SHEAR impact

SHEAR

A SET OF INSPIRING IMPACT STORIES FROM
THE SCIENCE FOR HUMANITARIAN EMERGENCIES
AND RESILIENCE PROGRAMME 2016-2022

SHEAR
Science for Humanitarian Emergencies & Resilience

Preface

The Science for Humanitarian Emergencies and Resilience programme (SHEAR) has been championing reducing disaster risk since 2016/2017. Funded by the United Kingdom's Foreign, Commonwealth and Development Office (FCDO) and Natural Environment Research Council (NERC UKRI), SHEAR involved unique interdisciplinary collaboration among practitioners and humanitarians that looked at ways to improve our understanding of climate-related risks as well as forecasts and early warning systems, in parallel with enhancing humanitarian actions to reduce this risk.

SHEAR focused primarily on working in Sub-Saharan African and South Asian countries. Bridging science and humanitarian practice has proved highly rewarding, offering many advances in the early warning of landslides, for example, and forecast-based action for hydrometeorological hazards.

During its lifetime SHEAR has achieved some impressive outcomes:
Nearly 100 research projects and grants
Work in at least 18 countries around the world
Nearly 70 global partnerships
Support to nearly 60 early-career researchers
Over 100 peer-reviewed papers (and counting)
At least 30 knowledge products (and counting)
Nearly 80 innovative tools (and counting).

The project ended this year; this report offers a taste of several impacts that the SHEAR programme has had over the years. These are but a few examples of this legacy.

We are grateful for the opportunity to advance collaboration by scientists and humanitarians and we continue to strive to scale up the many lessons, experiences and tools that SHEAR has brought, ensuring that its legacy will endure well beyond the programme itself.

The SHEAR Knowledge Broker Team:
Practical Action Consulting
Red Cross Red Crescent Climate Centre

Authors

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Report compiled in March 2022

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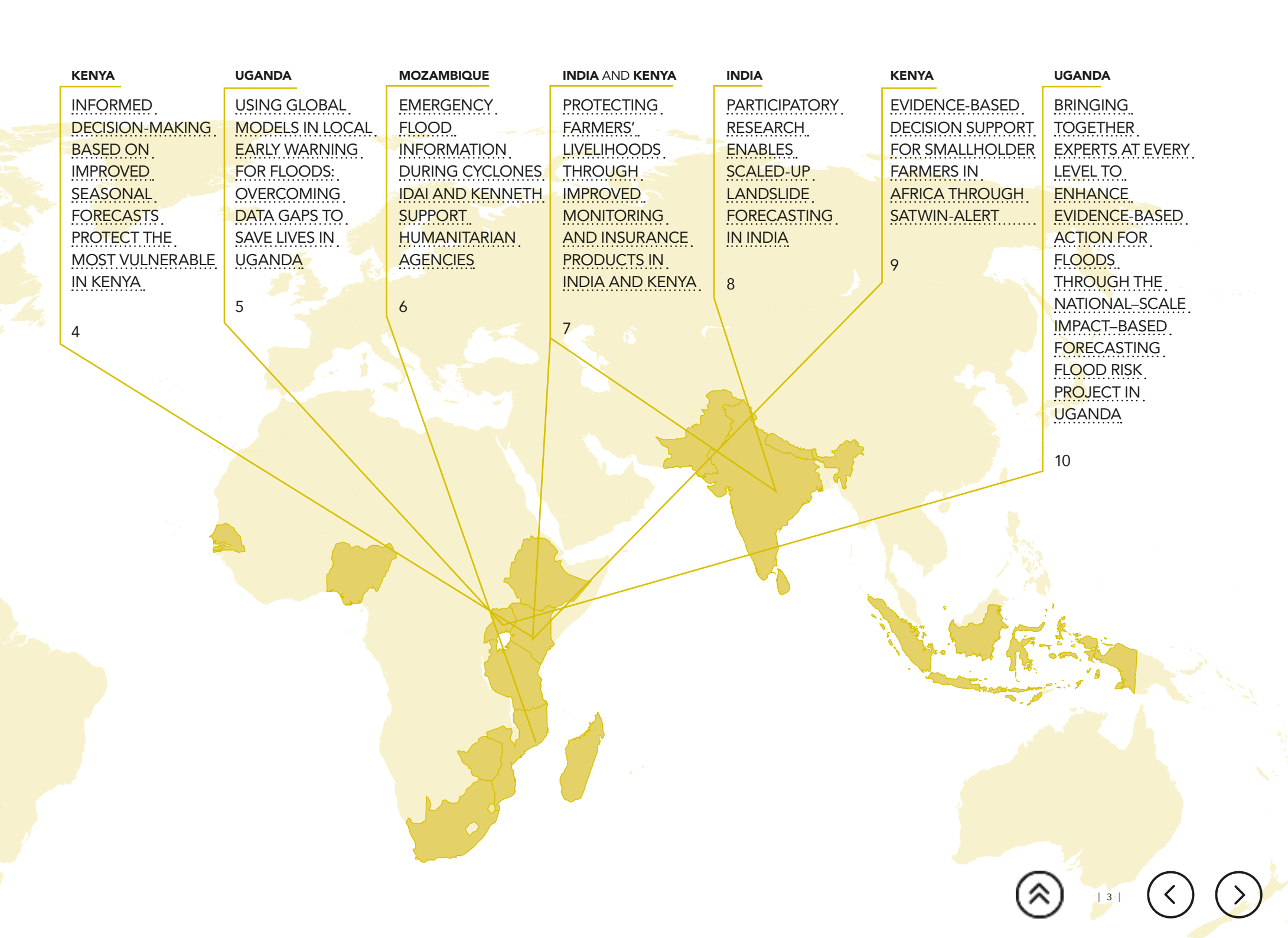
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Kenya

Informed decision-making based on improved seasonal forecasts protect the most vulnerable in Kenya

DROUGHT IN KENYA'S EWASO NGIRO RIVER BASIN
PHOTO: DENIS ONYODI/KRCS

CONTEXT

Kenya suffers from recurrent droughts, which impact lives, rural livelihoods and food security. Currently on average, 6.5 million people are affected by drought (13 percent of the population) per year, and this may increase up to 34 percent of the population by 2050 due to increasing exposure and climate change[1].

Disaster risk management efforts are currently insufficient to meet this challenge. There is a well-established drought management system, but this is largely reactive rather than anticipatory. For the 23 counties classified as arid and semi-arid (out of 47), the National Drought Management Authority (NDMA) of Kenya produces a drought bulletin each month, reporting on drought conditions and recommended actions. Actions are typically invoked only after a drought declaration, and reporting of drought conditions depended on observations rather than projections for the near future.

ACTION

The ForPAc team (which stands for Forecast-based Preparedness Action) has been working to address two key challenges: improving forecasts, and improving preparedness actions. To that end the project brought together researchers and agencies mandated for forecasting and risk management in a process of 'co-production' of new forecast information and use.

Forecasting was strengthened by drawing on the best available international science, global and regional modelling. The team developed a suite of new forecast products of decision-relevant indicators, like rainfall, vegetation, and soil moisture for drought across a range of forecast lead times, from days to months. The skill of these forecasts was thoroughly evaluated to help build trust in forecast-based actions.

ForPAc has worked with mandated agencies to demonstrate the potential of this new suite of prototype forecasts products and of the systematic approaches to making decisions based on forecasts. Preparedness actions were strengthened by designing anticipatory decision-making processes within the existing systems, triggered by these forecast products to reduce the drought hazard impacts. These new forecast products were piloted with the relevant risk management agencies, building an understanding of the products and their use in evidence-based decision-making.

IMPACT

Several mandated agencies in Kenya, such as the Kenya Meteorological Department (KMD) and in the region ICPAC (IGAD Climate Prediction and Application Centre), Regional Earth Observation Centre and RCMRD (Regional Centre for Mapping of Resources for Development) are now confidently and independently producing forecasts using ForPAc's co-developed methodology. As a result of the advances in operational forecast systems for drought in Kenya and increased confidence in the forecasts, the National Disaster Management Authority (NDMA) now shares drought forecast information in the national drought bulletins with advisories on appropriate actions, helping farmers to better anticipate and prepare for drought conditions to reduce their impacts -including during the 2021-2022 drought.

The collaboration and co-design have cemented partnerships among agencies involved and gave a platform for Kenya Red Cross and the NDMA to explore the potential of a drought management system that incorporates forecast-based actions in the future, which would mean a shift from a reactive system to an anticipatory approach. The national drought management system is currently undergoing a review. Kenya Red Cross Society has incorporated the drought (and flood) forecasts into the new operational Early Action Protocols which are designed to align with the national system.

Lessons learned during the ForPAc project for drought forecasting in Kenya are also shared widely in the region. This will be taken forward by the regional forecasting agency ICPAC, which has developed a roadmap for forecast-based actions for drought across the region.

1 CIMA. 2018. Disaster Risk Profile Kenya. https://www.preventionweb.net/files/64257_kenyareportreviewedweb.pdf

Additional information:

www.forpac.org
https://www.icpac.net/our-projects/forpac/
https://gtr.ukri.org/projects?ref=NE%2FP000673%2F1
http://shear.org.uk/research/ForPAc.html

Uganda

PHOTO: DENIS ONYODI/ URCS-CLIMATE CENTRE

Using global models in local early warning for floods: Overcoming data gaps to save lives in Uganda

CONTEXT

Each year, floods impact over 50,000 people and cause extensive damage across Uganda. However, in many flood-prone locations in the country and the region, early warning capacity is not well developed, nor is there clarity on what should be done if certain types of flooding are forecasted. Part of this gap is the lack of forecast models which can indicate when and how river levels are increasing. This limits the potential for preparedness actions that build the resilience of local communities.

ACTION

Forecasts for Anticipatory Humanitarian Action (**FATHUM**) researchers at the University of Reading have been working closely with the Ugandan Red Cross Society and the Ugandan Ministry of Water and Environment to expand their preparedness work and humanitarian action ahead of disasters based on hydrological forecast information. FATHUM's work included assessment of what forecasts are suitable for flood early warning, what might be appropriate forecast triggers and advising on the use of the global flood model GloFAS. FATHUM worked to improve GloFAS usability by improving the relevance of GloFAS skill assessments. Collaboration with in-country partners supported the development of the GloFAS web interface to benefit local decision-making by enabling forecasts to be accessible for strategic and vulnerable locations. Across sub-saharan Africa, fifty-one additional reporting locations have been coded into the web platform. This includes 24 in Kenya (the first there), eight new points each in Mali and Mozambique, while the total in Uganda has now increased from three to 14.

IMPACT

The new measuring points, both virtual and physical gauges, enable hydrological forecasts to be accessed in real-time at locations where direct comparisons can be made with observed river water levels. This helps day-to-day forecasting for key locations, as well as supporting quality control for flood forecasting science. The direct comparison between observed water levels and GloFAS forecasts not only gives confidence to the Uganda Red Cross and Ministry for Water and Environment for using the forecasts, but also highlights the areas of improvement needed to the GloFAS developers. The improvement in coverage of GloFAS and support to the forecasting system in general have enabled the Uganda Red Cross to scale up the concept of Forecast-based Financing in Uganda, and has spurred the use of flood forecasts in other countries in Sub-Saharan Africa, including Kenya, Ethiopia and Zambia. .

Mozambique

Emergency flood information during Cyclones Idai and Kenneth support humanitarian agencies

CYCLONE IDAI, MOZAMBIQUE, RESPONSE, 18-20 MARCH 2019, PHOTO: DENIS ONYODI/ IFRC-DRK-CLIMATE CENTRE

CONTEXT

In March and April 2019, two intense tropical cyclones (Idai and Kenneth) made landfall in Mozambique. While many think of destructive winds during tropical cyclones, intense rainfall causing inland flooding and coastal flooding because of high waves and storm surges are often much more dangerous. Rainfall consequences can last much longer, are more widespread, and often hamper the humanitarian response in the critical weeks and months after the disaster. Humanitarian and civil protection agencies, therefore, need to have access to high-quality and actionable forecast information on rainfall and potential flood risks. However, many challenges remain for international organizations to use forecasts systematically to respond ahead of disasters.

ACTION

The **FATHUM, HYFLOOD** and **PICSEA** project teams collaborated to provide real-time emergency flood bulletins to humanitarian agencies responding to Cyclones Idai and Kenneth in 2019, produced alongside forecast information and warnings from the national meteorological and hydrological forecasting services. Starting with Cyclone Idai, the team was prepared when a month later Cyclone Kenneth was predicted to hit Mozambique. The bulletins provided probabilistic information on the predicted tropical cyclone tracks and the amount and spatial extent of rainfall, alongside flood forecast information using the Global Flood Awareness System (GloFAS) model. The bulletins covered the weather forecast, flood forecast and outlined potential flood impacts. These were shared with the United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA), the Mozambican authorities and the Red Cross partners. Later researchers from PICSEA, FATHUM and HYFLOOD traveled to Mozambique and met together with representatives from the national, regional and local met- and hydro-services, the national disaster institute, Mozambique Red Cross, and academics from the technical university of Mozambique to exchange experiences and ways forward for forecasting and taking action ahead of cyclones, forging new collaborations and strengthening existing collaborations.

IMPACT

These bulletins were used to inform decision-making and early action in Mozambique before, during, and after Cyclone Idai and Kenneth, improving response by providing key information about the areas which would be most affected. Evaluations indicate that this was the first time that flood risk information had been provided in real-time to the humanitarian agencies involved. Because of the combination of weather, flood and impact-based forecasts in one bulletin, the type of information was considered extremely valuable, innovative and promising. As the bulletins were developed in real-time with feedback from the humanitarian agencies, information could be used on the same day for response planning. The information from the bulletins was used for the daily situation reports by UN OCHA (a key reference point during disaster response) and through this medium reached a wide range of decision-makers. Based on the bulletins, live-saving interventions could be set up targeting the region most likely to be affected, through sending an assessment team and preparing hygiene kits, tarpaulins, and water treatment kits ahead of cyclone landfall. Building on the experiences during cyclones Idai and Kenneth, PICSEA developed a free online training course about tropical cyclones in the southwest Indian Ocean. Collaboration is ongoing, and the team now produces bulletins for FCDO and humanitarian partners on a regular basis (e.g. for Tropical Depression Ana in January 2022, and for Tropical Cyclone Batsirai in February 2022).

"This is the first time we have been able to use science so early in both planning for and responding to the devastating impact of cyclones."

[PROFESSOR CHARLOTTE WATTS, CHIEF SCIENTIFIC ADVISOR FOR DFID]

Additional information:

Emerton et al., 2020, Emergency flood bulletins for Cyclones Idai and Kenneth: a critical evaluation of the use of global flood forecasts for international humanitarian preparedness 810 and response, International Journal of Disaster Risk Reduction.

Budimir et al., 2021 (in review), Development of forecast information for institutional decision-makers: landslides in India and cyclones in Mozambique, Geoscience Communication.

Online free course on tropical cyclones in the southwest Indian Ocean: www.the-iea.org/picsea

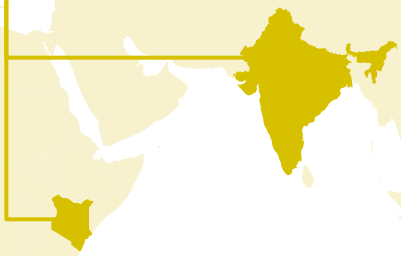
India and Kenya

KATAKWI LIVELIHOODS 2019, PHOTO: LUISA CIAMPI/ KATAKWI LIVELIHOODS.

Protecting farmers' livelihoods through improved monitoring and insurance products in India and Kenya

CONTEXT

Livelihoods of millions of smallholder farmers across the developing world are under threat from extreme weather events, such as droughts, floods, and heatwaves, with risks projected to increase significantly in future years due to climate change. Crop insurance protects farmers against financial risks posed by extreme weather events and has been widely advocated as a tool to help farmer households escape poverty traps and invest in climate-smart high-productivity agriculture. Yet, to date, the success and uptake of crop insurance schemes across the developing world have been extremely limited. The Mitigating Basis Risk project worked to improve the current poor performance of index-based crop insurance by using state-of-the-art environmental modelling and big datasets to reduce basis risk and better protect farmers against weather risks.



ACTION

The project has developed a new approach for scalable and low-cost crop yield estimation - combining crop models, smartphones, and satellite imagery in an innovative way. Following proof of concept work focused on wheat in India's northwest breadbasket, subsequent work with the Mahalanobis National Crop Forecasting Centre (MNCFC) of India focussed on improving the performance and cost-effectiveness of the Indian national crop insurance program for rice. The project integrated smartphone-based monitoring with crop simulation models to provide an accurate yield loss assessment, which captures both abiotic (e.g. heat and water stress) and mechanical (crop damage caused by hail/ wind, animal trampling, etc.) determinants of crop losses in smallholder agricultural systems. These innovative approaches are being further used and applied in picture-based insurance products across Africa and Asia, helping to mitigate financial risks faced by farmers and unlock investments in other climate-smart technologies in combination with agricultural advisories and credit support.

Additional information:

https://gtr.ukri.org/projects?ref=NE%2FR014094%2F1

https://www.ifpri.org/project/PBInsurance

IMPACT

This framework provides the basis for an improved data-driven approach to crop insurance design and provision for smallholder farmers. The research has shown that this method can provide reliable information about the timing of key crop growth phases and outperforms traditional crop monitoring through either satellite remote sensing or national crop surveys, demonstrating the potential of using smartphone images for simplified and more effective crop monitoring. In India, the tools by Mitigating Basis Risk are supporting efforts by the government to develop new data-driven approaches to transform a national crop monitoring system that currently serves over 30 million farmers. The learnings from this project support ongoing efforts to improve insurance products for smallholder farmers. Beyond loss prediction, the approach is now also applied to improve the design of insurance projects, including helping insurers in India, Ethiopia, and Kenya to more competitively priced products to incentivise the adoption of improved farm management practices and support improved access to credit amongst marginalised farmer groups.

India

Participatory research enables scaled-up landslide forecasting in India

A GROUP OF LANDSLIP INTERDISCIPLINARY RESEARCHERS WORKING WITH THE GOVERNMENT (GSI) IN KOLKATA IN NOVEMBER 2019 TO CO-DEVELOP THE STRUCTURE FOR THE FORECAST BULLETIN. PHOTO: LANDSLIP.

CONTEXT

About 12.6% of India is prone to landslides, causing significant loss and damage to lives, livelihoods, infrastructure, and property every year[1]. Landslides are primarily –triggered by rainfall and/or earthquakes. Certain land management practices (e..g. Deforestation, mining etc) can increase the likelihood of landslides and increased exposure as a result of development can increase their impact. The combination of environmental and human-induced factors in the triggering of landslides, and highly localised conditions mean that regional-scale forecasting systems mean that the forecasting of landslides is complex to forecast. Capturing data about landslide occurrence is key to understanding landslide triggers, developing landslide models, and determining thresholds to support early warning. However, acquiring consistent quantity and quality data in difficult terrain over large geographical areas can be challenging.

ACTION

The LANDSLIP project is contributing to understanding and improving landslide assessment and forecasting at a regional scale in India. It aims to help build resilience with early warning and preparedness actions that can reduce the losses for communities. The LANDSLIP project developed a prototype regional landslide early forecasting system for rainfall-induced landslides in two pilot locations in India (Nilgiris and Darjeeling), as a close collaboration between research partners, local organisations, and the Geological Survey of India (GSI). During the monsoon seasons of 2020 and 2021, GSI, supported by LANDSLIP partners, ran the forecast models developed within the project and issued experimental daily landslide forecast bulletins to the District Authorities in their study areas.

Key to the development of these prototypes is consistent local landslide data collection. Working with local partners (Save The Hills, Darjeeling, and Keystone Foundation, Nilgiris), partners from the LANDSLIP consortium co-developed a landslide tracker approach. Amrita University developed a landslide tracker mobile app (available in Google Store), with content further developed by the entire LANDSLIP team. This supports the systematic and standardised collection of landslide occurrence information. Building on this landslide occurrence information, together with the UK Met Office and NCMRWF[2] the project advanced understanding of local weather regimes and landslide susceptibility to identify suitable local landslide warning triggers (for short-range and medium-range forecasting). These innovative, collaborative approaches have enabled the establishment of a prototype, government-led, regional landslide early warning system.

1 Geological Survey of India (GSI). Landslide Hazard. Accessed March 2022.

2 The National Centre for Medium Range Weather Forecasting

IMPACT

In addition to the newly developed prototype of a regional landslide early warning system, LANDSLIP has enabled an increased dialogue between academics, national government/ Global Survey of India (GSI), local NGOs, and District Authorities within its two case study areas. Different actors are now more aware of the importance of engagement to share perspectives and co-produce tools that are meaningful and useful. GSI has also engaged with District Authorities to ensure the daily experimental landslide forecasts issued are appropriately understood, thus supporting District Authorities in determining preparedness plans. The advancements and knowledge gained in regional-scale landslide forecasting and early warning during the LANDSLIP project will be taken forward beyond the project lifetime by GSI through the establishment of a landslide forecasting centre, which is aiming to develop similar landslide early warning systems in other parts of India by 2030, providing crucial information to authorities to initiate preparedness activities.

"LANDSLIP has proven to be a shining example for the donor community, especially the bilateral and multilateral funding organisations in terms of not only the outcomes, but also the meticulously designed, iteratively implemented processes, legacy documents etc. that assure lasting success and sustainability. The knowledge and experiences generated by the LANDSLIP project at all levels have been commendable and noteworthy."

[WG CDR (RETD) PRAFUL RAO, SAVE THE HILLS]

Additional information:

LANDSLIP (2021) Home web page [Online] Available at: http://www.landslip.org/

LANDSLIP Global Knowledge Products. Available at: http://landslip.org/outputs/globalknowledgeproducts.html

SHEAR. 2019. LANDSLide multi-hazard risk assessment, Preparedness and early warning in South Asia: integrating meteorology, landscape and society, LANDSLIP Factsheet. Accessible from: https://practicalaction.org/wp-content/uploads/2019/07/LANDSLIP-fact-sheet.pdf

Amrita Vishwa Vidyapeetham University (2021a) Landslide Tracker Mobile Application. Google Play Store. Available at: https://play.google.com/store/apps/details?id=edu.awna.amrita.mht

Kenya

DROUGHT IN KENYA'S EWASO NGIRO RIVER BASIN (APRIL 2017)
PHOTO: DENIS ONYODI/KRCS

CONTEXT

Africa's smallholder farmers are the main producers of food on the continent, but also represent the largest portion of Africa's population living in extreme poverty. Poverty makes farmers particularly vulnerable to the types of extreme weather expected to increase due to climate change; most cannot afford expensive mitigation strategies, such as irrigation and re-planting, that would otherwise allow them to adapt to weather variability. Indeed, of the estimated 33 million smallholder farms across Africa (employing approximately 175 million people), only 4% are irrigated. Farmers therefore struggle to optimize crop yields, underpinning Africa's severe staple crop yield gap and widespread food insecurity.

Analysis of historical data suggests that suboptimal decisions on when to plant can reduce yields by 7-10%. Optimizing planting dates therefore provides a clear pathway towards improving yields and reducing food insecurity, but such information has not historically been available to smallholder farmers for two reasons: Firstly, the provision of local, scientifically credible guidance has been limited by immature technologies for producing information at sufficiently high-resolution. Secondly, there is a significant communications challenge in packaging information so that it is understandable and actionable to a large number of farmers in a timely manner, particularly those with limited literacy and education.

Evidence-based decision support for smallholder farmers in Africa through SatWIN-ALERT

ACTION

Currently, local agricultural management advice is predominantly provided to smallholder farmers via over-stretched in-person agricultural extension services. Lower resolution information (e.g. at county or sub-national level) may also be available from meteorological services, often distributed through bulletins. For example, ICPAC produces maps of seasonal onset for East Africa. Practically however, many farmers, particularly those with limited literacy, are unable to translate bulletins into meaningful advice on planting.

SatWIN-ALERT developed a decision support tool (DST) for planting, based on the TAMSAT-ALERT soil moisture and seasonal drought forecasting system. For two years, advisories based on the DST have been shared with >500,000 farmers in southern and eastern Africa, in partnership with One Acre Fund (OAF).

IMPACT

Comparison of planting date, optimal planting date and yield suggests that farmers in southern and eastern Africa plant later than the optimal time, with significant detrimental impact on yield. Evaluation of the DST recommended planting dates showed a potential improvement in yield of 7-10% for farmers who plant near the DST recommended date.

More important than the desk analysis, however, are evaluations by the farmers receiving the advice. The majority of farmers in Kenya (95%), Zambia (78%) and Uganda (72%) said that they trusted the guidance. In Zambia, 81% of farmers said that they felt confident to plant after receiving the guidance. In Uganda, most of the farmers said that they planted earlier than usual. Based on income improvements and adoption rates in the pilot study, OAF estimates that when the DST is provided to all their Kenyan farmers next season, it will result in an additional $3.8M in income.

Additional information:
https://satwin.iri.columbia.edu/
http://www.tamsat.org.uk/
https://rmets.onlinelibrary.wiley.com/doi/10.1002/met.1959

Uganda

UGANDA WAS HIT BY SEVERE FLOODING IN 2007. MANY PEOPLE LOST THEIR CROPS, THEIR LIVELIHOODS AND WERE LEFT WITH NOTHING.
PHOTO: JAKOB DALL/DANISH RED CROSS

Bringing together experts at every level to enhance evidence-based action for floods through the *National–Scale Impact–Based Forecasting Flood Risk project* in Uganda

CONTEXT

While forecasting science for flooding is rapidly improving, warning messages often fail to motivate actions. The National–Scale Impact–Based Forecasting Flood Risk in Uganda project – known as NIMFRU – is a partnership project that is engaging with researchers, policymakers, local councils and local farmers to improve the targeting, relevance and communications of flood warning and response in Uganda, focussing on Katakwi district. Katakwi District in Northern Uganda is chronically affected by flooding, both by seasonal events and major flooding, as well as flash flooding.

Building on the FATHUM project's results in Uganda, the NIMFRU project worked on ensuring timely access to relevant information for communities at risk of flooding, with the improvement of impact-based forecasting science and through engagement with communities around their understanding of the scientific information.

ACTION

The project partners of NIMFRU engaged directly with communities to better understand the impacts of flooding on local livelihoods, thereby co-producing new insights for impact-based forecasting. Activities included Farmer Agri-met Village Advisory Clinics (FAMVACS) - local events where communities meet with staff from the Uganda National Meteorological Authority (UNMA) and local Agricultural Extension services. In these meetings, participants share traditional systems for anticipating weather events and explore how new science may support farmers. These meetings involved critical discussions on why weather warnings received through national media were not always accurate or useful to farmers and led to genuine co-production of potential solutions.

The Farmers Voice Radio programmes took these interactions further, as people could phone in and talk to weather- and agriculture experts live. The key to the success of the radio programmes was to schedule this at times when women generally would be free, as the initial results from the FAMVACS showed women have difficulty accessing information and support services in the district.

Additional information:

NIMFRU Project | Walker Institute

FAMVAC and Listening Group Facilitation Handbook

A step by step guide to using RAINWATCH, version 1.0 | Zenodo

NIMFRU News: Improving Flood Resilience in Uganda | Walker Institute

NIMFRU News: Katakwi Interviews begin | Walker Institute

Learning to Co-Produce | Walker Academy

Assessing Livelihood Vulnerability to Extreme Shocks (ALiVE) Foundation | Walker Academy

NIMFRU Partners project website

UKRI National-scale Impact-based Forecasting of flood risk in Uganda (NIMFRU)

Minimising flood impacts in Uganda: NIMFRU project update | Evidence for Developmen

IMPACT

The engagement through the FAMVACS and the Farmers Voice Radio programmes (20 individual episodes) reached 67,000 people across the rural areas of Katakwi District (42% of the population). The initiatives were greatly appreciated by communities, as they felt listened to by experts. At the same time, the interactions supported tangible local changes: the district now owns several tractors to speed up the rehabilitation of lands after flooding, and farmers have a better understanding of practical action to take when weather forecasts signal a risk of flooding. The overall finding was that it would be valuable to extend the radio programme to other local radio stations in local languages. For the UNMA experts participating, the initiatives helped them understand how to engage in co-production, and communicate impact-focussed warning messages. The project has led to the production of a handbook on the principles and implementation for FAMVAC-type exchange groups.

The results from the FAMVACS and radio programmes were presented to the Parliamentary Committee on Climate Change and Environment. The positive experience resonates through the work of local partner CAN-U, in their engagement with the Uganda Climate Change Act, advocating for more district-level vulnerability and capacity assessments as they seek to scale out the consultation approaches, such as the FAMVACS. The Climate Change Act now also explicitly recognizes gender and technology as vital areas for assessment, which were key learnings from NIMFRU. The outcomes from the FAMVACS and radio programmes also confirmed the importance of ongoing work to better link flood forecasts to livelihood impacts, to improve communication and ultimately support preparedness and recovery.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