficult. Despite these setbacks, the project team demonstrated resilience and adaptability, ensuring that key outcomes were still delivered under challenging circumstances.

8.3.1 Community impacts from the SFA

By working closely with communities to promote CSA practices, the NARI Aiyura and UoG teams have achieved significant community-level impacts across eight districts in the EHP: Daulo, Goroka, Lufa, Okapa, Henganofi, Oburawonenera, Kainantu, and Bena. Key outcomes include enhanced understanding of climate risk management, improved farm practices tailored to different rainfall scenarios, and increased confidence in farming decision. Farmers have also recognised the value of improved irrigation and proper fertiliser application.

The community-level impacts began with field trials that raised awareness about the importance of managing climate risk followed by engaging key stakeholders from the government, development partners, NGOs, and industry partners. This was further reinforced through the dissemination of the SFA. Through this project, farmers have gained a clearer understanding of which practices are most effective under varying rainfall conditions, fostering better farm management. As the agricultural calendar becomes increasingly uncertain due to climate change, services like the SFA may offer one of the most promising tools for improving resilience and productivity in rural communities. As one farmer from Goroka put it, “I used to farm by guessing. Now I farm with confidence.”

However, the dissemination of the SFA has faced challenges. The SMS version of the SFA was delayed for one to two months, and such inconsistencies risk reducing farmers’ interest and engagement. Despite these setbacks, the WhatsApp group has emerged as a key tool for sharing the SFA with farmers and extension workers. This platform has enabled real-time observation of changes at the community level, as farmers share pictures and updates on how they are applying the recommendations on their farms. The WhatsApp group has also facilitated peer learning, bringing farmers together to exchange experiences and ideas on implementing the information they receive. Additionally, it has provided institutions with a valuable feedback mechanism, enabling them to identify and address challenges raised by farmers, thereby improving the delivery of services and ensuring the relevance of their support. Whilst the SMS messaging has now stopped, the WhatsApp messaging will continue.

8.3.2 Recording indigenous knowledge

Another key impact from this project is the collation of indigenous knowledge from different communities in PNG. Although rural smallholder farmers have rich indigenous knowledge passed on over generations on their agricultural practices and how to survive on the land, this knowledge is not easily discussed. These indigenous approaches have been captured in documents and videos produced as part of this project.

In small group discussions, farmers discussed the field trials in the project and how they incorporated their own knowledge, where applicable, in their farm practices. This then led to farmers producing a self-directed video diary on a selected crop and farm trials on land preparation, insect and disease management, irrigation and nutrient management. The Patep prehistoric irrigation system in Bulolo district in Morobe province was rediscovered as part of a community survey activity to determine climate resilient community food production practices and to preserve this community-based irrigation scheme. Additionally, the identification of traditional forest-related knowledge of the Patep communities offered insights on Calendar trees, tree species which used in forecasting weather.

8.3.3 Potential negative impacts on communities

The NARI Aiyura team identified a potential risk of misinformation stemming from misinterpreting SFA messages, especially regarding above-average rainfall forecasts. This risk is heightened when information is shared with those unfamiliar with NWS terminology, though no such issues have occurred to date. Meanwhile, FPDA reported improved farmer capacity through field trials, with some farmers adopting new practices and sharing positive feedback—though these have yet to be verified through follow-up visits. UoG faced challenges in sustaining participation in video training, as some farmers withdrew due to unmet expectations of financial compensation. While UoG provides lunch and travel reimbursements, its strict ethics policy limits further incentives, creating difficulties when other partners offer higher payments. Despite these challenges, project partners have made strong progress in building farmer capacity and promoting improved practices. Continued attention to clear communication, ethical engagement, and follow-up is essential to sustaining impact.

8.3.4 Economic impacts

While the project did not set out with specific economic objectives, its focus on building farm resilience in PNG has led to notable economic benefits. By promoting improved management practices and restoring farmer confidence, it encouraged the cultivation of higher-value, riskier crops and boosted yields. These gains have translated into increased market sales, including in urban centres like Port Moresby, without causing market oversupply. Perceptions feedback from SFA recipients highlights these impacts: 95% reported increased yields, 97% saw higher incomes, 86% saved money, and 85% maximised profits by following the advisory's guidance.

Case study: George Mosinokave

George Mosinokave, a semi-commercial farmer from Ifiyufa, Goroka, has been involved in the project's farm trials since 2021 and has received the SFA since its launch in September 2023. In 2022, he lost over PGK 40,000 after planting cabbage during what he expected to be a wet season, only to face unexpected dry conditions. Discouraged, he vowed never to grow cabbage again. However, with guidance from the SFA, George has regained confidence, resumed planting cabbage and other vegetables, and is once again selling in Port Moresby. He says he wouldn't have taken the risk without the SFA.

8.3.5 Gender impacts

Despite the broader context of gender inequality in PNG, the project made strong progress in promoting gender inclusion. Women played key leadership roles within the project, with participants generally viewing it as inclusive. Notably, Ruth Baiga (NARI), Lonica Aris (FPDA), and Dr. Lilly Sar (UoG) were instrumental in shaping the RMM and SFA. Ruth and Lonica were promoted during the project, taking on expanded responsibilities and further training. Their leadership was recognised as critical in engaging female farmers and breaking down gender barriers, as highlighted in the 2023 Project Partner Health Check Survey. While inclusivity was more evident at the partner level, engaging women at the farmer level remained a challenge due to cultural norms and limited female staff in some regions. UoG led with a whole-family approach, ensuring women's voices were heard and actively engaging marginalised groups. NARI and FPDA also implemented gender-sensitive strategies, such as gender-segregated sessions and gradual improvements in gender balance at field trials. However, disparities persisted—for example, only 30% of SFA SMS recipients were women, and men dominated WhatsApp group. These gaps underscore the need for targeted outreach to improve women's access to information and decision-making in farming. With a limited number of female participants and resource and cultural challenges to engage them, the project was not able to identify gender-differentiated impacts of the project. As identified in the SNA, women's unique information needs and their role in sharing knowledge within households make them vital agents of change. Future work should consider targeted strategies, including more women project staff, to support women's engagement in the SFA service.

8.4 Communication of activities

Knowledge and information sharing has been a cornerstone of the project, with effective communication and outreach activities playing a pivotal role in empowering farming communities. PNG partners have demonstrated the value of employing innovative communication approaches to transform weather and agronomic information into actionable knowledge that improves farm management practices.

By ensuring that farmers have access to reliable and practical information, the project equips them to better adapt to changing environmental conditions. This collaborative effort not only enhances agricultural productivity but also fosters resilience and sustainability within the sector, supporting long-term benefits for both farmers and their communities.

The project team has also been proactive in sharing the findings of the project to other interested stakeholders in PNG, Australia, and the Pacific through news, publications, and presentations.

8.4.1 Presentations and publications

The project team has increased communication and dissemination activities to academic audiences through presentations at conferences. These presentations are listed below:

- In November 2020, Dr. Rachel Friedman (ANU) presented at the Australian Social Network Analysis Conference.
- In July 2021, Dr. Friedman, with inputs from Sustineo, delivered a presentation at the RDI Conference, titled "Engendering Climate Information Networks for Agricultural Adaptation"
- In August 2021, Dr. Steve Crimp (ANU) delivered a presentation for the 18th Annual Meeting of the Asia Oceania Geosciences Society, titled "Seasonal Climate Forecast Development Challenges – a Papua New Guinea Case Study".
- Dr Crimp provided a virtual presentation was given at the Asia Oceania Geosciences Society annual meeting in September 2021.
- Presentation in the PNG Update in October 2022. The presentation was a panel discussion organised by ANU ICEDS with Ms Mahealani Delaney.
- In October of 2023, Mr Mauro Okrupa presented at the 7th Annual Research Science and Technology Conference at UniTech on the topic.
- 5 posters were developed and displayed during the 2024 NARI Agricultural Innovation and Morobe Agricultural Show and gathered significant interest.
- In November 2024, Mr Okrupa (NARI) and Ms Bianca Suarez (ANU) delivered presentations at the Pacific Small-Island Developing States Solution forum in Nadi, Fiji. Their respective presentations were entitled, "Development of SFA based on forecasting & rainfall management matrix" and "Designing and circulating agri-climate info in PNG."
- In November of 2024, Mr Okrupa delivered a presentation upon request by the Australian Humanitarian Partnership Annual Learning Agenda on Climate Change Adaptation.

- In December 2024, Ms Suarez delivered a presentation on the project at the ANU Development Policy Australia International Development Conference, titled "Developing seasonal farm advisories in PNG."
- Presentation at the UoG Somare Research Institute seminar series in April 2025.
- Mr Okrupa presented an Academic Poster Presentation at the 2025 Pacific Regional Research Forum in Tonga
- A request from the Pacific Island Communities for Mr Okrupa to represent NARI and participated in the Millenbay Pacific reconnaissance mission on Climate by August 2025

Following this, the project team has published two academic journal articles and has several reports in process from the project:

- Representatives from NARI, PNG NWS, ANU, and Sustineo co-published an article titled "Designing Climate Information Services to Enhance Resilient Farming Activities: Lessons from Papua New Guinea" in the journal of Frontiers in Climate".
- Representatives from ANU and Sustineo co-published another article, "Networking for gender equitable climate-smart agriculture" in the journal of Climate and Development.
- Drafting a Manuscript: Adoption of Short Messaging Service (SMS) for Seasonal Farm Advisory Services in PNG to inform Policy and Practice for the South Pacific Journal of Agriculture and Forestry
- Draft a technical manual on how to use the Seasonal Climate Farm Management and the RMM to produce seasonal farm advisory
- Drafting 4 x field trial technical reports on the following topics;
- Potato Variety x Fungicide Technical Reports – Mauro Okrupa et al
- Potato Irrigation x fertilizer - Mauro Okrupa et al
- Bulb onion fertilizer x irrigation - Rodney Aku et al
- Bulb onion variety evaluation – Rodney Aku et al
- L. Sar, S. Toposona, E. Alex, S. Crimp, N. Nalish and S. Sar-The Patep prehistoric irrigation system: Building on traditional ecological knowledge for sustainability and community resilience against climate variability and change (Submitted)
- Draft paper on video communication materials

These publications are significant for communicating lessons from PNG to the field of study on CSA, while also bolstering the scientific discoveries of this project through the peer-review process.

The team has also produced 25 fact sheets in Tok Pisin and English on the RMM.

8.4.2 NARI media and communications strategy

Photo 10 SFA project results in Morobe Agricultural Show

The NARI Bubia team has taken a leading role in disseminating communication products to raise awareness about the project in PNG. Between 2023 and 2024, several issues of the *NARI Nius* newsletter featured key updates on the project's activities, including coverage of the 2023 SFA Workshop and the provincial films produced by UOG. In addition, NARI distributed fact sheets outlining SCF-informed farm management responses for five major crops. These fact sheets have been shared with key government agencies and agricultural institutions, serving as a vital outreach activity to increase awareness of the potential value of CSA and the SFA in PNG. These efforts are crucial for building understanding and support for CSA initiatives across the government and agricultural sectors. NARI also featured the project outputs and outcomes at the NARI Agricultural Innovation Show 2024 and Morobe Agricultural Show 2024. This generated significant interest from the attendees and resulted in news articles about the project.

8.4.3 Videos

The videos were a key mechanism for communicating with farmers in case study communities about farmers' stories participating in the project and promote farmer to farmer learning. UoG produced six videos documenting the personal stories of farmers participating in the project. Some were filmed and directed by the UoG team and others were filmed and directed by the farmers themselves, who participated in training from UOG and were provided with equipment. The videos are a novel communication and outreach strategy which can empower farmers to share their own stories.

Evaluation

UoG evaluated its video materials by screening them in seven rural communities across EHP, ENB, Morobe, and Madang, followed by participant surveys. The evaluation focused on three objectives: integrating scientific and indigenous climate knowledge, demonstrating the value of combining knowledge systems, and improving access to SCF and SFA services.

Findings showed strong support (95%) for blending indigenous and scientific knowledge, with traditional practices—especially in planting and seasonal timing—remaining highly trusted. The type of video medium influenced how participants adopted traditional practices, highlighting the importance of delivery methods. Participants found the films helpful for understanding CSA, including planting techniques, climate impacts, and irrigation. Preferences for agricultural inputs varied, and responses were influenced by factors such as gender, age, and location—emphasising the need for tailored communication strategies.

Traditional observation methods were the most common source of weather information, followed by media and technology. Participants reported learning about farm management practices and expressed a strong emotional connection to the films. Many preferred traditional forecasts over official sources, reinforcing the value of local knowledge.

Overall, the videos effectively promoted CSA practices and demonstrated the power of combining traditional and scientific knowledge. However, demographic differences shaped learning outcomes, underscoring the need for context-specific approaches in future agricultural extension and climate adaptation efforts.

9 Conclusions and recommendations

The production and dissemination of a digital SFA service is an important milestone achievement for PNG as the first-ever agricultural service of its kind. The SFA platform provides access to tailored SFA digital information service that covers the growing seasons all year around. Farmers say that the SFA is useful and that they have adapted their management practices. Through the SFA, they have increased the climate resilience of their farms, economic benefits from their crops, and confidence in their own farming decisions.

Overall, the project has achieved three out of four objectives. The project only partially delivered on the object to provide Government, Industry and NGOs access to the SCF and SFA information, through the sharing of information facilitated by PNG NWS. Further formal engagement with government agencies would be key to enhancing these relationships further.

It has been successful due to extensive community engagement, institutional collaboration, and interdisciplinary research. With a proof of concept confirmed, the next steps need to focus on getting an external evaluation of the work that looks at behaviour change and agronomic impact, introducing local telecommunication providers, securing government buy-in, and automating and documenting processes for upscaling. Currently, there is already demand from Jiwaka and Simbu provinces for an SFA service and interest from other international agencies such as Care International, Asian Development Bank, and APEP. Meanwhile, the work behind the SFA, such as the SNA and RMM, are useful outputs and frameworks that can be easily adapted and/or applied to future projects in PNG. NARI, NWS, FPDA, and UoG intend to create a plan to continue this work. The plan will include key recommendations such as integrating SFA with government extension services, ensuring digital inclusion for women and youth, and investing in platforms that support real-time community knowledge-sharing.

The conclusions and recommendations of this report draw on lessons learned throughout the project and identify potential areas for improvement to guide future initiatives. Additionally, targeted recommendations are provided to support the effective scaling up of the SFA. A more in-depth discussion can be found in the final M&E report.

9.1 Lessons learned from the project

Open and effective project management: Effective project management has fostered a collaborative working environment which has been critical to the success of the project. Regular, open meetings where partners feel comfortable to share feedback and different perspectives ensure all partners have a sense of ownership and autonomy in the project. This has also allowed the project team to seize opportunities and adjust in response to challenges.

Dedicated staff are essential: The success of the project is due to dedicated staff from all in-country partners. To ensure a successful SFA service, specific staff in NWS, NARI, and FPDA are needed to support the development and adoption of the SFA. Meanwhile, local institutions, such as UoG, are key partners to supporting community engagement and translating complex ideas into something appropriate for local communities. Any further work to upscale the SFA will require similar levels of collaboration across institutions. The lack of buy-in from senior management is detrimental to the staff’s ability to contribute to the project.

Broad and collaborative stakeholder engagement: A variety of stakeholders have contributed to the project’s success. First, community engagement is an essential component to ensure the products are suitable for community adoption. Probability is a complex concept and translating it to something the farmers could understand was only possible by engaging these farmers. Second, participation of extension officers, within and outside the project team, has been essential to support uptake of the SFA and obtain feedback from farmers. Without the guidance and support from extensions officers, the SFA would provide good advice but not be acted upon. They were also essential to the refinement process of the SCF products to ensure the outputs were also relevant to them.

Utilising existing information networks: The SNA was a crucial step to identifying key information brokers within communities. Due to the low digital adoption in rural PNG, capitalising on existing information hubs and trusted figures increases the impact in local communities. It is also important to understand the diversity of networks between genders and across locations to help the project adapt appropriately. Specific strategies need to be implemented to ensure women and marginalised groups are reached.

9.2 Recommendations

Conduct a formal evaluation to capture the project's impact: Due to resource constraints, an endline evaluation of the project was not completed. However, one would provide more evidence to support the sustainment of the SFA service. This report should verify anecdotes from farmers and provide some quantitative evidence around agronomic, economic, and practice impacts. It would also be helpful if the evaluation reviewed how well the SFA utilises existing social networks and see how many people receive the SFA beyond the SMS recipients. A rapid perception survey has been conducted in lieu of a more extensive review.

Increase government institutions capacity to independently manage SFA: NWS and NARI are equipped to independently manage the SFA. However, senior government buy-in, such as from DAL leadership, is needed to ensure sufficient government resources are allocated towards sustaining the SFA. Therefore, DAL and other relevant government agencies, such as CCDA, need to be re-engaged. Project team members from NWS and NARI also need to create comprehensive training programs to ensure they can train other staff to create SFA. This will also help train additional officers to expand the work into other provinces.

Expand the SFA recipients to improve extension services: The SFA would benefit from a gender strategy to ensure more women receive and benefit from the SFA. Only 27% of SFA recipients are women. Therefore, more targeted work needs to be done to ensure they receive this vital information, such as engaging church and women's groups. Meanwhile, the SFA should be integrated into agricultural extension services to increase its impact. This would require engaging all agriculture-related institutions such as DAL, FPDA, CIC, and Cocoa Board. There is also interest to expand the SFA to other provinces. This would be beneficial to PNG farmers but would require a thoughtful approach to ensure the same level of quality. The team should also consider adopting Farmer Field Schools approach to support further community engagement and translation work. Another option would be to engage innovative farmers to support interest and understanding in SCF data collection.

Develop a sustainable model: The current SFA is expensive since it is dependent on a US-based company to deliver the SFA via SMS. A local telecommunication provider is essential to decrease the costs and broaden future options. The SFA-generation process also need to be automated to enhance the efficiency and decrease the reliance on staff. To sustain the SFA service, NWS would need a dedicated staff member to produce the SCFA. Meanwhile, NARI would need dedicated staff in each province to facilitate the creation of locally-relevant SFAs. The local telecommunication provider would also need staff that will facilitate the SFAs delivery. Moreover, local institutions in each new province, such as CBOs and universities, are needed to engage with farmers and introduce them to probability and SCF. Province-specific RMMs would also need to be introduced to incorporate local indigenous knowledge and context specific conditions into the SFA. To minimise the risk of scaling up too fast, the group should introduce the service into one province at a time, ensuring that the service has been appropriately adapted to that province's needs. Considering their central role in this process—from creating the RMM to delivering the SFA and engaging farmers—NARI should be the institutional home for the SFA.

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11 Appendices

11.1 Appendix 1: List of tables, figures, and photos

11.2 Appendix 2: Final M&E Report

This appendix is attached separately.

11.3 Appendix 3: Full activity table

Objective one: To incorporate scientific and indigenous seasonal climate information into farming practices (both subsistence and commercial) to improve the climate resilience of PNG food production.

No.	Activity	Output and due date of output/ milestone	Risks / Assumptions	Applications of outputs	Project Team Comments	Review Team Assessment
1.1	Face-to-face meeting with all the project partners to agree timelines for research activity completion and to build relationships between all partners. **Case study selection has been partially achieved via SNA survey activities undertaken in Eastern Highlands and Morobe Provinces, funded by DFAT. Further selection activities in ENB will be undertaken as part of the first project team meeting.** ***A & PC***	Five case study sites identified in PNG. April 2019	• Local farmers and/or commercial growers are representative of the broader community and are accessible. • Local farmers and/or commercial growers are enthusiastic to engage in this research activity. • In-country partners have staff who can routinely visit these locations.	• The five case study sites will be the catalyst for changes in local farming systems.	Five case studies have been identified. Completed in June 2019.	
1.2	Develop and finalise the design of the SNA (200 surveys per case study location). **This activity has been supported by funding from DFAT.** ***A & PC***	Baseline SNA survey designed and available. April 2019	• The SNA will contain all necessary questions to develop the agro-meteorological advisory and user interface for the weather station data.	• The baseline SNA becomes a regular tool for understanding the knowledge landscape.	SNA design developed and finalised. Completed as part of DFAT project.	
1.3	Translate the SNA into Tok Pisin and formally test the translation process and outputs. **This activity has been supported by funding from DFAT.** ***PC***	Tok Pisin version of the SNA and household surveys will be designed and available. April 2019	• The re-translation from Tok Pisin back to English confirms no meaning has been lost in the original translation from English to Tok Pisin.	• The SNA survey becomes a baseline analysis tool for other potential locations in PNG.	SNA has been translated into Tok Pisin. Completed in 2019-20.	

1.4	Develop the rapid appraisal household survey for use in each of the five case study sites (30 interviews per case study location). **This activity has been supported by funding from DFAT.** ***A & PC***	Household survey developed and available July 2019	• The household survey will contain all necessary questions to understand and track the benefits of this project	• The household survey becomes a successful approach for tracking the impact of project activities with communities.	Household survey has been developed. Completed in July 2020.	
1.5	Initiate SNA analysis in all three case study regions (i.e. EHP, Morobe and ENB). **SNA activities in EHP and Morobe have been supported by DFAT, survey required to be initiated in ENB.** ***A & PC***	SNA survey analysis underway. August 2019	• Software accurately captures the survey data and allows accurate investigation of responses.	• The SNA software becomes an important tool for analysis of the survey data.	SNA survey analysis completed. Completed in May 2020.	
1.6	Complete a comprehensive literature review of CSA implementation globally and identify common successful elements for implementation in PNG. Include in this review and examination of approaches for the aggregation of scientific and Indigenous knowledge as well as examples of engendered approaches to SCF extension. ***A***	A report outlining the findings of the literature review and recommendations for PNG. July 2019	• Literature is extensive and detailed enough to undertake an effective comparison and provide insights for PNG.	• The recommendations will form the basis of CSA activities in PNG case study locations.	Literature review completed and report presented to the working group. Completed in February 2021.	
1.7	Establish a working group to work through the results from the CSA review, SNA and household surveys as well as AIP activities when completed. ***A & PC***	Working group established. July 2019	• Working group participants are enthusiastic to engage in this review of results. • The working group is representative and knowledgeable about the farming activities in the case study sites.	• The working group will be the catalyst for changes in local farming practises.	Working group within the project team was established. Completed in April 2021.	

1.8	Translate the household survey into Tok Pisin and formally test the translation process and outputs. ***PC***	Tok Pisin version of the ~~SNA and~~ household surveys will be designed and available. August 2019	• The re-translation from Tok Pisin back to English confirms no meaning has been lost in the original translation from English to Tok Pisin.	• The household survey becomes a successful approach for tracking the impact of project activities with communities.	Household survey translated in Tok Pisin. Completed in December 2020.	
1.9	Incorporate both SNA and household surveys into the AKVO software for use on tablets, task to be undertaken by Sustineo. **SNA already incorporated onto 11 tablets via funding from DFAT. Eight more tablets a required to be purchased and AKVO software loaded. IDM will need to be loaded on all the tablets.** ***A***	Tablet versions of the surveys are available for use. August 2019	• The electronic surveys will allow timely analysis of the data and provide the insights required to develop an effective agro-meteorological advisory.	• The tablet survey approach will become a baseline methodology for surveys in PNG.	SNA and household surveys have been incorporated into tablets. Completed in August 2019 and December 2020.	
1.10	Undertake survey training sessions in PNG. This will include field testing of the survey. **Survey training has taken place in EHP and Morobe with funding from DFAT.** ***A & PC***	NARI, DAL and FPDA staff trained to undertake the SNA surveys. Training of approximately 15 individuals will be completed. August 2019	• Staff from the collaborating organisations are allocated and available for training. • Once trained, the staff will be made available to undertake survey work.	• Staff training increases institutional capacity and forms the basis for further training if required by the project.	Training sessions completed. 22 staff from NARI, FPDA, and DAL trained. Completed in August 2019.	
1.11	Train NARI staff to undertake the ‘WonderCrop’ extension activity as part of AIP interactions with communities. ***A***	‘WonderCrop’ training completed with NARI staff August 2019	• NARI Staff are able to understand and communicate the aspects of the ‘WonderCrop’ activity.	• ‘WonderCrop’ becomes a baseline approach to communicating probabilities.	Training of NARI and FPDA staff done. Completed in February 2020.	
1.12	Initiate survey analysis at all five case study sites. **SNA survey underway in EHP and Morobe via funds from DFAT.** ***A & PC***	Household survey analysis underway. September 2019	• Software accurately captures the survey data and allows accurate investigation of responses.	• The SNA software becomes an important tool for analysis of the data.	Household survey analysis completed. Completed in February 2021.	

1.13	Begin the development of video communication material through case study visits. ***PC***	Video material under development September 2019	• Participatory approaches effectively capture the indigenous knowledge.	• Video becomes an important communication device.	Two videos translated to Tok Pisin in September 2020. One is on the influence of climate on food security and the other is a video on using weather information to make decisions about irrigation of crops. A third video for training completed in June 2021. Completed.	
1.14	Initiate the AIP development process at each of the case study locations to capture the indigenous seasonal knowledge and underlying beliefs and aspirations regarding agricultural production. Undertake the 'WonderCrop' activity with communities in order to extend the understanding of probabilities. Ensure that the AIP process has clear male and female participation opportunities. ***A & PC***	AIP process underway in each case study community. September 2019	• AIP participants are pro-active and clearly articulate underlying beliefs and aspirations. • AIP process allows equitable participation of both males and females. • AIP members able to work proactively with each other.	• AIP continues to operate in each of the communities to deal with other technological innovation issues.	AIP process initiated in August 2020. Two field days in EH, 1 in Morobe and 1 in ENB. Estimated participation was 186 for EH, 45 for Morobe and 37 for ENB. Completed.	

1.15	Analyse the surveys and extract the information pertaining to knowledge requirements, timing and format for SCF factsheet development. Translate the analysis results back into Tok Pisin and provide to project partners for broader circulation. ***A & PC***	SNA survey analysis completed by Sustineo. March 2020 Household survey analysis and findings collated in a summary report May 2020 Briefing notes on results developed and disseminated. July 2020	• Analysis accurately captures the survey data and allows accurate investigation of responses. • The summary report and later briefing notes are accurately translated to Tok Pisin. • The materials are effectively disseminated and utilised.	• Summary report and briefing notes will become the baseline information regarding SCF requirements for ACIAR and in-country partners.	SNA survey analysis completed in May 2020. Household survey analysis completed February 2021. Briefing notes not completed.	
1.16	Finalise development of the video material.	Video material completed and ready for screening with communities August 2020	• Video material is able to communicate the importance of using seasonal climate information and provides insights relevant to the communities.	• Video becomes an important communication device for broader dissemination.	8 videos completed as of February 2025. One video on SFA to be finalised by March 2025. Draft version finalised and reviewed by PI.	
1.17	Establish a seasonal forecast focus group (SCFG) with PNG NWS, Australian BoM and the Asia Pacific Climate Centre to see how developmental SCF products for PNG could be accessed and used in the CSA initiatives. ***A & PC***	Seasonal forecast focus group (SCFG) established. May 2020 Meetings held biannually.	• Staff from the collaborating organisations are allocated and available for participation in the SCF advisory.	• The advisory becomes a baseline knowledge product for use by rural communities, industry and Government agencies.	SCFG, including BOM, NWS, and DFAT, established in May 2020. Agreement and training established for receipt of Australian SCF information. 12 Meetings held in total from 202 until 2024. Assessment report completed in May 2020 and reported in Annual report.	

1.18	Synthesise the information from the AIPs regarding indigenous seasonal knowledge and underlying beliefs and aspirations regarding agricultural production. PC	Synthesis of results available for the Working group. September 2020	• Analysis accurately captures the AIP interactions and allows accurate investigation of responses.	• AIP information becomes a baseline for ensuring indigenous information is reflected in advisories.	Information has been captured in videos by UoG (9 in total) and PowerPoint presentation by NARI. Completed in 2024.	
1.19	Analyse the surveys and extract information pertaining to possible gender differentiation of knowledge products and/or extension activities based on pre-determined questions contained in both surveys. A & PC	Analysis of potential differences in male and female climate information requirements completed. September 2020 Briefing notes on results developed and disseminated to project partners and working group. October 2020	• Analysis accurately captures the survey data and allows accurate investigation of responses. • The summary report and later briefing notes are accurately translated to Tok Pisin. • The materials are effectively disseminated and utilised.	• Summary report and briefing notes will become the baseline information regarding gender SCF requirements for ACIAR and in-country partners.	Analysis of gender differences completed in September 2020. Results documented in Annual Report 2 and 3 and publication in 2023. Briefing note in Tok Pisin has not been developed.	
1.20	Assess whether the level of forecast skill and service provision in weather services in PNG is commensurate with the lead time needed to address the farm management decisions identified in the CSA review, surveys and AIP activities. PC	Assessment report completed. December 2022	• The assessment accurately identifies the feasibility of the use of the existing SCF information to inform identified farm management decisions. • The findings are effectively incorporated into the SCF advisory.	• The assessment report provides a baseline feasibility test for the SCF and potential form of the SCF advisory.	Forecast assessment completed in December 2022. Standalone report produced in 2022. Completed.	

1.21	Expand the training and extensions material associated with Wondercrop to include Tok Pisin translation and video material relevant for capacity building with communities. PC	‘WonderCrop’ training material completed by UOG. March 2023	• NARI and FPDA staff are able to understand and communicate the aspects of the ‘WonderCrop’ activity. • Materials developed are well received by community members	• ‘WonderCrop’ becomes a baseline approach for communicating probabilities with the communities.	WonderCrop training delivered to NARI and FPDA staff in all three Case study regions. Follow-up training delivered to NARI staff and report by Dr Geoff Kheune compiled in 20022 outlining training undertaken and refinements made to the model. WonderCrop translation to Tok Pisin completed in June 2023. ‘WonderCrop’ dart game developed by UoG in 2024. Prototype dart board game to be completed by March 2025. Description of Dartboard game to be finalised and delivered in conjunction with Final Report.	

1.22	UoG, NARI and FPDA staff deliver extension materials associated with Wondercrop at each of the case study sites. PC	'WonderCrop' training delivered to case study communities. July 2023	• NARI and FPDA staff are able to understand and communicate the aspects of the 'WonderCrop' activity. • Materials developed are well received by community members	• 'WonderCrop' becomes a baseline approach for communicating probabilities with the communities.	'WonderCrop' dart introduced to farmers in January 2025 for feedback and refinement. Final engagement with farmers on dart board game scheduled the week after the end of project review (March 2025). Training materials not delivered to farmers at each case study site.	
1.23	Assess the effectiveness of the video extension material with participating rural communities. PC	Assessment report completed. July 2023	• The assessment accurately identifies the effectiveness of the videos for extension activities. • The findings are effectively incorporated into the SCF advisory.	• Video becomes an important communication device for broader dissemination.	Video feedback has been collected. Final report on the videos effectiveness is still pending. A parallel report will be provided upon delivery of the final report	
1.24	Expert working group established to develop a contingency table of recommended action associated with different season types and different crops.	Crop contingency table completed and available for the seasonal farm advisory. October 2022	• The contingency table adequately addresses the information requirements of all the project partners and participating communities.	• The contingency table becomes a baseline knowledge product for use in the SFA.	A working group was deemed infeasible in the timeframe, so two experts were consulted on the form and content of the RMM. This feedback was provided and integrated in the evolving RMM by January 2023. Completed.	

1.25	Working group to complete analysis of the results from the CSA review, household surveys as well as AIP activities and develop a draft seasonal climate forecast advisory advisory/s. Draft the SCF information factsheet in both English and Tok Pisin. A & PC	A draft version of the SCF advisory designed and circulated to the project partners and communities to test its effectiveness and interest in PNG. July 2023	• The SCF advisory adequately addresses the information requirements of all the project partners and participating communities. • The SCF advisory format and contents is easily accessible and understood by the communities.	• The SCF advisory becomes a baseline knowledge product for use by communities, industry and Government agencies.	Draft SCF advisory developed in May 2023 and tested with project partners and stakeholders. Completed in second half of 2023.	
1.26	Revisions made to the SCF advisory based on feedback from the project partner and community feedback. A & PC	A final version of the SCF advisory completed. August 2023	• The SCF advisory adequately addresses the information requirements of all the project partners and participating communities. • The SCF advisory format and contents is easily accessible and understood by the communities.	• The SCF advisory becomes a baseline knowledge product for use by communities, industry and Government agencies.	SCF advisory continuously revised based on feedback from partners and farmers. Latest version of the advisory was finalised in October 2024 and continues to be produced.	
1.27	An end line survey will be undertaken to obtain feedback on the Seasonal farm advisory and opportunities to improve this product or delivery going forward. This will be undertaken with project partners. PC	End line survey completed. February 2025	• Software accurately captures the survey data and allows accurate investigation of responses.	• The end line survey identifies were SFA delivery or design could be improved.	Due to the high costs involved in the baseline survey, the MTR recommended not doing an endline survey (see MTR documentation). The end-line survey has not occurred.	
1.28	Analyse the endline survey to examine opportunities to improve the SFA content or delivery going forward. A & PC	End line survey analysis completed. July 2024 Household survey analysis collated in a summary report. February 2025	• Analysis accurately captures the opportunities to improve the delivery and content of the SFA.	• Summary report will become the baseline information regarding the SFA service provision.	Since the endline survey did not occur, no report on its results has been developed.	

1.29	UoG farmer engagement: survey design and implementation; and videography of farmer experience.	Survey and video production complete. March 2025	• Survey analysis accurately captures the benefits of engaging with the SFA and identifies opportunities to improve its content and delivery	• Survey results will be incorporated into project review and continuous improvement of the SFA • Videos will be used to communicate seasonal climate information and possible responses	4 farmer-directed videos have been completed as of February 2025. Completed.	
1.30	NWS production of baseline forecast information for the SFA	Ongoing, regular delivery of forecast information to March 2025	• Forecast reflects seasonal conditions	• Baseline forecast information is the foundation of the SFA	NWS has provided 16 SCF advisories for the SFA as of February 2025.	
1.31	NARI translation of baseline forecast information into farm advice	Ongoing, regular production of farm advice content to March 2025	• SMS messaging in line with seasonal conditions	• Translation of baseline forecast information into a form that is meaningful to farmers	NARI has sent out 152 text messages to farmers in the EH case study region. This includes 17 forecast alerts 135 advice SMS	
1.32	Uploading of farm advice to SMS platform and quality assurance, including ensuring messages are sent/received. (ANU's technical contractor, Sibjan)	Ongoing, regular uploads to March 2025	• Reliable and affordable access to SMS platform	• Technical foundation of SFA	SFA SMS has regularly been uploaded and will continue until March 2025. There was a disruption in SMS delivery from March to May 2024 due to the initial service provider increasing its costs. A new service provider was identified and began sending out SMS in June 2024. Current sender success rate is measured at 87% (see Sibjan presentation for 2025 EPOR)	

Objective two: To demonstrate the potential value of integrating scientific and Indigenous knowledge to improve food production outcomes for rural communities via field trial activities.

No.	Activity	Output and due date of output/ milestone	Risks / Assumptions	Applications of outputs	Project Team Comments	Review Team Assessment
2.1	Through the initial AIP activities identify a set of management decisions (heuristics) that both male and female farmers would be willing to modify using the information from the SCF advisory. Determine if heuristics used by men and women are fundamentally different. Through the AIPs also establish how farmers would modify heuristics in order to inform the design of the field trials. ***A & PC***	A priority list of community heuristics established for case study sites reflecting both male and female farmer input. The report will contain a list of management decisions common to all five sites as well as decisions specific to each site. The report will also differentiate between male and female decisions. September 2020	• AIP participants are pro-active and clearly articulate underlying beliefs and aspirations. • AIP members able to work proactively with each other.	• The heuristics become an established method of agricultural decision-making for participating farmers. • The heuristics will provide guidelines for the design of the SCF advisory. • The heuristics also highlight opportunities for the NARI Climate Resource Centres to take on new agronomic training.	Heuristics identified in 2021 and incorporated into 2021 annual report. A subset of heuristics was taken forward to field trials. All field trials completed in August 2024. Completed.	
2.2	Through the working group, determine a priority set of heuristics to formally test in conjunction with the SCF advisory information. Circulate the priority list back to the AIPs to seek feedback. ***A & PC***	Consensus list of heuristics determined by the working group. October 2020 Modification made to the list based on AIP feedback. November 2020	• The working group is able to agree on a priority set of heuristics. • The AIPs endorse the priority list of heuristics.	• The broader set of heuristics becomes adopted by the community as options for decision-making.	Heuristics to be tested through field trials were identified in 2020 and 2021. Additional field trials incorporated farmers' feedback. All field trials were completed by 2024. Completed.	

2.3	Examine how the heuristics and other forms of indigenous knowledge (i.e. derived via AIPs and surveys) can be effectively drawn together to inform the content of the SCF advisory. ***A & PC***	Consensus list of heuristics and indigenous knowledge compiled by the working group. December 2020	• The working group is able to agree on a priority set of heuristics and indigenous knowledge inputs.	• Heuristics and indigenous knowledge inputs become a baseline for the SCF advisory.	Farmer feedback field trials included opportunities to include indigenous knowledge in the seasonal farm advisories. RMM reflects the combination of heuristics from literature, expert and indigenous knowledge. RMM is the basis for both SFA and SMS messaging.	
2.4	Align the operational SCF data outputs based on activity 1.20 with the heuristics to determine which can be effectively addressed on a routine basis. ***A & PC***	Prioritisation of heuristics based on comparison against existing SCF data outputs. December 2020	• PNG NWS SCF data outputs are readily available for use.	• The gap analysis becomes the final basis for the development of the SCF advisory.	Information used to develop the RMM. The initial for RMM EHP was completed in mid-2023. RMMs for Morobe and Kerevat were completed in in 2024. Completed.	
2.5	Design field trials at the three NARI research stations in collaboration with NARI, DAL and FPDA that highlight the priority list of heuristics and how they would be modified using the SCF advisory. ***PC***	Field trial designs completed and project team management plan established. December 2020	• Field trial designs are well considered. • Project teams are able to implement and manage the field trials. • NARI, DAL and FPDA are able to contribute equitably to the field trials.	• Field trials provide further information for the effective design of the SCF advisory.	Field trial designs were finalised in early 2020. Completed.	

2.6	Produce hardcopy and electronic version of the SCF advisory product. ***A & PC***	Advisory available for circulation. February 2023	• Agreement reached by PNG NWS and NARI to web host the Advisory and to deliver it as an operational product.	• The Advisory becomes a baseline SCF product for use in other industries.	SCF Advisory from NWS was first produced in June 2023. 16 editions of the SCF advisory have been produced. These have been made available online. Some hardcopies were distributed to key government agencies and CBOs for their feedback. Completed.	
2.7	Develop a field trial protocol that will be applied at each research station to establish how crop production will be monitored and measured. This protocol will include a baseline crop rotation, a treatment rotation and monitoring protocol. ***A & PC***	Field trial protocol established. February 2021	• Data gathered is sufficient to establish yield benefits from the use of SCF information. • In-country partners are capable of delivering the protocol.	• The protocol becomes the basis for undertaking the field trials and ensuring sufficient data is collected for the modelling.	Field trial protocol was finalised in July 2020. Standalone protocol document developed and shared with NARI and FPDA staff at each of the three case study regions. Completed.	
2.8	Male and female farmers from the case study sites transported to the field trial sites shortly after planting and just before harvesting (Field trial one). ***PC***	Farmers first visit (post planting) to the field trial site completed. May 2021 Farmers second visit (pre- harvest) will be completed. November 2021	• Staff from the collaborating organisations are allocated and available for participation. • Farmers are enthusiastic to engage in this research activity.	• Field trial management options are adopted by the village communities and so improve baseline agronomic management.	6 field visits occurred in 2020 (EH, Morobe and ENB case study locations). No field days were conducted in 2020 and 2021 due to COVID. 10 field visits were conducted in 2022 (EH and Morobe) 6 field visits were conducted in 2023 (EH only). Estimates from FPDA farm visits (14 in total) were Informal estimates are that 221 male farmers and 249 female farmers attended these field visits. Completed.	

2.9	Male and female farmers from the case study sites transported to the field trial sites shortly after planting and just before harvesting (Field trial two). ***PC***	Farmers first visit (post planting) to the field trial site completed. May 2022 Farmers second visit (pre- harvest) will be completed. November 2022	• Staff from the collaborating organisations are allocated and available for participation. • Farmers are enthusiastic to engage in this research activity.	• Field trial management options are adopted by the village communities and so improve baseline agronomic management.	6 field visits occurred in 2020 (EH, Morobe and ENB case study locations). No field days were conducted in 2020 and 2021 due to COVID. 10 field visits were conducted in 2022 (EH and Morobe) 6 field visits were conducted in 2023 (EH only). Estimates from FPDA farm visits (14 in total) were Informal estimates are that 221 male farmers and 249 female farmers attended these field visits. Completed.	
2.10	Develop a field trial protocol that will be applied within communities to demonstrate the value of using SCF information to modify management decisions. ***A & PC***	Field trial protocol established. March 2023	• Data gathered is sufficient to establish yield benefits from the use of SCF information. • In-country partners are capable of delivering the protocol.	• The protocol becomes the basis for undertaking the field trials and ensuring sufficient data is collected for the modelling.	See above Completed.	
2.11	Harvest data from the community-based field trials and research stations analysed to develop information regarding the value of using seasonal climate information. ***A & PC***	Data collated from all the field trials. December 2023	• Data gathered is sufficient to establish yield benefits from the use of SCF information.	• Harvest data becomes the baseline information to support the use of Seasonal climate information.	Results from the field trial were collated and shared with ANU in January 2025. Technical reports are available from NARI but have not been published as standalone documents. Completed.	

2.12	AIPs will be presented with trial results (i.e. yields and profitability) from the second field trial to allow male and female farmers to determine if production is sufficient for their own consumption, cash sales and customary obligations. Feedback from the AIPs will be used to redesign the second-year trial. ***PC***	AIPs will have shared the results from the second field trial and provided feedback for the second field trial. March 202~~3~~4	• AIP participants are pro-active and clearly articulate underlying beliefs and aspirations. • AIP members able to work proactively with each other.	• Field trial management options are adopted by the village communities and so improve baseline agronomic management	6 field visits occurred in 2020 (EH, Morobe and ENB case study locations). No field days were conducted in 2020 and 2021 due to COVID. 10 field visits were conducted in 2022 (EH and Morobe) 6 field visits were conducted in 2023 (EH only). Estimates from FPDA farm visits (14 in total) were Informal estimates are that 221 male farmers and 249 female farmers attended these field visits. Completed.	
2.13	Based on the yields and other metrics from trials, determine how heuristics could be further developed to link the flexible decision-making with climate knowledge. ***PC***	New heuristics established for PNG farmers. July 2024	• Yield data is sufficient quality to allow numerical analysis. • Farmers and wider community will adopt new heuristics and change agronomic practices.	• New management decisions identified and considered by other farmers.	The team created the RMM to incorporate findings from the field trials and insights from literature and experts to create a guide of management practices dependent on the forecast. Standalone RMM's have been developed for each of the three provinces, but insufficient testing has been undertaken on Morobe and ENB RMMs. Partially completed.	

2.14	Based on the field trial results direct extension and training with each of the AIPs in the implementation of the new heuristics into community-based food production activities. ***and PC***	New heuristics available to farmers. August 2024	• Farmers are able to integrate the new heuristics into their existing farming systems. • AIP participants see value in adopting the new heuristics.	• New management practises form the basis for improved livelihoods.	Delivery of RMM, SMS and WhatsApp messaging has occurred for EH region only. New heuristics are delivered to farmers through SMS advisories and WhatsApp platform in relation to forecast for the season. 135 advisory SMS have been delivered to farmers as of February 2025. Project team has anecdotes of farmers adopting the advice from the SMS but no evaluation study has occurred to quantify the uptake level among recipients. The draft SFA video contains anecdotal information regarding SMS and SFA value. Small scale survey to be undertaken with a subsample of the 460 SMS recipients in June 2025, outside the project timelines. Partially completed.	

PC = partner country, A = Australia

Objective three: For Government, Industry and Non-Government organisations (NGOs) to provide access to and disseminate SCF knowledge products to farming communities across a broader area of PNG.

No.	Activity	Output and due date of output/ milestone	Risks / Assumptions	Applications of outputs	Project Team Comments	Review Team Assessment
3.1	Based on the results of SNA, AIPs trials and video's, undertake extension activities with the DFAT post, and other Government agencies to broaden the impact of this project.	Scheduled briefings: 1. DFAT post – four meetings a year from 2019. 2. Other Government agencies – meetings on a per needs basis (at least three per year). 3. Universities and other NGOs - meetings on a per needs basis (at least three per year). Meetings to be synthesised in annual reports for 2020, 2021, 2022, 2023 and 2024.	• Government staff are receptive to the information. • Sustained interest from Universities and other NGOs.	• Government agencies use presentation materials and reports to develop ongoing programs.	Eight meetings undertaken with DFAT post staff in Port Moresby. 2 meetings with the Forum on Disaster Risk Management, held in 2019 and 2020 4 meetings with senior DAL officials in 2019, early 2020. 5 meetings with CCDA staff in 2019 and 2020. 6 Virtual meetings held between 2019 and 2022. 3 virtual meetings with CREWS PNG team from 2019 to 2023 as well as 2 face-to-face meetings in 2019-2021.	

3.2	Assist CCDA and UNDP negotiations to develop the "Strengthening Multi-Sectoral Adaptation Responses Through climate-related information" (SMART) Climate Initiative.	Scheduled briefings with CCDA and UNDP staff. March 2019, 2020, 2021, 2022	• CCDA staff and UNDP determine the results from this project directly relevant to their programme.	• The SMART Climate Initiative will include the recommendations from this project.	Project team contributed to the proposal in 2021 but it was unsuccessful.	
3.3	Engage APEP to broaden out the extension of the SFA via SMS with a major phone carrier in PNG.	Extension of the SFA to begin in April 2023 and continue on a monthly basis until 2025	• Community groups are receptive to the extension material. • Sustained interest from phone carrier.	• SFA becomes widely acknowledged and used.	ANU has met APEP and submitted a proposal for their consideration in January 2024 and was updated in July 2024. The proposal is still under consideration.	
3.4	Work with Digicel to develop a viable subsidised or user pays model to continue the service	Scheduled briefings with Digicel in early 2025 .	• Sustained interest from phone carrier.	• SFA becomes widely acknowledged and used	ANU and APEP met with Digicel in June 2024. Digicel is interested in the project and submitted a budget in July 2024. The proposal is currently under consideration of APEP.	
3.5.	Present a recommendation report in collaboration with NARI and NSW PNG to Government to seek ongoing funding to support and expand the SFA service.	Scheduled briefings with Government staff in late 2024 and early 2025.	• Government staff determine the results from this project directly relevant for ongoing funding support.	• SFA becomes widely acknowledged and used.	ANU has met APEP and submitted a proposal for their consideration in January 2024 and was updated in July 2024. The proposal is still under consideration.	

Activities and outputs designed to enhance the project's overall performance but are not linked to a specific research objective

Activity	Outputs/ Milestones	Due date of output/ milestone	Risks / assumptions	Applications of outputs	Project Team Comments	Review Team Assessment
Re-examination of existing survey data from the SRA and incorporation from DFAT project activities.	Complete the re-analysis of survey data from the three Eastern Highland villages and identify additional insights and knowledge gaps that are present **(funded by DFAT)**.	December 2018	• Additional information and insights can be extracted from original raw data collected in PNG.	This re-analysis activity will explore additional questions related to gender equity and knowledge sharing. This information will underpin how the extension of the SCF information will be undertaken.	Data examined and analysis presented in DFAT final report in 2019. Completed	
Extending existing weather station numbers as well as training for data extraction and maintenance.	Purchase weather stations (3) and touch pads (11) for later use in the project and ship to PNG **(funded by DFAT)**.	December 2018	• Stocks are available and shipping will occur without incident.	Weather stations will provide ongoing data for communities to use in food production decision-making.	Weather stations purchased and installed at NARI research stations. Completed	
	Purchase weather stations (2) and touch pads (10) for use in the project and ship to PNG.	June 2019	• Stocks are available and shipping will occur without incident.	Weather stations will provide ongoing data for communities to use in food production decision-making.	Touchpads purchased for SNA survey. Touchpads used for SNA and household surveys. Completed	
	Provide construction, maintenance and data management training for one NARI staff **(funded by DFAT)**.	February 2019	• Training offered is effectively targeted for NARI staff.	The training will allow NARI to ensure that the weather stations remain operational and that data extraction can be done seamlessly.	3 NARI staff trained to maintain automated weather stations. Only 2 remain operational, although currently not in field. Completed	

Survey design training and implementati on	Design and translate the SNA survey as well as undertake survey training with NARI staff and begin the survey activity in the three case study locations **(funded by DFAT)**.	October 2018	• Staff are made available for training and able to visit the case study locations. Translation of the surveys is done accurately and without loss of meaning.	The survey design and translation activities will allow the development of an SNA survey that will be able to be used at other locations in PNG.	SNA designed and tested at each of the case study regions. APR, NARI and FPDA staff trained as enumerators. APR lead the survey and data collection activity. Completed	
	Complete guidelines for IDM rapid appraisal and roll out across the five case study sites.	March 2019	• Rapid appraisal approach will work in a broad range of communities.	This approach will allow a more rapid appraisal of other case study sites as the ACIAR part of the project begins.	IDM deemed unsuitable for use and alternative survey instrument was developed. Variation 1.	
	Complete analysis of the survey data for the five study sites, compare, and contrast with the earlier SRA case study data to continue to test the concept of scalability. Compare differences between the five new case studies that would require tailoring of SCF information.	February 2019	• Critical number of surveys undertaken form each community to allow robust insights. • Data is collected in a correct manner to allow statistical analyses to be undertaken.	This analysis will be used to determine common regional information requirements as well as community and gender specific information requirements. This will be used to inform the development of an SCF factsheet.	Analysis completed and results were presented in Annual Report 1 and 2. One journal publication was produced and published.	
	Develop a CSA extension training module and establish an implementation schedule for NWS, NARI, DAL and FPDA; likely to be implemented over one year	June 2019	• Institutions will continue to use the training module after the project ends. • Module is flexible enough to extend to other communities.	This module will be used to train staff in the extension of SCF information to communities in order to build capacity to understand and use the SCF information.	Report completed on appropriate CSA approach to use. Results were contained in the DFAT project report in 2019.	

Dissemination of research to agencies	Establishment of a working group with representation from PNG NWS NARI, DAL, FPDA, CCDA and others.	March 2019	• Agencies will be receptive to the SCF information and be able to use it to support strategic planning.	The working group will serve as a conduit for the dissemination of SCF information to other Government and NGOs.	Annual project meetings have been held to disseminate project information. A project SharePoint exists for project teams to upload and download project data.	
ACIAR review meetings	Inception, mid-term review and end of project review meetings	February 2019 (Inception meeting) June 2022 (mid-term review) January 2025 (End-of project)	• Partners are engaged in the meetings and willing to take the review outcomes on-board and alter activities.	Inception and mid-term review meetings will be used to direct research activities for the remainder of the project.	Inception, MTR and EOPR completed.	
Face-to-face team meetings	Annual research planning meetings will occur across the life of the project. These meeting will include capacity building activities focused on interpretation of SNA information, Seasonal climate forecast interpretation and extensions as well as tablet-based survey development.	September 2019 June 2020, 2021,2022 Final meeting in July 2024.	• Partners are engaged in the meetings and willing to revise work schedules and timelines based on previous milestone achievements.	Meetings will be used to direct research activities for the remainder of the project.	Face-to-face meeting held in 2019, 2023, 2024 and 2025. COVID disruptions resulted in a monthly online meeting schedule to be established in 2020.	

Scheduled meetings	Scheduled briefings: 1. DFAT post – four meetings a year from 2019. 2. Other Government agencies – meetings on a per needs basis (at least three per year). 3. Universities and other NGOs - meetings on a per needs basis (at least three per year).	Meetings to be synthesise d in annual reports for 2020, 2021, 2022, 2023,2024, and 2025.	• Other agencies, NGOs and Universities will maintain an ongoing interest in the project.	Meetings will be used to direct research activities for the remainder of the project and/or explore opportunities to scale out the existing activities.	Eight meetings undertaken with DFAT post staff in Port Moresby. 2 meetings with the Forum on Disaster Risk Management, held in 2019 and 2020 4 meetings with senior DAL officials in 2019, early 2020. 5 meetings with CCDA staff in 2019 and 2020. 6 Virtual meetings held between 2019 and 2022. 3 virtual meetings with CREWS PNG team from 2019 to 2023 as well as 2 face-to-face meetings in 2019-2021.	
SNA and household survey synthesis reports	Synthesis reports completed outlining the results from SNA and household surveys	September 2020	• Survey data is accurately collected and informative.	SNA and household survey information form the basis for other SCF related activities.	SNA and household survey reports prepared by Sustineo. One journal publication produced on SNA analyses.	

Field trial reports	Field trial results are summarised for trial one and two across the three NARI research stations.	March 2022, 2023 and 2024	• Field data is accurately collected and informative.	Field data forms a baseline for further field work testing other management decisions.	Field trial results included in Annual Report, 2, 3 and 4. Technical documentation available in draft form only. Final review required by NARI for release of reports.	
Conference and formal presentation materials	Materials completed for at least one international conference per year and on a need's basis for other meetings.	June 2023	• Conference material is well received by the audience.	Conference material is the catalyst for other project or research partnerships.	5 conference abstracts submitted.	
Journal papers	Production of at least four journal publications	September 2024	• Research material will be of interest to the journals. • Review process is successful.	Journal papers represent the baseline approach for SCF integration into other PNG activities.	3 journal publications produced. 5 conference abstracts published. 3 journal papers remain in draft form.	

11.4 Appendix 4: Data Inputs of Bioeconomic model

Data, and input and output coefficients Data on the technical coefficients used in the model were gathered from the local farming community and expert knowledge from extension service and researchers. These include crop types, soil types, yields, input prices, costs and use of inputs such as fertiliser, pesticide, fungicide and labour. The inputs used in the model include the following: forecast data includes the probabilities for five season classes viz. 'drier, 'near average', 'wetter'. Available land at village level was determined per soil type i.e. black soils (40 ha), red soils (16 ha) and sandy soils (80 ha). The total agricultural area of the village is set as 100ha (this can be changed to reflect any village case study as this model is at a village scale. In terms of labour availability, it is currently set as 50 but can be changed as required. Labour requirements per crop per ha and per season type have been gathered from expert opinion. Price of hired labour was set at PNG K 25/person/day. Market prices for different crops were gathered from expert opinion and market reports. Costs of pesticide, fungicide, implements and seed per crop type were gathered from the experts and various published reports. The usages of different fertilisers, pesticides and fungicides are determined for each crop type and season type. Seeding rate is calculated as kg/ha and costed in PNG K/kg. Crop yield has been gathered from expert knowledge and published reports. Yield (kg/ha) is specified per crop by season type. The model results include: • Crop areas • Variable costs, revenue and profit at village scale • Input (labour, machinery, fertilisers, pesticides and fungicides use) • Expected gross margin for the village (the objective function value).

Irish Potato
Bulb Onion
Sweet Potato
Taro
Peanut
Yam
Maize
Cassava
Bean

Crops considered in the model.

Typical labour inputs (person-days/ha)			
	Drier	Near_Average	Wetter
Irish_Potato	200	400	400
Bulb_Onion	200	275	400

Sweet_Potato	200	350	400
Taro	200	300	400
Peanut	200	175	400
Yam	200	350	400
Maize	200	275	400
Cassava	200	350	400
Bean	200	225	400

Irish Potato	2.50
Bulb Onion	6.50
Sweet Potato	1.50
Taro	3.50
Peanut	6.00
Yam	4.50
Maize	4.00
Cassava	0.80
Bean	3.00

Current price to farmers (K/kg)

After deducting marketing costs. They are for growers who live reasonably close to markets or points of sale (such as the Highlands Highway). These are for produce sold as fresh food, not for industrial use (eg maize, peanuts or cassava). These prices are somewhat less than late 2022 main market prices to allow for the cost of transport to market and marketing costs.

Prices given here are for locations where these crops are commonly grown and sold. Prices in Port Moresby are typically much higher.

Costs

	Planting material	
Irish_Potato	*4.6*	*PER KG*
Bulb_Onion	*1500*	*PER KG*
Sweet_Potato	*0.2*	*PER VINE*
Taro	*2*	*PER SUCKER*

Peanut	*3*	*PER KG*
Yam	*5*	*PER KG*
Maize	*25*	*PER KG*
Cassava	*0.5*	*PER STEM*
Bean	*245*	*PER KG*

National newspaper article on Pangia seed potato producer (https://www.thenational.com.pg/seed-farming-grows/) (K160/35 kg bag); Price for tins containing 100 g of seed (Brian Bell stores)

NARI Aiyura rate for PT sweet potato vines, but a negligible number of people actually buy SP planting material; NARI rate for taro suckers, but a negligible number of people actually buy taro planting material

Price in Markham Valley for peanut seed is K120-150 for a 40-50 kg bag, say K150/50 kg

NARI Aiyura price for West African yam. This species was introduced in the 1990s and is still being adopted in PNG; Planting material of the common yams (Diocorea alata and D. esculenta) are not normally sold in PNG; Humphrey Saese (Lae based) sells larger volumes of open pollinated maize at K20-30/kg. Imported hybrid maize seed from Qld costs K60/kg in PNG; NARI Aiyura price for corn is K10/kg, but they have very limited supply, so it would be safer to use the commercial source for OP corn (H. Saese)

NARI Aiyura rate for cassava stems, but a negligible number of people actually buy planting material as it's abundant; Bean seed not sold in PNG, except small quantities in retail stores, such as Brian Bell

Terranova NZ price for Labrador variety is equivalent to K64.24/kg sold in 500 g packs. (NZ 14.18/500 g). Prices are lower for larger packs (1, 5, 25 kg packs); Retail price would be much higher given transport costs, import duty, significant retail mark up, taking the price to over K200/kg.

Retail price for small a 30 g pack in PNG is equivalent to about K245/kg

Working mean crop yield (kg/ha)			
	Drier	Near Average	Wetter
Irish Potato	14,000	20,000	18,000
Bulb Onion	15,000	14,000	8,000
Sweet Potato	10,000	12,000	8,000
Taro	5,000	8,000	9,000
Peanut	1,400	1,500	1,200
Yam	12,000	13,000	9,000
Maize	3,000	4,500	5,000
Cassava	20,000	22,000	20,000
Bean	5,000	7,000	6,000

Notes: Yield varies considerably between locations, soil, and growing season.

The relative yields under different rainfall conditions are likely to be a reasonably good estimate.

Notes:

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The relative yields under different rainfall conditions are likely to be a reasonably good estimate.

Crop	Rainfall conditions
Potato	*For Potato, excess rain does not impact tuber yield too much. Very dry conditions impact yield especially in tuber bulking phase (towards end of crop life). Mounding to remove excess soil water is important.* *The yield used here for average conditions of 20 t/ha is for high input conditions, that is, using a variety resistant to potato late blight, a high rate of fertilizer, spraying for late blight and possibly controlling insects with insecticide. Most farmers would not do all this, so a working yield for average rainfall and soil moisture conditions would be 16-18 t/ha.*
Bulb onion	Bulb Onion is best to plant in dryer period. Rain increases downy mildew and other diseases, especially in the PNG lowlands (Laloki experience) where yield could be less than 8 t/ha in wet periods. In general, onions are vulnerable to very wet weather.
Taro	Taro likes plenty of water and will grow in ponds in the highlands, ideally if there is some water flow. High temperatures (ie lowlands) and high rainfall *increase taro blight. There is less blight above ca 500 m and it is rare above an altitude of 1300 m. It does not like dry conditions.*
Peanuts	Peanuts are vulnerable to fungal diseases. Yield is increased by fungicide, although none are applied to peanuts by subsistence or commercial growers in PNG
Yam	Yield is reduced in very wet soil conditions. D. alata is vulnerable to leaf diseases, which presumably are worse in wet conditions. D. esculenta is more important in PNG but is only common at up to 900m altitude.
Maize	Corn thrives in high rainfall locations. In seasonally dry environments, such as Markham Valley, Ramu Valley, drier parts of Eastern Highlands, it is planted at the start of the wetter months (Sept-Oct-Nov); harvested when rainfall is high.
Cassava	Cassava thrives under very high range of rainfall conditions, in locations where mean annual rainfall ranges from 1000

	mm/year to over 4000 mm/year Yields are low to very low in severe droughts, such as 1997, as they are for all crops.
Bean	There is very limited information on yield of common bean under smallholder conditions. Some experimental data are available from lowland and highland sites.

Planting rates(kg/ha)			
Crop (weight kg/ha)	Drier	Near Average	Wetter
Irish Potato	2000	2400	2600
bulb Onion	22	26.4	28.6
Sweet Potato	2750	3300	3575
Taro	363	435.6	471.9
Peanut	100	120	130
Yam	1500	1800	1950
Maize	25	30	32.5
Cassava	360	432	468
Bean	80	96	104

Sweet potato

Planting rates vary considerably with some crops, eg recorded planting density for sweet potato in PNG ranges from 18,000 to 172,000 cutting/ha. Mean planting density in 5 studies was 55,000/ha. Sweet potato is unusual in that the planting density has little effect on the final total yield. Planting density does impact the number and weight of tubers. When planted at low density, one has fewer, but larger tubers. At high density, there are more tubers, but they are smaller.

Seeding rate change with season for some or all crops is not normally done in PNG. Too technical for commercial PNG growers given that planting density varies enormously anyway.

Maize (corn)

The range of weight of seed per hectare for maize in PNG is 20-25 kg/ha. Under high rainfall or irrigated conditions, maize is planted at 60,000-80,000 plants/ha. Under lower rainfall conditions, the planting rate is lower (40,000-50,000 plants/ha). The rate given here is for non-irrigated corn, grown at start of wetter months in a seasonally dry climate, such as Markham V., Ramu V., Eastern Highland drier valleys, Port Moresby area. This is where corn is most common in PNG.

Potato

In the Rainfall Management Matrix, the recommended planting rate is a bit lower (31,250 plants/ha). Presumably this rate come from FPDA or NARI staff. If one plants at 40 cm by 80 cm spacing, the plant density is 31,250 plants/ha. If one plants at 35 cm by 70 cm, the plant density is a bit over 40,000 plants/ha.

Peanuts

Hughes et al. (2008. Growing peanuts in Papua New Guinea. ACIAR, Canberra) give planting rates of 150,000 to 200,000 plants/ha in the lowlands and 250,000 plants/ha in the highlands. This is for improved varieties. The URL is https://www.aciar.gov.au/sites/default/files/legacy/node/9915/mn134_growing_peanuts_in_papua_new_guinea_a_best__12068.pdf.

	Fertilizer (rate kg/ha)	Drier	Near Average	Wetter
Irish Potato	10_25_12_B_mix	1000	1200	1300
Irish Potato	10_25_12_B	1200	1440	1560
Bulb Onion	12_12_17	250	300	325
Bulb Onion	DAP	80	96	104
Sweet Potato	NA	0	0	0
Taro	NA	0	0	0
Peanut	12_12_17_mix	500	600	650
Yam	NA	0	0	0
Maize	12_12_17_mix	400	480	520
Cassava	NA	0	0	0
Beans	NA	0	0	0

Notes

N,P,K,Mg (12:12:7:2) sometimes used at 750 kg/ha plus triple super at 250 kg/ha. In the Rainfall Management Matrix, the FPDA recommended rate is 1200 kg/ha, not 1000 kg/ha suggested by Hughes et al (2009) Source: Kanua, M.B., Freeman, M. and Kamis, P. (1993). A guide to successful vegetable production in the highlands of PNG. Harvest 15(1):15-30.

Maize is not usually fertilized in PNG as it is normally grown in the first planting after a long fallow period. Kanua, Freeman and Kamis (1993) recommended application of 12:12:17 mix, but this is not done in practice

Source: Kanua, M.B., Freeman, M. and Kamis, P. (1993). A guide to successful vegetable production in the highlands of PNG. Harvest 15(1):15-30

Crop	***Insecticide used***		***Rate***	
		Drier	*Near Average*	*Wetter*
Irish Potato	*Orthene*	*0.5*	*0.6*	*0.65*

Irish Potato	*Karati*	*24*	*28.8*	*31.2*
Bulb Onion	*None*	*0*	*0*	*0*
Sweet Potato	*None*	*0*	*0*	*0*
Taro	*None*	*0*	*0*	*0*
Peanut	*None*	*0*	*0*	*0*
Yam	*None*	*0*	*0*	*0*
Maize	*None*	*0*	*0*	*0*
Cassava	*None*	*0*	*0*	*0*
Bean	*None*	*0*	*0*	*0*
Broccoli	*Orthene*	*2*	*1 kg/ha*	
Cabbage				
Pak choi	*Karati*	*48*	*24 mL/ha*	

Notes

Sources: The two insecticides and two fungicides are those sold by Farmset (and other agricultural suppliers). Rates are the best information found from product guides on the web. Importantly, these may not be the recommended rates by FPDA in PNG.

Potato Fungicides are used by many potato growers to control potato late blight (Phytopthora), but some rely on using resistant varieties only. Fungicides can be applied up to 6 times in the life of a crop, but in practice probably much less and often no fungicides are used.

James Moruwo (Farmset, Goroka) advises that the rate is 3-10 L of AgriFos in 600-850 L of water. He advises that application commences at flowering and spraying continues every 7-14 days to harvest. It is suspect that this is a recommendation, rather than actual practice for most ware potato growers.

Insecticides (orthene or karati) are occasionally applied to control insect pests, but only by some farmers and sometimes.

Maize smallholders do not normally apply pesticide to maize (corn) in PNG. There are a number of insect pests which can reduce yield significantly including Asian Corn Borer and the recently arrived Fall Army Worm. Insecticides are applied to control the last named by at least one large scale maize producer in the Markham/Ramu valley area.

Brassicas

James Moruwo advises that farmers apply insecticides when insects are a problem. Rates are 10 ml Karati per 10 L of water (400-500 ml/ha) OR 5 g Orthene per 4.5 L water (1 kg/1000 L water/ha). He advises that insecticide is applied when insects damage is noted and is repeated every 7-10 days. (Again, I suspect that this is a recommendation.

Insecticides are applied to control diamond back moth and other insect pests on brassica crops intended for distant markets (and sometimes for local markets as well).

Sweet potato, taro, peanuts, yam, maize, cassava, beans

Normally, no pesticides are applied to these crops in PNG. Inorganic fertilizers are not normally applied to these crops in PNG, although it is possible that small amounts of NPK or urea fertilizer are used on maize.

Crop	*Fungicide*	*Fungicide rate Litres/ha*		
		Drier	*Near Average*	*Wetter*
Irish Potato	*AgriFos_600*	*3*	*3.6*	*3.9*
Irish Potato	*Barrel_bikpela_720*	*1.5*	*1.8*	*1.95*
Bulb Onion	*None*	*0*	*0*	*0*
Sweet Potato	*None*	*0*	*0*	*0*
Taro	*None*	*0*	*0*	*0*
Peanut	*None*	*0*	*0*	*0*
Yam	*None*	*0*	*0*	*0*
Maize	*None*	*0*	*0*	*0*
Cassava	*None*	*0*	*0*	*0*
Bean	*None*	*0*	*0*	*0*

Fertilizer use					
	Fertilizer	***Cost/25 kg***	***Cost/kg***	***Rate***	***Notes***
Irish Potato	*10:25:12 +B mix*	*214.50*	*8.58*	*1000 kg/ha*	*N,P,K,Mg (12:12:7:2) sometimes used at 750 kg/ha plus triple super at 250 kg/ha*
	(Potato mix)				*Source: M. Hughes et al. (2009). Sweet potato agronomy in Papua New Guinea.*
					In G. Kirschoff (ed). Soil fertility in sweet potato-based cropping systems in the highlands of Papua New Guinea. ACIAR Tech. Report No 71
					If smallholders applied 1000 kg/ha (40 bags/ha), the cost would be K8580/ha. This seems very unlikely.
					Surveys of 7 elite seed potato growers by Matt Kanua in 2014 suggest current costs might be closer to K3150/ha (see table in 'Any other costs' section).

	10:25:12 + B	*214.50*	*8.58*	*1200 kg/ha*	*In the Rainfall Management Matrix, the FPDA recommended rate is 1200 kg/ha, not 1000 kg/ha suggested by Hughes et al (2009)*
Bulb Onion	*12:12:17*	*203.50*	*8.14*		*James Moruwo (Farmset, Goroka) advises that farmers use 12:12:17 NPK mix at a rate of one handful per 4 rows in the nursery.*
	10:25:17 + B	*214.50*	*8.58*		*James Moruwo (Farmset, Goroka) advises that farmers use 10:25:12 NPK mix (I think that this is 10:25:17 +B mix) at a rate of 15 g/plant in the field.*
	12:12:17	*203.50*	*8.14*	*250 kg/ha*	*Source: Kanua, M.B., Freeman, M. and Kamis, P. (1993). A guide to successful vegetable production in the highlands of PNG. Harvest 15(1):15-30*
	DAP	*137.50*	*5.50*	*80 kg/ha*	*Source: Kanua, M.B., Freeman, M. and Kamis, P. (1993). A guide to successful vegetable production in the highlands of PNG. Harvest 15(1):15-30*
Sweet Potato	*None*				*A few people place a small amount of NPK mix in the planting area in parts of Eastern Highlands, but this is very uncommon*
Taro	*None*				
Peanut	*None*				
Yam	*None*				
Maize	*12:12:17 mix*	*203.50*	*8.14*	*500 kg/ha*	*Maize is not usually fertilized in PNG as it is normally grown in the first planting after a long fallow period.*
					Ideally, DAP would be applied at planting, with a fertilizer high in nitrogen (eg urea) applied later in the crop life.
					In practice, this would not be done in PNG, so a N,P,K mix could be applied at 500-800 kg/ha at planting.
Cassava	*None*				
Beans	*None*				*Kanua, Freeman and Kamis (1993) recommended application of 12:12:17 mix, but this is not done in practice*

	12:12:17 mix	*203.50*	*8.58*	*400 kg/ha*	*Source: Kanua, M.B., Freeman, M. and Kamis, P. (1993). A guide to successful vegetable production in the highlands of PNG. Harvest 15(1):15-30*
					This is the recommended rate, but fertilizer is very rarely applied to bean crops. Rather beans are used in the first planting after a fallow period.

Notes: Fertilizer rates for cabbage, cauliflower, broccoli, Brussel sprouts, Chinese cabbage, bean, carrot, tomato, bulb onion and zucchini are given by Kanua et al. (1993). They also give planting rates, experimental yield data, and recommended varieties