Monograph:

Visman, E orcid.org/0000-0002-5215-1818, Hirons, L orcid.org/0000-0002-1189-7576, Todd, M orcid.org/0000-0003-4847-5921 et al. (21 more authors) (2022) Institutionalising co-production of weather and climate services: Learning from the African SWIFT and ForPAc projects. Report. GCRF African SWIFT Policy Briefs . University of Leeds , Leeds.

https://doi.org/10.48785/100/99

GCRF AFRICAN SWIFT
SCIENCE FOR WEATHER INFORMATION AND FORECASTING TECHNIQUES

SHEAR Science for Humanitarian Emergencies & Resilience

Institutionalising co-production of weather and climate services: Learning from the African SWIFT and ForPAc projects

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Executive summary

There is growing recognition of the multiple benefits of co-production for forecast producers, researchers and users in terms of increasing understanding of the skill, decision-relevance, uptake and use of forecasts. This policy brief identifies lessons learnt from two operational research projects, African SWIFT and ForPAc, on pathways for embedding co-production into operational weather and climate services as the new standard operational procedure.

Experiences across these projects identifies the following potential pathways for institutionalising co-production practises within operational weather and climate services:

- **Changing mindsets and systems to enable co-production of enhanced forecasts and systematic approaches for their use.**
- **Strengthening in-country institutional links between operational forecasting centres and academic institutions** to develop sustainable and improved forecasting capacities to meet users' evolving weather and climate information needs.
- **Ensuring continued access to raw forecast data from global forecasting centres** to continue and further develop new and improved decision-relevant forecasts.
- **Formalising user engagement in co-production,** through agreeing standard and continuity of representation and commitment to providing regular feedback.
- **Mainstreaming stakeholder engagement and co-production in meteorological training, forecasting operations and environmental research.**
- **Working through existing channels**, such as agricultural and livestock extension services, **and harnessing social media and remote ways of working to develop sustainable forms of continuous user engagement.**
- **Establishing monitoring systems to demonstrate the benefits of investing in forecasting capacities.**
- **Incentivising collaboration between complementary initiatives.**
- **Addressing the risks of operationalising new and improved weather and climate services in resource-constrained environments.**

1. Introduction

The urgent need to strengthen climate-resilience is widely recognised across international and regional frameworks[1], as well as within national and sub-national policies and programmes. Anticipatory, including preparedness, capacities are recognised as fundamental to strengthening resilience to longer-term climate change, yet systematic use of weather and climate services remains low. This has led to a growing focus on co-production as a way of co-developing services with users to ensure they are trusted, relevant, accessible and used, and so avoid them turning to alternative, less accurate sources of weather and climate information. However, co-production is not yet standard practice. This brief identifies key learning from two recent consortium projects supported by the UK Foreign, Commonwealth and Development Office (FCDO) and UK Research and Innovation (UKRI), African Science for Weather Information and Forecasting Techniques (African SWIFT) and Towards Forecast-based Preparedness and Action (ForPAc) on how to embed co-production as the norm.

In ForPAc, co-production efforts were focused on strengthening drought and flood preparedness. The project co-produced forecasts to strengthen the National Drought Management Authority (NDMA) Drought Early Warning System (DEWS), as well as addressing flood risk in the Nzoia and Tana river basins and Nairobi City. In African SWIFT, co-production efforts were focused within two testbeds, where prototype forecast products are co-produced and operationally trialled in real-time. These were the first testbeds to be held in Africa, with one focused at the Sub-seasonal to Seasonal (S2S) timeframe, while the short-term forecasting test bed focused on 0-72 hours. Both ForPAc and African SWIFT sought to promote local leadership and Table 1 outlines the respective aims, partners, geographic coverage and duration of each project, as well as the principal co-production activities and approaches through which users were engaged.

Both African SWIFT and ForPAc identified specific time for ongoing and post-event reflection amongst those directly involved, with wider project partners and key users. Drawing from this wealth of learning, this policy brief identifies the benefits and challenges of operationalising the co-production approaches employed within the projects and routes for operationalising co-production as the norm.

Glossary of Terms

Anticipatory Action: Seeks to reduce or mitigate the impact of disasters and enhance post-disaster response, using forecasts or early warning of imminent shock or stress[2].

Climate Services: Providing weather or climate information (over timeframes) in ways that assist decision-making by individuals and organisations[3].

Co-production: Bringing together different knowledge sources, experiences and working practices to jointly develop new and combined knowledge for addressing societal problems of shared concern[4].

Forecast-based Action: Use of forecasts to support consistent and defensible preparedness action. Early Action Protocols seek to enable the pre-identified 'forecast-based financing', or FbF, required to underpin systematic Forecast-based Action (FbA).

Operational Centre: Encompassing both National Meteorological and Hydrological Services and regional and pan-Africa climate centres.

Participatory Impact Pathways Analysis: A series of tools for developing shared understanding of the problem partners seek to jointly address and agreed pathways for addressing it.

Nowcasting: A very short term prediction of the weather for the next few hours, based on analysing the current observed weather rather than using a forecasting model.

S2S: Sub-seasonal to seasonal: forecast predictions beyond two weeks but less than a season.

Short-term forecasting: Encompassing both nowcasting and synoptic forecasting (0-72 hours, spatial scales from ~10 km to~1000 km).

Synoptic: Forecast of the weather for the next 1-3 days.

Testbed: A forum where prototype forecast products are co-produced and operationally trialled in real-time.

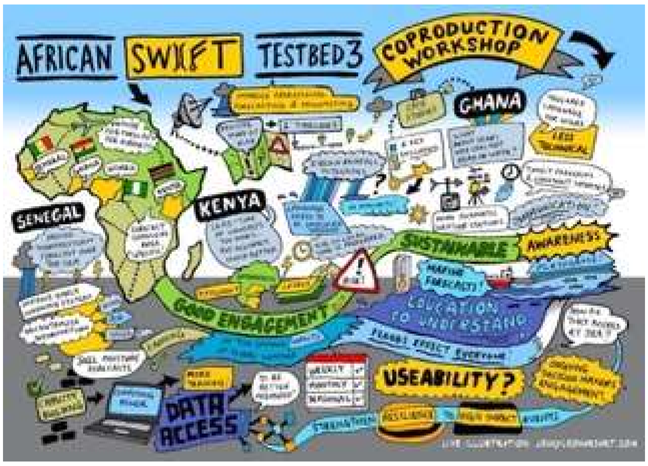

Figure 1: Live-sketch of cross-country reflection during African SWIFT Short-term forecasting testbed co-production workshops held in Ghana, Kenya and Senegal. *Source: Jenny Leonard, 2021.*

Table 1: Overview of African SWIFT and ForPAc aims, partners, duration and co-production activities & approaches

	ForPAc with associated projects AstroCast[a], INFORM[b], HyPAc[c], L2CP[d]	**African SWIFT**
Aims	Supporting drought and flood preparedness in Kenya through: - Improving daily to seasonal forecasts of decision-relevant information. - Improving the use of forecasts employing Forecast-based Action methods. The associated AstroCast, INFORM and HyPAc projects further developed forecasts to support partnering institutions' specific requirements, while Learning to Co-produce (L2CP) sought to embed co-production within meteorological training curriculum.	Recognising that improved accuracy of weather forecasting is critical for people's safety, and for key economic sectors including aviation, agriculture, energy, water and emergency response, African SWIFT aimed to: - Deliver a step change in African weather and forecasting capability from hourly to seasonal timescales. - Build research capability to continue forecasting improvements in Africa for the foreseeable future. The project coordinated the first testbeds to be held in Africa. Three testbeds were held and engagement of users was a focus in the Sub-seasonal to seasonal (S2S) and Short-Term Testbeds.
Partners	In Kenya: KMD, ICPAC, Kenya Red Cross Society (KRCS), NDMA, Water Resources Authority (WRA) and Regional Centre for Mapping of Resources for Development (RCMRD). In the UK: the Met Office and Universities of Sussex, Oxford, Reading and Bristol and King's College London.	Forecasting centres and universities in Senegal (ANACIM and UCAD), Ghana (GMet and KNUST), Nigeria (NiMet and FUTA) and Kenya (KMD and UoN), regional climate centres (ACMAD and ICPAC) and UK partners (NCAS, University of Leeds, University of Reading, UK Centre for Ecology & Hydrology and the UK Met Office).
Duration	2016-2022	2017-2022
Geographic coverage	Kenya and sharing learning with the Greater Horn of Africa region	Ghana, Kenya, Nigeria and Senegal and wider coverage through regional climate centres.

Principal project activities through which co-production was undertaken				
	ForPAc		**African SWIFT**	
	Drought-preparedness case study	**Forecasting flood-risk**	**S2S testbed**	**Short-term testbed**
Aims	Co-develop actionable forecast products to enable national- and County-level drought preparedness and promote transition from monitoring to forecasting drought conditions.	Exploring the potential to improve forecasts of basin fluvial and urban pluvial flooding.	National meteorological agencies, regional climate centres, universities and forecast users co-create and operationally trial sub-seasonal (1-4 weeks ahead) forecast products.	Test and evaluate new tools and methods for nowcasting and forecasting high-impact weather, from a few hours to a few days. Co-developing forecasts tailored to specific user groups.
Focal sectors	NDMA and members of Kitui County Government's cross-sectoral County Steering Group.	Nairobi County Government. Basin and national flood disaster risk management institutions.	Disaster Risk Management Energy Health Agriculture Food Security	Aviation Disaster Risk Management Agriculture Fishing Water Resources Transportation

[a] AstroCast provides enhanced vegetation index forecasts in pastoral livelihood zones in Kenya to support drought preparedness.
[b] INFORM developed sub-seasonal soil moisture and water requirement forecasts which have been integrated within NDMA DEWS.
[c] HyPAc assesses the potential for flood forecasting.
[d] Online Learning to Co-Produce (L2CP) training to strengthen meteorologists' and climate researchers' engagement with decision-makers.

<table>
<tr><td>Forecast timescale</td><td>S2S</td><td>Synoptic to S2S</td><td>S2S</td><td>Nowcasting and synoptic</td></tr>
<tr><td>Co-production approach</td><td colspan="2">Embedded project staff member in each partnering national institution.
Adapted Participatory Impact Pathways Analysis (PIPA) workshops.[5]
Ongoing climate information training for key users to enable forecast-based decision-making.[5]
New and improved co-produced forecasts piloted in real time through continuous user engagement and joint reflections and review.
Strengthening capacities to institutionalise development and use of new and improved forecast products.</td><td>Joint forecaster-researcher-user workshop to co-develop operational co-production action plans formalising relationships for the testbed and responsibilities for maintaining collaboration in product development, communication, and evaluation.[6],[7]</td><td>Co-design PIPA workshop.
Development of hybrid approach.
Co-production workshops to explore users' forecast needs and introduce users to nowcasts.
Co-evaluation of forecast products.
Users engaged in dry run and live two-week testbed and review.</td></tr>
<tr><td rowspan="2">Monitoring</td><td colspan="2" rowspan="2">Monitoring, evaluation and learning framework and Theory of Change used on an ongoing basis.
Baseline reviews of national and regional drought and flood early warning systems and existing forecasting services.
Baseline, mid- and end of project key informant interviews on use and perceptions of forecasts, and benefits of forecast-based action approach
Evaluation surveys after workshops and trainings.
Monitoring national, county and international policy development to identify opportunities for institutionalising forecast-based action.</td><td>Bi-annual forecast producer and user questionnaires:
Producer questionnaire - if and how new testbed products are incorporated into operational procedure; how they have sought to address user feedback.
User questionnaire - how new testbed products are used in the decision-making context they were designed for.</td><td>Evaluation questionnaire after co-production workshop.

Participatory evaluation of testbed products.</td></tr>
<tr><td colspan="2">Staff development monitored via annual self-assessment 'Skills tracker', where user engagement and co-production amongst the key skills monitored.</td></tr>
<tr><td rowspan="2">Learning</td><td colspan="2" rowspan="2">Theory of Change and PIPA outputs supported ongoing review and revision.
Regular review of case-study plans.
Stakeholder learning events after pilot phases.
Final project meeting included user product evaluation and discussing routes to institutionalise new/improved products.
Project learning and complementary initiatives shared via ForPAc-supported regional workshops hosted by ICPAC.</td><td>Semi-structured interviews with key users</td><td>Post-testbed cross-country team reflections</td></tr>
<tr><td colspan="2">Reflections within each testbed, with learning subsequently shared across testbeds and the wider African SWIFT team.
End of project meeting engaged key users to reflect on benefits, challenges and potential for institutionalising co-production of weather and climate services as standard practice.</td></tr>
</table>

2. The benefits of co-production

Both projects recognised multiple benefits of co-production, including and beyond those identified within complementary initiatives [7],[8]. Noted benefits included:

- **Supporting the operationalisation of new and improved services**

Both projects reported co-production as enabling increased operationalisation of new and improved, co-produced forecasts, deepened forecaster appreciation of decision-makers' specific forecast needs and increased user ownership and uptake of co-produced services. For example, NDMA has integrated within its DEWS products created by ForPAc and further developed through African SWIFT. KenGen has operationalised products co-produced through the Weather and Climate Services for Africa (WISER) Strengthening Climate Information Partnerships in East Africa (SCIPEA)[9] project and in the African SWIFT S2S testbed. [10],[11]

- **Investing in building common ground on what is useful and possible and the skills and channels to support ongoing user-forecaster-researcher collaboration.**

Both ForPAc and African SWIFT recognised the vital importance of **ensuring both that users have sufficient appreciation of key climate concepts and how they can be appropriately used and forecasters and climate researchers have sufficient understanding of the decision-making contexts they are seeking to support**. The inclusion of training on key climate concepts within ForPAc[5] and the African SWIFT Short-term testbed enabled users to actively inform the co-production process, including product development, visualisation and verification. Similarly at its kick off meeting, the African SWIFT S2S testbed enabled joint problem identification and operational planning. Users in ForPAc and the S2S testbed also appreciated receiving forecasts with attached probabilities. This may help in overcoming reluctance amongst some operational forecasters to providing these. Building common ground also highlighted **routine challenges facing operational centres**.

Moreover, while originally planned to be undertaken in one country, covid-19 restrictions led to the Short-term testbed adopting **a hybrid approach. Combining in-country engagement between researchers, forecasters and users with remote support from international partners and online cross-country reflections**, the hybrid approach enabled the Short-term testbed to be run in the project's four partner countries (Table 1). This format exemplifies a less resource intensive form of co-production whilst still enabling the benefits of directly engaging multiple stakeholders and the diverse perspectives and opportunities they bring.

- **Enabling user feedback and real-time verification of new and improved forecast products**

Co-production activities have built in ongoing user-feedback, enabling participatory verification of forecast skill and evaluation of forecast relevance. Harnessing of social media and direct user engagement in the Short-term testbed supported real-time verification through instantaneous user feedback.

Feedback from users and forecasters has also informed ongoing and potential future research. For example, the development of meningitis warnings within the S2S testbed has encouraged research into drivers of dry conditions across sub-Saharan Africa[12]. Co-development of the meningitis bulletins has also raised consideration of how S2S data could support the prevention of other tropical diseases and other areas of health.

- **Strengthening in-country links between national operational centres and academic institutions to support sustainable improvement in forecasting capacities**

Both ForPAc and African SWIFT invested in building forecasters' skills. Topics of focus included: accessing and using new data sets; assessing forecast skill; and designing impact-based forecasts. Engagement in operational testbeds highlighted the vital importance of in-country collaboration between national operational centres and research institutions to sustain strengthened forecasting capacities. These linkages were particularly bolstered within the Short-term testbed, for which each country's national operational centre and partnering university co-operated in setting up the Nowcasting Satellite Application Facility (NWCSAF) to be run locally at each institution. University staff and students travelled to the national operational centre to participate in the testbed. In some instances, this cooperative work resulted in a memorandum of understanding between the national operational centre and partnering university.

- **Shortening the timescale between the development of meteorological forecasting knowledge and its application in decision-making[11].**

Both projects were originally designed to support the non-operational trialling of new and improved services. However, co-production led to the operationalisation and institutionalisation of new and improved products. For example, KMD has incorporated the Standardised precipitation index (SPI) within its October, November, December seasonal forecasts, and NDMA has integrated, within the DEWS bulletin Vegetation Condition Index (VCI) and SPI forecasts initiated in ForPAc and further developed through the African SWIFT S2S testbed. These products have also been incorporated into the nation-wide Red Cross drought early action protocol and, more widely, are informing international agencies' anticipatory risk management initiatives. The S2S testbed also produced services tailored for specific energy and agriculture companies. This highlighted the opportunity for national operational centres to generate income through developing bespoke services for the private sector. Partnering national operational centres are also integrating NWCSAF into operations as a result of the Short-term testbed. However, as discussed in Section 3, operationalisation of piloted forecasts has led to challenges in ensuring continued access to required data and raised ethical questions in regard to piloting new services in resource-constrained environments.

- **Aligning efforts across complementary initiatives**

Across the two projects, there have been significant benefits in sharing evolving learning and aligning work to enable projects to build on and capitalise effort. This has supported progressive and more sustainable forecast development. The S2S testbed further developed soil moisture outlooks for ForPAc's drought preparedness case study, and weekly forecasts co-developed by partnering institutions across the two projects were shared with Nairobi County stakeholders to inform urban flood preparedness. Furthermore, TAMSAT-ALERT[13] soil moisture outlooks developed for Kitui County in Kenya as part of ForPAc, were modified and extended for national application in Kenya, Ghana and Nigeria as part of the African SWIFT S2S testbed. This expanding user base directly precipitated the development of more comprehensive, stand-alone training materials.

Table 2: User, forecaster and researcher perspectives on some of the benefits and challenges of co-production

Benefits of co-production			
	ForPAc	**S2S testbed[14]**	**Short-term testbed**
User	Forecasting drought risk metrics enabled the national Drought Early Warning System (DEWS) to become partially forecast-based. Increased awareness of the potential for earlier drought and flood preparedness. Supported a regional roadmap on Forecast-based Financing and Anticipatory Action for East Africa. Strengthened KRCS contingency planning process. Informed development of national drought and flood Early Action Protocols (EAPs).	Improved hydropower generation scheduling and water resources management in Kenya, alongside reduced diesel usage and uninterrupted energy production. Meningitis vigilance maps for the Sahel enhance meningitis preparedness and prevention. Customised forecasts enhanced flood preparedness and better equipped Nigerian farmers[15]. Equipped the Central African regional climate centre with state-of-the-art S2S forecasts.	Supported development of flood EWS and flood-preparedness in Kenya. Frequently updated information resulted in cost reductions for Kenya Airways' local flights. New and more timely and accessible warning information for Ghana's marine sector.
Forecaster/ researcher	Strengthened appreciation of specific user needs. This facilitated institutionalisation of project outputs within DEWS and heightened awareness of demand for forecasting flood risk, including within informal settlements. Enhanced capacity to engage with non-technical stakeholders. Built trust and strengthened institutional links.	Enabled forecasters to explain key forecast concepts to users. Operationalisation of testbed outputs and demand for continuation of initiated services. User feedback serves as a subjective verification. Feedback from users and forecasters informs research. Strengthened relationships between forecast user and producer institutions.	Improved forecasters' knowledge of nowcasting. Improved users and researcher understanding of the processes and challenges of operational centres. Near instantaneous user feedback through daily survey. Created user demand for nowcasting, a new service for operational centres. Supported development of impact-based forecasts.

Challenges of co-production			
	ForPAc	**S2S testbed**	**Short-term testbed**
User	Strengthening confidence in appropriately using forecasts to inform decision-making. Integrating forecast-based approaches within institutions undergoing restructuring. Changing institutional practices, systems and individual mindsets.	Communication of forecast uncertainty – especially when spatial scales of skill do not match local decision-making requirements. Resource intensive. Incorporating new knowledge into existing communication pathways and gaining trust from users. Downscaled forecasts and training required for users to benefit from forecasts. Reduction in the use of technical terminologies in forecasts.	Public awareness and capability to take forecast-based decisions greatly varies. Need for more inclusive forecast communication, feedback and verification systems, including in local languages. Strengthening synergy between ministries and services. Strengthened national observation networks to meet user needs. Requirement for more localised forecast.
Forecaster/ researcher	Continuous user engagement was time intensive. Lack of systematic communication of forecast probability and skill, vital for forecast-based action. Lack of alignment between issuing forecasts and DEWS process. Information needed at finer spatial resolution requiring higher computing capacity.	Discontinuation of access to data enabled through the S2S testbed jeopardises continuity of project-initiated services. Number of users was by design limited to meet data requirements. Limited resources constrained iterative engagement. Limited user feedback risked inclusive representation. S2S data new to both forecasters and users. Limited preparatory phase curtailed discussion with users about what was possible. Unwillingness to bring together scientific and local and/or indigenous knowledge sources.	Impact-based metrics are complex for users to understand. Limited timeframe to test co-produced products. Limited staff time and resources led to discontinuation of some user-specific testbed forecasts and enhancements. Access to appropriate computational resources.

3. Challenges of co-production

There are recognised needs to strengthen observational networks, human resources and computational and forecasting capacities.[6],[14],[16],[17] Clearly these significantly constrain operational centres in meeting users' forecast requirements. Equally there are a range of challenges related to the institutional relationships between users, forecasters and researchers required to co-produce and support forecast uptake. These challenges include:

- **Co-production is resource intensive**

Few staff at operational centres have stakeholder engagement as one of their core roles. Partners in both projects recognised that the time and resources required to support user engagement had been underestimated.

This, in some instances, contributed to insufficiently high-level or sustained representation from across partnering user institutions. The S2S testbed faced particular challenges in securing continuous user feedback. This resulted in inadequate forecast verification and evaluation from the users' perspective. Moreover, the users' needs differ both across sectors and decision-making levels, making it hard to scale-up efforts. One partnering national disaster management agency, for example, highlighted the very different services required to inform the public rather than specialised agencies.

African SWIFT's UK partners also reflected on the extent of co-production within the UK's weather and climate services. While linkages between physical and social sciences, and with key user institutions, are being strengthened, resource limitations and long-established institutional practises can curb more inclusive climate service development and climate adaptation processes.

- **Extend climate information training for specific sectors and decision-making levels**

ForPAc and the Short-term testbed noted requests to extend and deepen training for users on key climate concepts and appropriate forecast usage to engage additional sectors and levels of decision-making. This was particularly noted in regard to impact-based forecasting, where user inputs are vital to assessing potential impacts.

- **Changing mindsets and working practices to enable systematic forecast-based action**

Bringing together different value and knowledge systems, co-production challenges existing ways of working. The S2S testbed, for example, noted unwillingness amongst some forecasters to consider ways of bringing together scientific and local and/or indigenous knowledge.

Moreover, demonstrating the feasibility of preparedness based on probabilistic forecasts requires a sustained period of investment. ForPAc developed new and improved forecast products specifically tailored to informing the existing national drought early warning system, and these were institutionalised in both KMD and NDMA. However, aligning the issuing of forecasts with the timing of key drought risk management processes remained a challenge. Forecast-based action and preparedness has only recently been introduced to many disaster risk management agencies. Efforts to transition from monitoring to forecasting drought and flood risk requires significant changes in institutional practices. These include changing systematic communication of forecast probability and skill, and a willingness to invest in preparedness based on probabilistic forecasts. This in turn requires more extensive climate training for decision-makers and extended analysis of the costs and benefits of potential preparedness actions.

- **Risks in operationalising new pilot products in resource-constrained environments.**

Both projects recognised the need to institutionalise training to sustain project-supported improvements in forecasting capacities. Moreover, while products initiated through the S2S testbed have been operationalised, their continuation is jeopardised through discontinued free access to the data enabled through the testbed.

While co-production of weather and climate services facilitates operational uptake, both projects identified the risks of operationalising piloted services before they have been fully evaluated. These risks are clearly heightened in contexts where there are limited safety nets for those people likely to be most directly impacted. There is a risk that operational time constraints or a rush to operationalise new services limits the time for evaluation of both the forecast skill and its user relevance (particularly in a region that perhaps lacks these kind of services). This underscores the need to allocate specific resources to the research elements of development and evaluation prior to and during the co-production of new and improved forecasts.

4. Pathways to normalising co-production in climate services

The benefits of co-production realised in ForPAc, African SWIFT and complementary initiatives underlines the need for it to become standard practice for operational centres. This requires developing a strong enabling environment for co-production, permitting institutionalisation of the capacities and processes envisaged within the World Meteorological Organisation's (WMO) Global Framework for Climate Services[18]. It entails a commitment to invest in building the common ground required to enable co-production and strengthening users' appreciation of key climate concepts so they can take an active role in the co-production process. It also requires ensuring sustained investment in strengthening the capacities of African forecasters and researchers to produce actionable forecasts with sufficient skill and user relevance.
[6],[13],[15],[16]

While there are now a growing number of successful pilots[7], scale up and sustainability requires articulation and institutionalisation of each partner's respective roles and responsibilities in the co-production process. African SWIFT and ForPAc have identified the following pathways to normalise co-production in climate services:

- **Strengthening institutional links between operational centres, academic institutions and regional climate centres**

Guidance on co-production of climate services often use the term 'climate information producers', agglomerating the respective roles of national meteorological and hydrological services (NMHS), national and international climate-specialist research institutions and regional and global climate centres. There has, to date, been limited consideration of the interlinkages amongst 'producers' required to ensure sustainable in-country capacities to respond to evolving user needs. Linkages between operational centres and national universities and research centres are vital to ensuring the sustainable in-country capacities required to meet users' diverse and evolving weather and climate information needs.

Cross-project learning also demonstrates **the benefits of aligning efforts**. Incentivising such collaboration could promote more sustainable investment in services and capacities. Cross-disciplinary research may be able to play an important role in developing understanding of how local and indigenous knowledge can strengthen forecasts.

- **Mainstreaming stakeholder engagement and co-production within meteorological training, forecasting operations and research.**

The projects have highlighted the need to **integrate stakeholder engagement and co-production as core elements of meteorological training**. To this end, African SWIFT has developed a chapter on co-production within a forecasters training resource*, while ForPAc and a wide range of partners, including African SWIFT, co-developed and piloted an online training course titled "Learning to Co-Produce", aimed at strengthening forecasters' and climate researchers' stakeholder engagement capacities.

R**ecognising co-production as a core skill linked to career progression**, operational centres and research institutions can build on African SWIFT's example through including stakeholder engagement and co-production as a key performance indicator within monitoring of staff development.

- **Formalising user engagement in co-production**

Recognising that user engagement and feedback is essential in the process of developing decision-relevant weather and climate services, the role of users needs to be clearly articulated and formally agreed from the outset. Institutional agreements clarifying partners' respective roles in the co-producing process could, for example, encompass requirements for appropriate level and continuity of user representation, commitment to regular feedback and participatory verification and evaluation. Through ongoing engagement over several projects, KMD secured a MoU with KenGEN, while African SWIFT partners are integrating user engagement within SOPs for future testbeds. GMet's use of social media to enable widespread user feedback and the hybrid approach used in TSB3 well illustrate the potential for harnessing social media and remote ways of working to develop sustainable forms of continuous user engagement and feedback.[19],[20]

- **Developing systems to demonstrate the benefits of investing in forecasting capacities**

Project learning reinforces the recognised need to integrate user-relevant metrics in forecast evaluation.[6],[13], [20] Demonstrating the tangible benefits of new and improved forecasts is key to securing continued investment in the infrastructure, capacities and access to raw forecast data. Potential options for strengthening monitoring and evaluation of climate services include linkage with existing national monitoring systems or partnerships with national universities and research institutions, Equally, establishing business models for developing tailored forecasts will be vital to securing sustained governmental and private sector investment.

- **Ethics of operationalising new and improved weather and climate services**

Co-produced operational research can offer significant benefits for all partners, including participating decision-makers and the at-risk groups they serve. Accelerating the uptake of improved forecasts can

* Chapter on 'The role of forecasters in co-producing weather and climate information services', multi-author chapter with 18 case studies, within the East African Forecasters' handbook, due to be published in 2022.

strengthen resilience to the increased frequency, intensity and extent of high-impact weather events induced by anthropogenic climate change. But there remains a need to ensure a safe space for developing anticipatory action. This requires strengthening decision-makers' understanding so that they can make an informed decision of the risks and opportunities of forecast-based action. Most fundamentally, it also requires ensuring that forecasts have sufficient skill to justify investment in anticipatory actions and that piloting of new and improved forecasts is linked with the safety nets that enable safe learning.

Acronyms

ACMAD	African Center of Meteorological Application for Development
African SWIFT	African Science for Weather Information and Forecasting Techniques
ANACIM	Agence Nationale de l'Aviation Civile et de la Météorologie - Senegal's National Civil Aviation and Meteorological Agency
DEWS	Drought Early Warning System
ForPAc	Towards Forecast-based Preparedness and Action
FUTA	Federal University of Technology, Akure
GCRF	Global Challenges Research Fund
GMet	Ghana Met Agency
ICPAC	InterGovernmental Authority on Development Climate Predictions and Application Centre
KMD	Kenya Meteorological Department
KNUST	Kwame Nkrumah University of Science and Technology
NDMA	National Drought Management Authority (Kenya)
NMHS	National Meteorological and Hydrological Services
NiMet	Nigerian Meteorological Agency
NWCSAF	Nowcasting Satellite Application Facility
PIPA	Participatory Impact Pathways Analysis
S2S	Sub-seasonal to Seasonal
TAMSAT-ALERT	Tropical Applications of Meteorology using SATellite data and ground-based Observations – AgriculturaL Early waRning system[12]
UCAD	Université Cheikh Anta Diop de Dakar
UKCEH	UK Centre for Ecology & Hydrology
UoN	University of Nairobi
WHO	World Health Organisation

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This work was supported by UK Research and Innovation as part of the Global Challenges Research Fund, Grant Ref: NE/PO21077/1 and the Science for Humanitarian Emergencies and Resilience (SHEAR) programme, funded by the UK Natural Environment Research Council (NERC), the Economic and Social Research Council (ESRC) and the UK Foreign Commonwealth and development Office (formerly the Department for International Development (DfID)), grant numbers NE/P000673/1, NE/P000568/1, NE/P000428/1 and NE/P000444/1.

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DOI: https://doi.org/10.48785/100/99