WEATHERING THE STORMS

FOSTERING OUR UNDERSTANDING OF CLIMATE-RELATED RISKS AND OUR CAPACITY TO RESPOND

A compendium of essays for the
Allianz Climate Risk Research Award 2018

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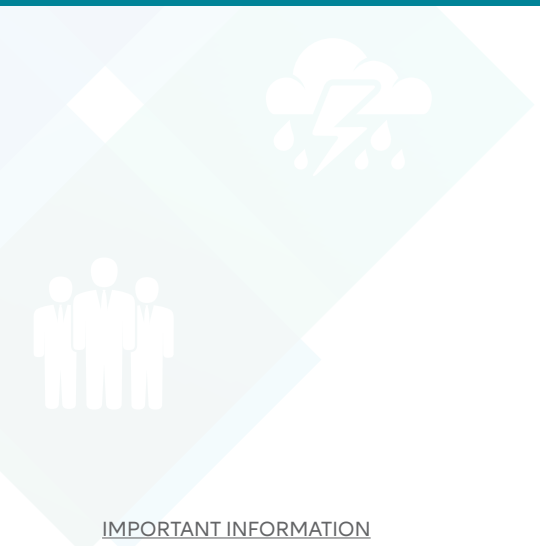
ABOUT THE COMPENDIUM

The Allianz Climate Risk Research Award supports scientific research that improves our understanding of climate change-related risks. The 2018 edition is intended to support researchers whose work focuses on:

- Reducing the risk of extreme weather events that are intensified by climate change
- Fostering resilience by applying technological solutions

The compendium is a compilation of selected essays from participants of the 2017 and 2018 editions. This compendium is published exclusively for didactic purposes.



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INTRODUCTION
UNDERSTANDING RISK CREATES VALUE

AMER AHMED
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By now it's largely undisputed that Climate Change is a major existential threat to the world as we know it, to the health of this planet we live on, and consequently to people's health and wellbeing, to the future of mankind. Although it takes a comprehensive, coordinated, global approach to slow down the course of climate change, we know that some of its effects have already irreversibly emerged. However, we can minimize these destructive impacts, if enough efforts are made on proper risk management, as it is provided, for example, by the insurance and reinsurance industry.

Insurance protects people and countries against the financial impacts from natural disasters, which we expect to increase in frequency and severity through Climate Change. The G20 InsuResilience Global Partnership recognized this specific role of the insurance industry by explicitly establishing insurance as a solution. The ambitious target agreed at the G7 summit in 2015 is to insure an additional 400 million people in vulnerable and developing countries by 2020. Allianz actively supports the partnership by developing innovative insurance approaches to climate-related risks in several countries.

However, this is not as straightforward as it sounds. "Understanding Risk – Protecting and Creating Value" has been Allianz Re's mission statement for years and it gains an extended meaning in the context of Climate Change. To provide insurance on a broad range in highly risk prone ("vulnerable") and largely unexplored ("developing") areas requires new approaches to understand these complex risk landscapes and how they will likely develop. Take for example today's ever growing megacities, probably the fastest changing risk landscapes in the world, especially in Asia. In 2070, Asian cities will dominate the top 10 cities ranked by asset exposure to coastal flooding. In 2008, the top 10 cities were all in the US, the Netherlands and Japan.

For years, insurers have assessed future risks based on what happened in the past. Now, with climate and societal changes, the past can no more be relied on to predict the future. We need new ways to understand what happens to protect ourselves adequately. It's this vital need that brought the Allianz Climate Risk Research Award into being. In this compendium, you'll read exciting examples of innovative and dedicated research that can help us as an insurer to better quantify, price, underwrite and manage Climate Change risks and better protect the world against Climate Change impacts.

FOREWORD
RESEARCH IMPROVES OUR UNDERSTANDING OF EXTREME WEATHER EVENTS

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Climate change is a key challenge for our society. The Intergovernmental Panel on Climate Change (IPCC) has highlighted some of the expected risks of climate change, occurring on various spatiotemporal scales. Besides the rather long-term aspects of melting arctic environments, rising sea levels or changing habitats, there is an abundance of extreme events, such as inland and coastal flooding, landslides, storms, thunderstorms heat waves and droughts, extreme precipitation, hail, wildfire and storm surges. Changes in the characteristics, frequency and severity of extreme events are typically responsible for the most important impacts and consequently are amongst the most significant aspects of climate change to understand and predict. Current research must examine:

a. how high impact events work,

b. how they can be described and understood by taking advantage of modern environmental monitoring systems including remote sensing,

c. how they can be simulated accurately in numerical models and

d. how we might be able to project future global and regional changes, including composition-climate interactions, feedback and societal impacts from local to regional scales.

The societal and environmental impacts of extreme weather depend on how the weather conditions interact with other components of the natural and built environment and human systems. These interactions can be highly spatially and temporally variable, are inherently complex leading to catastrophic consequences. Thus, to understand extreme weather and mitigate its impacts, it is important to understand societal vulnerability and how it interacts with weather and climate conditions to create risk or harm. Given the diversity of local responses to the impacts of climate change on extreme weather and climate events, the appropriate context for adopting this approach is one of collaboration between scientists and practitioners; i.e. research in this domain must support farmers, first responders, critical infrastructures, essential service providers, municipalities, governments and insurance companies. Transdisciplinary research in this context must better blend with information regarding exposure and vulnerabilities to improve scientific projections and predictions of change and consequently robust and reliable information.

Ultimately, climate risk research must be targeted toward an improved capacity to provide adequate emergency responses to extreme weather and climate events, leading to shorter reaction times and higher efficiencies to minimize casualties and mitigate adverse impact.

Driven by these emerging research necessities, the Allianz Climate Risk Research Award encourages the thinking outside of the disciplinary mainstream. It challenges early career scientists to present ground-breaking and innovative research projects to a transdisciplinary audience.

This compendium presents selected essays of these highly prospective young researchers. The presented topics cover a broad range of fresh and thoughtful research concepts and applications from around the world, and shed light on the latest technological developments in the respective research domains; they highlight the recent advances of climate risk research from natural sciences, social sciences and engineering perspectives and clearly demonstrate the advantages of integrated research when dealing with the manifold risks of extreme events under conditions of climate change.

I would like to thank all authors for their substantial contribution to this emerging research domain and wish the audience joy with this exciting and inspiring reading.

STAYING AHEAD OF THE WATERS

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BIOGRAPHY

Winner of the 2017 Edition of the Allianz Climate Risk Research Award, Viktor is a Ph.D. candidate at the Institute of Earth and Environmental Science at the University of Potsdam, Germany. His research tries to understand and model the processes that lead to damage of residential homes caused by rain-related floods. The goal of his work is to help cities around the globe to better cope with an increasing risk of extreme rainfall events, by providing the background for improved early warning systems and mitigation strategies.

THESIS TITLE

Real-time impact-based pluvial flood warning in cities

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Combining machine learning and probabilistic models could finally deliver an early warning system for floods caused by heavy rain.

Floods unleashed by storms severely damage cities, destroy buildings and infrastructure and claim lives. The devastation caused by pluvial flooding, so known because it is caused by rainfall and not by rivers or other bodies of water, was starkly evident in Houston, Texas, when Hurricane Harvey struck in 2017.

Similarly, in Copenhagen in July 2011, a cloud burst inundated the city with six inches of rain in less than three hours, flooding cellars, streets and key roads. The damage was estimated at $1.04 billion. A flash flood in Beijing in July 2012, caused by a 24-hour downpour, saw 57,000 people evacuated, 82,000 homes destroyed and claimed 79 lives. The cleanup price tag was estimated at $1.6 billion.

Such damage is likely to become more common and costlier due to two converging factors. First, rainstorms are expected to increase in frequency and intensity due to a changing climate. Second, the trend to global urbanization is continuing strongly, which concentrates people and assets in cities and increases the risk of large-scale devastation when floods hit.

OVERLOOKED DISASTERS

Unlike river or tidal flooding, pluvial flood risk is often excluded or neglected in risk management and mitigation strategies. This is because pluvial flooding often only affects a few streets or a neighborhood in a city. Pluvial flooding requires risk assessments and early warning systems that are reliably able to cover such small-scale variations.

Standard risk assessment and management practices used for other flood types are difficult to adapt to pluvial floods for two reasons:

1. Large-scale hydraulic simulations used to estimate the flood areas given a certain stream flow in a river are computationally expensive when used on large areas with high spatial resolutions. This means that the computation time needed would exceed the lead time of a warning being issued to areas that could potentially flood.
2. The expected impact in terms of direct economic losses to buildings are usually estimated using a simple relationship between the expected inundation depth of a building and expected losses. Although this gives sufficient estimates when losses are spatially aggregated over large areas and variations in the estimates are "averaged out," the complex interactions on the level of streets or individual buildings during a pluvial flood lead to highly uncertain estimates.

PROPERTY LOSS ESTIMATOR

The approach presented during the 2017 Allianz Climate Risk Research award tackles these issues by combining a data-driven machine learning approach with probabilistic network models into an impact-based early warning system for pluvial floods. The idea is based on the assumption that although additional information on expected flooding (for example, if the water is expected to be contaminated with oil or sewage) can help to better estimate the expected impact, such information might not be immediately available and often is not immediately relevant when a rainstorm is approaching.

However, the use of a probabilistic network compensates for this lack of information by considering it in the shape of a higher uncertainty range in the prediction. This allows for a real-time estimate of the flooded areas and expected losses as soon as the forecast of a rainstorm comes in.

Although these estimates can be highly uncertain, it gives emergency responders and decisionmakers a better understanding about possible scenarios. As the rainstorm approaches, the uncertainty reduces as new information becomes available (such as inundation depth from a hydraulic model or social media information on contaminated flood water) turning the early-warning system into a near-real-time property loss estimator.

With this approach, decisionmakers can release an early public warning (when the uncertainty of the estimates falls below a certain threshold so as to reduce false alarms) and prioritize emergency responses based on areas where losses are expected to be high. In order to decide which additional information is needed to reduce uncertainty, machine learning scans loss information of past pluvial flood events to identify predictors that influence the level of loss of buildings. These newly identified predictors can then be used to extend the existing probabilistic network model.

While this is highly flexible and computationally efficient compared to existing approaches, the predictive performance of the model in an early warning system is highly dependent on available data. However, the ever-growing amount of actively and passively collected data from digital devices and the emerging field of smart cities and smart homes opens up many opportunities for data-driven early warning systems and loss models in the future.

CALCULATING AMBIGUITY

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BIOGRAPHY

Since 2015, Corinna has been pursuing her Ph.D. at the Department of Statistics and Operations Research, University of Vienna. With a background in mathematics, her research examines methods that consider ambiguity in assessing risk and in selecting probability model in the context of natural disasters. She is also involved in a project at the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria, which aims at finding new mitigation insurance scheme for drought in parts of Austria, especially under climate change.

THESIS TITLE

Insurance contracts under ambiguity. Application in extreme climatic events

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Climate change and rare events are introducing new sources of ambiguity that complicate the assessment of risk for insurance companies.

The success of insurance companies relies on the ability to precisely quantify risk, that is the probability (chance) of occurrence and the magnitude of any associated losses. During the early development of insurance theory, the most common technique to quantify risk was to assume that losses follow a known distribution and the premium charged could be calculated using various standard principles.

However, full knowledge of the loss distribution cannot be assumed when it comes to rare events. As a consequence, there is increasing interest in techniques that deal with ambiguity either in the occurrence probability of a specific event and/or in the size of losses.

Ambiguity is crucial in situations where high losses could occur with low probability. Climate change and other global dynamics like population growth and environmental damage are adding extra risks to the insurance industry. Moreover, especially for rare events, the lack of data and the difficulty in forecasting increase the model ambiguity.

Therefore, an optimal strategy to reduce the risk associated with losses caused by rare events should not only compensate for uncertainty in the risk, but at the same time for the ambiguity in the selected model. It is the aim of this project to examine methods that consider the ambiguity in assessing risk and in selecting the probability model in the context of natural disasters.

The decision problem investigated is to find an optimal division of the available budget into insurance and risk reduction. More precisely, a layer approach is proposed to decrease the risk where small losses are covered by pre-existing capital or subsidies and large losses, caused by extreme events, are insured. To ensure the robustness of the approach, the optimal decision is determined by considering possible model misspecification of the loss distribution.

REDUCING EXTREME WEATHER RISKS

The goal of the project is to reduce the risk associated with extreme weather events whose consequences are intensified by climate change. On one hand, small losses suffered by households are covered by an allocated budget or governmental subsidies. For example, the ongoing project with the International Institute for Applied Systems Analysis (IIASA) on risk reduction in the agriculture sector shows that government subsidies for farmers are efficient techniques to lower risk, while influencing the incentive to purchase insurance for higher damage protection.

On the other hand, insurance contracts can be seen as tools for risk reduction that are more effective in catastrophic losses. The design of this type of contract is not well established in the literature due to challenges imposed by insured events. Moreover, the sources of ambiguity mentioned earlier directly affect the insurance market and should be viewed as significant variables in understanding the decision-making process.

The reason to consider alternative models in the decision process can be demonstrated by the use of catastrophe modelling. Due to the challenges caused by climate change, it is difficult to choose a single perfect match. It is more reasonable then to consider a set of alternative models, known as an ambiguity set.

With statistical modelling and based on their internal methods, insurance companies can construct a baseline model that can be approximate as close as possible the actual loss model. As discussed, the ambiguity in model selection cannot be ignored. This means defining a neighborhood around the baseline model.

The radius of the neighborhood reflects the risk averse or risk seeking attitude of the insured person. If the insured person exhibits risk aversion, then he/she would not buy an insurance contract computed only as a function of the baseline model, instead such a person would rather enlarge the ambiguity radius and consider more models to protect against worst-case scenarios. However, in a risk-seeking case, the insured person would trust the baseline model and ignore alternative scenarios.

CONTRACT ROBUSTNESS

The research proposes an optimization problem for finding the balance between the parameters of a limited stop-loss contract that minimizes the risk associated with the losses over a specific period. To include contract robustness of the decision against possible model misspecification, the optimal decision is taken with respect to all models in the neighborhood of the baseline model.

It is concluded that, in the risk-averse setting, an insured person is more likely to cover small losses using a risk reduction procedure in exchange for protection against high loses offered by the insurance company.

CLIMATE HUMANS IN THE AGE OF CLIMATE CHANGE

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BIOGRAPHY

Erwin was a finalist of the 2017 Allianz Climate Risk Research Award. He is a human geographer focusing on climate change and urban studies. He has nine years of experience in urban and climate change research, project management and policy advocacy. His current research focuses on the politics and governance of climate change adaptation, urban climate change resilience, disaster risk reduction, urban political ecology and governmentalization of risk and resilience.

THESIS TITLE

Becoming climate human in the age of climate change

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In the oncoming era of climate change, resilience has become an undisputable and seamlessly applicable formula governing cities and their citizens.

Three years ago, the world pledged to keep global warming "well below" 2°C hotter than pre-industrial times. The extreme weather events that have since occurred must give rise to fears that we are losing the battle.

In the last few months, extreme weather has been seen in heatwaves in Europe, rising temperature in Africa and extreme flooding in Japan and the United States. In this age of climate change, we must anticipate and mitigate all imminent impacts and future risks of extreme weather.

More consequently, the idea of being "climate humans" requires urban citizens to respond to and take action to mitigate, anticipate and prepare for climate change. My research analyzed how "resilience" has become a new discourse shaping the idea of being climate humans in urban Asia.

In this regard, the Rockefeller Foundation several years ago undertook a project in South and Southeast Asia to experiment with Urban Climate Change Resilience (UCCR) when they funded the Asian Cities Climate Change Resilience Network (ACCCRN), a multi-year and multi-countries program. Initially implemented in 10 cities in four countries, ACCCRN aimed to increase urban resilience to climate change impacts.

Although ACCCRN formally closed in 2016, the program has expanded to 40 cities and added two additional countries: Bangladesh and the Philippines. The Rockefeller Foundation describes ACCCRN as attempting "to catalyze attention, additional funding and action on building climate

change resilience of cities as a whole – and within that ensuring that the resilience of vulnerable and poor communities is enhanced also."

My research focused on Bandar Lampung and Semarang, known as early adaptor cities in Indonesia. The ACCCRN demonstrated an ability to drive UCCR initiatives that engaged with actors at the city level and in local communities and operated within multi-level governance across city, national and international levels. Beyond that, ACCCRN is a unique example of how resilience inspires urban citizens to prepare and anticipate climate change impacts.

EXISTENTIAL THREAT

Climate human is a dialogue concerning human survival to existential threats from Mother Nature. It provides an opportunity for us to act, as individuals and as a collective society, to ensure our future. In effect, this culture of resilience is a circular interplay between the Human and Nature, whereby Nature is continually being shaped and our Humanity will take shape.

In the Indonesian ACCCRN cities, several formations of climate humans were evident. The first image is of human survival, a notion that is becoming more nuanced in the face of climate change. Humanity's capacity to plan, manage and act accordingly to climate change risks will depend on the adaptive capacity within human systems.

Climate human from this perspective are deemed to be "free" from the dangers of climate change when they can accommodate their ability to open learning, undertake mitigation measures and consistently build their capability to prepare for climate change. The outcomes mean local communities will be "less shadowed by threat," as Judith Rodin, the former President of the Rockefeller Foundation, described in her 2015 book, The Resilience Dividend. The different imaginaries of becoming climate human is expressed by research respondents as becoming educated, independent, self-aware and self-adaptable communities.

The second image of climate human is of "responsibilization." Some researchers discussed responsibility as "no longer understood only as a relationship with the state, but as an obligation toward those for whom the individual cares most: his or her family, neighborhood, workplace and, ultimately, community."

Others argue that resilience offers a new ethics of responsibility. The new paradigm of resilience in Indonesia exemplifies a collective action where people must collaborate with others, breakdown the siloes of institutions, reinforce and enable other elements of resilience, and leverage existing resourcefulness.

During its implementation, ACCCRN provided pathways for the formation and reproduction of new identities of the climate humans. Different identities have now evolved including local cadres and women emerging as climate leaders.

CLIMATE CHANGE, CULTURAL CHANGE

It has been argued, "that climate has always been in change," and we as a "society must always react to it." The more nuanced point is that, "If climate has always changed, how we react to it is a cultural question." If this is valid, then we need to question ourselves as to what type of society and what kind of individuals or communities we want to become? More critically, the question is also what kind of urban citizens should we be and how should we be shaped by the government of knowledge?

In a world of climate change, resilience as a new discourse has brought in new relations between nature and culture. What is exemplified in Indonesian ACCCRN cities is that building urban climate change resilience has created multiple formations of climate humans as survival and responsible subjects in the face of climate change.

THE DRY FACTS

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BIOGRAPHY

Hossein is a postdoctoral researcher in the Department of Civil Engineering at Catholic University of Leuven in Belgium. For his Ph.D. thesis, he worked on climate change and variability impact analysis on hydro-climatic extremes and water availability in Europe and the Middle East for which he received the 2016 Ernest du Bois Prize from the King Baudouin Foundation for the best Ph.D. thesis in Belgium on the theme of water, resources and management

THESIS TITLE

Climate variability and change in Europe and Middle East

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A fine-scale assessment of seasonal climate in the Middle East reveals that the effects of climate change have been drastically underestimated.

As climate change takes effect, the Middle East is expected to become even more hostile to human life. While societies there have successfully adapted to water scarcity and heat for thousands of years, the dramatic effects expected as part of climate change could render parts of the arid region all but uninhabitable.

Already one of the driest places on the planet, the Middle East will experience longer droughts and more intense rainfalls leading to flooding. With the region highly dependent on climate-sensitive agriculture, particularly rain-fed cereals, these changes will harm crop yield and degrade food security. If such conditions adopt a prolonged pattern, it will increase the already high level of water stress and force people to migrate or live in conditions of water poverty. This will also increase the risk of political conflict over transboundary water resources.

A SEASONAL FINER-SCALED ANALYSIS

My analysis on future hydro-climatic hazards investigates the impact of climate change on extreme and mean precipitation in the Middle East from a seasonal point of view. The results show drought periods will be longer (up to 90%) in about 80% of the area and spring rains will decrease in 58% of the lands. This identifies the region as a climate change hot spot where extreme precipitation is expected to increase in all seasons toward the end of this century.

Significantly, the results of this fine-scale model compared to coarse-scale climate models show a large seasonal discrepancy, particularly for summer when model spatial revolution plays a more important role for precipitation simulations. In addition, the heavier the precipitation, the larger the discrepancy between fine- and coarse-scale results. This underscores the need of using fine-scale models as otherwise the risks of future extreme precipitation and flood hazards may be underestimated.

What emerges from this study is that the Middle East will have a "highest increase in autumn, lowest increase in spring" pattern of precipitation. This finding contradicts the simple "dry gets drier, wet gets wetter" paradigm often touted in relation to climate change. The differing results stem from the type of data/model used and the transition of humid regions toward drier conditions or vice versa under future climate conditions.

GRIM OUTLOOK

The results of this study show that climate change signals over the Middle East vary remarkably with seasons, which highlights a flaw in analyses that combine the climate change impacts of all seasons. The issue is that such an approach may lead to a compensation of increasing and decreasing signals in the individual seasons and understate the expected changes and related damages to society in terms of human health and mortality and to the ecosystem.

The headline news is that the rainy season in the Middle East is shifting as a consequence of climate change, which will exacerbate existing water management issues (such as water stress and dry zone expansion). The rains will also come too late and out of the growing season of crops. Later, unexpected and more intense rainfalls at harvest will also harm yield and further degrade food security.

FUTURE RESEARCH

The projected changes represent an unprecedented challenge for the Middle East, so the growing risk of hydro-climatic hazards needs to be precisely analyzed. As these result from a combination of interacting physical processes occurring across multiple spatial and temporal scales, a multi-hazard risk assessment is required.

However, conventional risk assessments focus on single extremes in a given geographic area during a specific time period. This ignores the complex interaction between multiple hazards and results in an underestimation of the risks associated with extreme conditions.

For a more realistic estimate of the consequences, the risks of different hydro-climate extremes must be analyzed in a compound manner. Such an analysis can then provide a basis for better decision-making to curb the growing impacts of the extremes.

Providing more reliable risk projections related to extreme weather events improves our understanding of the challenge ahead. In particular, it helps reduce the damage by providing accurate information on the potential losses that confront societies in the coming years.

This enables more resilient systems to be planned and built. It also presents the most cost-effective insurance-related solutions to deal with the risks posed by climate-inducted extreme events. This is particularly important for vulnerable developing countries because they will shoulder a far greater burden of loss and damage due to inadequately built infrastructure, weaker preparedness and low levels of capacity to respond to disasters.

IMPROVING GLOBAL CROP FORECASTS

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THESIS TITLE
PRECYOUS – A global crop yield forecasting system

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A global system for forecasting crop yields well before harvest could lower risks for food security from climate change. Such a system, called PRECYOUS, is under development.

The crops that feed the world depend on favorable weather to produce large yields. Extreme weather, like drought, floods or heat waves, devastate harvests. With climate change expected to increase both the frequency and intensity of extreme weather, it is becoming urgent to quantify harvest risk around the globe. Real-time estimates of harvested yields, as well as pre-harvest forecasting, deliver critical insights that allow timely counter measures to be taken. They also support post-harvest logistics and market plans. Such early warning systems may also prove valuable in preventing global food crises, such as occurred in 2007/2008, as well as in providing early estimates of crop indemnity payments.

Such yield forecasting already exists. Based on a mixture of crop models, expert opinions, farm surveys, historical trends, remote sensing data and seasonal weather forecasts, systems such as China's CropWatch, the MARS bulletin of the European Commission and the USDA Commodity Forecasts all strive to predict crop yields.

However, the performance of such systems is neither well documented nor evaluated. Moreover, forecasts often prove misleading in extreme years. For example, no major forecasting system foresaw the large loss of wheat and barley crops experienced in France in 2016. In addition, systems are often tailored to limited regions which makes it difficult to assess global effects.

In my research, I propose to complement existing forecast systems with a global yield forecasting framework that covers staple crops, is consistent in methods, self-evaluating and fully public. This global framework, called PRECYOUS, for "**P**otsdam **RE**altime **C**rop **Y**ield **OU**tlook System," could serve global early warning needs.

METHODS

The idea of PRECYOUS is to use the best possible methods derived from the literature, refine and upscale them where necessary and combine them into a large, consistent framework. Figure 1 illustrates the flow of input (orange boxes on the left) into a data crunching system.

There an ensemble of models developed from the literature with an optimized, self-adapting weighting scheme based on machine learning (green boxes) forecasts crop yield forecasts and associated further outputs (blue boxes). It also calculates the uncertainty of outlooks. The major inputs are historical yield data, satellite remote sensing data and weather observations, which help formalize relations between crop yields and environmental conditions and so anticipate future yields.

Quality control is present in four components. First, an automatic evaluation of models and input data with machine learning techniques after each forecasting and harvest round allows unreliable methods to be marginalized. Second, all forecasts will be made public, enabling a comparison with other systems. Third, an easy system for user feedback will be available to allow for public evaluation of the forecasts. Fourth, all input data and applied methods are either based on peer-reviewed publications or will be published to maximize the transparency of methods.

EXPECTED RESULTS

A global crop yield forecast system will be established. This will be publicly accessible and produce yield forecasts at least two months before harvest for global staple crops (initially maize, rice, soybeans and wheat). Continuously self-evaluating, the system will improve every year by comparing forecast and reported yields and also evaluating intermediate steps including input data and models. The system will be module based, so future extensions are easily possible. The output will include monthly report bulletins containing an overview of changes since the last forecast with a focus on possible loss hot-spots.

PRECYOUS will complement – not replace – existing systems as each of these systems has a different scope of crops, spatial detail and extent, and possibly also readership. Existing systems usually contain, in different shares, an expert-based opinion in the final forecasts. PRECYOUS will not contain expert judgments, but rather be fully automated. This may result in forecasts different to existing systems, and all forecasts together will provide a range of uncertainty.

A basic version of the nascent system has already been created based on weather data and with a performance comparable to existing systems. In the next steps, the forecasting models will be refined, further data sources included and the machine learning for model selection and weighting will be improved.

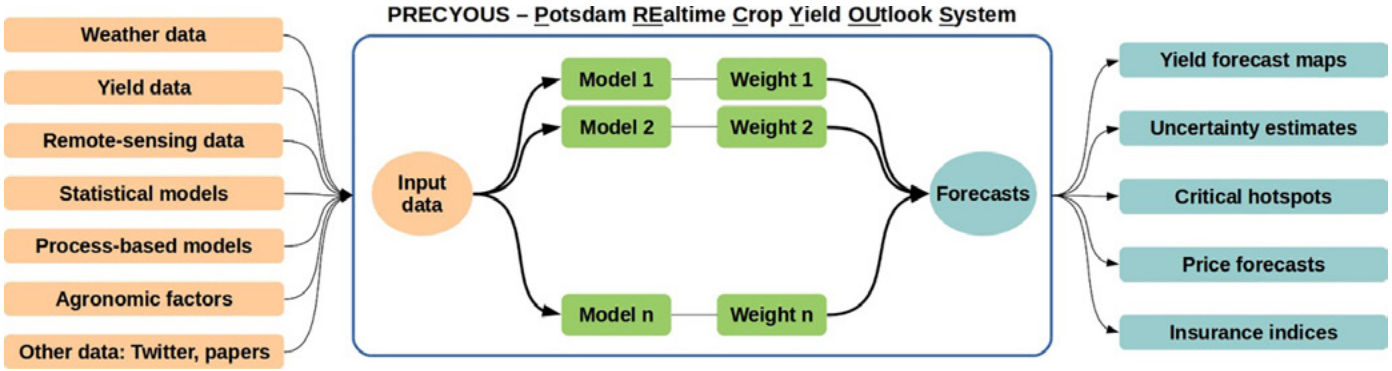

Figure 1: Scheme of the PRECYOUS forecasting system

UNDERSTANDING VULNERABILITY

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THESIS TITLE

Spatial Landslides Vulnerability Assessment for Appropriate Resilience Policy in Western Rwanda

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Improving access to information will reduce the loss of human lives to rain related disasters in Rwanda.

Rwanda is a poor and densely populated country in East Africa where the effects of climate change and landscape degradation are readily evident. Dubbed "a country of a thousand hills," Rwanda finds its undulating landscape often prone to severe flooding from torrential rains, as well as landslides and mudslides.

While mud and landslides can be a devastating natural phenomenon, human activity, such as cutting trees for firewood or land clearing for housing, expose the soil and exacerbate the natural effects. When torrential rains come, they saturate the exposed soil until it becomes waterlogged. When the ground eventually gives way, it results in mudslides that rapidly gather force and pick up boulders and other debris with deadly effect.

In 2018, disasters relating to heavy rains caused 222 deaths, destroyed 14,491 houses and 8,978 hectares of crops until the end of August, according to Rwanda's Ministry of Disaster Management and Refugees. Since the 1960s, millions of people have been killed, injured or left homeless, while untold amounts of crops have been damaged and infrastructure like roads and bridges laid waste.

There is evidence that the incidence of such events has increased since 2000. While climate change is one culprit, poverty plays a role as people cannot afford to build sturdy housing. The government too is restricted in the infrastructure it can afford to help avert disasters. The consequences of such disasters are not only that they damage the infrastructure and natural resources on which people depend for their livelihoods, they also impact upon the community well-being and delay sustainable development attempts.

RESILIENCE EDUCATION

The problem Rwanda faces is that it lacks a community approach to preventing disasters, as well as regular vulnerability assessments and timely information sharing. This weakens the understanding of an area's disaster catalogue, of the major causes of the disasters and of the kind of behavior needed for adaptation and resilience.

My research investigated vulnerability resilience in the context of Rwanda's ongoing disasters. I believe that conducting a thorough analysis of vulnerability causal factors would strengthen community risk awareness, minimize vulnerability and build resilience, while identifying the measures policy makers needed to undertake to reduce risks.

While disaster resilience education is available in Rwanda, it is presented mainly at universities and restricted to urban areas. This weakens delivery and means risk awareness in rural areas is minimal. The rural Western Province is the second-most inhabited area in Rwanda and typically registers high losses due to landslides. Because of this vulnerability, Western Province was chosen as the subject of study.

Within the research, 11 vulnerability drivers were analyzed: elevation, slope, soil texture, rainfall, land use/cover, population density, poverty level, health facilities, literacy rate, household mean size and possession of mobile phone, radio and television. The choice was based on the opinion of experts, a review of the literature and the distribution of previous landslides among the seven districts of the Western Province. The Analytical Hierarchy Process (AHP) was used to weight the vulnerability drivers and identify major factors, while a geographic information system (GIS) was used to spatially reveal each district's vulnerability.

RESULTS AND POLICY IMPLICATIONS

Elevation (15%), slope (13%), population density (12.4%) and rainfall (12%) proved to be the major triggers to landslides vulnerability in Ngororero, Nyabihu and Rubavu districts. It is striking that in these districts that less than 40% of residents own either a mobile phone, radio or television.

Increasing access to or enabling cheaper purchasing options of these communication tools would significantly reduce vulnerability among citizens by enabling the delivery of resilience and risk reduction messaging. Further, as climate change alters the rainfall intensity/frequency and is among the key drivers to landslide vulnerability, the risks are likely to increase. This suggests that emphasis should be placed on science and technological research, along with modern weather monitoring for climate change mitigation and adaption in the Western Province.

In conclusion, the research shows that as vulnerability varies, proposed mitigation and adaptation policy measures should be based on the specific conditions of each district. In this way, the community can come to understand its vulnerability magnitude and the drivers to vulnerability and then either leave highly vulnerable areas and settle in low vulnerable areas or establish behaviors and practices that minimize the incidence of vulnerability. Such initiatives could include proper land use/ management practices, bench terraces, rain harvest and community meetings for information sharing.

With such an approach, policy makers, the local community and other partners can easily understand the types of disaster that are occurring and likely to occur in the future and their key causes. They can then undertake appropriate mitigation and adaptation measures. Further analysis on the extent to which disaster risk reduction is mainstreamed and prioritized within policymaking schemes (environmental, political, social and economic and cultural) is suggested.

ANTICIPATION AND RESILIENCE

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BIOGRAPHY

Raphael is a post-doctoral researcher at the University of Johannesburg, South Africa, having completed his Ph.D. at the Faculty of Environmental Sciences at the Technische Universität Dresden in Germany. Given his expertise in resilience, climate risk management strategies, he is motivated to further develop his career in in the field of risk management with a clear objective to contribute to research, policy and international development in the future.

THESIS TITLE

Flood risk management strategies and resilience: The capacity of key stakeholders to respond to the unexpected course of flood disasters in the city of Accra, Ghana.

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Rainfalls in Africa are increasing in both intensity and frequency and resulting in devastating flooding, yet anticipatory strategies to combat them often lack one powerful element – resilience.

Perched directly on the Atlantic coast on a low lying plain, Accra suffers chronic and deadly flooding. It is far from the only African city devastated by punishing storms that sweep in from the ocean. Dakar in Senegal and Lagos in Nigeria, also located on the Atlantic, are among the other cities that are highly vulnerable to flooding, yet Accra well illustrates the damage flooding can wreak both on a society and its environment.

The Ghanaian capital also shows how societal change can increase the risks of floods, as well as the impact climate change is having on coastlines. With interest growing in making Accra more resilient to floods, the seafront city of 2 million holds valuable lessons for other cities in developing countries exposed to flooding.

My doctoral thesis focuses on Accra and seeks to understand how key decisionmakers in the city and in relevant organizations deal with the unexpected disasters that can occur during floods, in addition to the features they expect in their management strategies. The focus is on including resilience as an anticipatory part in flood risk management (FRM) strategies. The argument is that increasing flood disaster risk leads to unexpected flood disasters and impacts that go beyond the response capacity of anticipatory FRM strategies. The research describes flood disaster risk and outlines why there is a need to consider resilience in addition to anticipation in FRM strategies.

MANAGING FLOODS

Managing floods involves coordinating decision-making and resources to prevent, mitigate and reduce risk. FRM also includes a societal process of analysis, evaluation and reduction of flood risk. This can be holistic and continuous and involve various organizations and adjacent locations with different interests and resources.

The classical approach to FRM is seen in Accra where stakeholders employ drainage and spatial land-use management strategies to mitigate and respond to floods. Other approaches tried in Accra include eviction, relocation, public education and emergency relief.

None of these initiatives have been particularly successful due to implementation challenges, inadequate resources and the unforeseen course that flood disasters can take. In particular, unregulated urbanization and the uncertainties accompany climate change are exacerbating the unexpected course of flood disasters.

During flooding, these uncertainties can lead to dramatic consequences. An example is the disaster of June 3, 2015, when more than 150 people were killed as they sought shelter from seasonal rain and flooding at a petrol station. Leaked fuel floating on the rising waters caught fire, burning down the station and trapping people inside and in vehicles before the petrol pumps exploded.

While scholars have researched flooding in Accra, the topic of resilience in FRM strategies has not been tackled. Resilience is the capacity of a system to bounce back or return to a stable state in the face of disturbances. It also means persistence in, resistance to and recovery from disturbances.

Including resilience in FRM strategies would add an additional capacity that will allow key stakeholders to deal with unexpected disasters that can arise during floods. Combining resilience with traditional anticipation strategies would enable stakeholders to respond to the unexpected consequences, as well as proactively prevent, protect and mitigate expected flood risks and impacts.

Noted American political scientist Arron Wildavsky once explained that anticipation is a mode of control and of efforts made to predict and prevent potential dangers. Resilience is the capacity to cope with unanticipated dangers after they emerge.

REDEFINING FRM

My thesis argues that FRM strategies should contain both resilience and anticipation to be prepared to respond to both the expected risk and the unexpected course that floods can take. The study applied qualitative research methods consisting of document analysis, expert interviews and stakeholder validation workshop.

The main result of this research is a generic framework for the operationalization of resilience in FRM strategies with a specification of indicators and identifiers. The specification of the identifiers and indicators is useful for dealing with unexpected risks that arise during a flood and which are hardly considered in conventional approaches to flood risk management.

FORECASTING THE FLOOD

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BIOGRAPHY
Josias is a Ph.D. Candidate at the Center of Applied Research in Hydrometeorology (CRAHI) at the Polytechnic University of Catalonia, Spain. He is developing a method that forecasts the socio-economic impacts of flash floods in real time, to improve decision support for emergency managers.

THESIS TITLE
Flash flood impact forecasting – Bridging the gap between science and emergency management

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A new approach to flash flood forecasting holds promise in bridging the gap between what science can deliver and the needs of emergency management.

A weekend at a Arizona swimming hole turned deadly in July 2017 when a flash flood killed 10 people, including five children. Although it had not rained at the popular Payson swimming hole, a deluge from a nearby thunderstorm raced downstream catching people enjoying the hot summer day unguarded and sweeping many away.

Such flash floods regularly occur across the globe every year wreaking havoc on lives and property. According to the Intergovernmental Panel on Climate Change (IPCC), extreme rainfall events will increase in frequency and magnitude with one effect being more frequent and severe flash floods. These impacts will continue to grow, unless climate change is mitigated by measures to improve flood preparedness and response.

As seen in the tragedy at Payson, Arizona, the main characteristic of a flash flood is an extremely short lag time between the rainfall and the response in the river – usually not more than a few hours. To emergency managers, this rapid pace leaves little time to make decisions and coordinate responses, such as issuing warnings, making evacuations and closing roads.

Early warning systems help increase the response time during flash floods. However, they are only effective if forecasts are delivered to decision makers in a timely and appropriate form. The World Meteorological Organization (WMO) has identified that an information gap exists between developers of early warning systems and their users and has proposed a paradigm change.

Rather than providing hazard forecasts, such as water level at a given river section, it is more useful to emergency managers to have tools that predict the socio-economic impacts that can result from flash floods, such as the estimated number of affected people. These tools could reduce the potential for suboptimal decisions and extend the timeframe emergency managers have to coordinate responses.

This is crucial because every minute counts and potentially decides if a warning reaches the affected population in time or not.

REAL-TIME FORECASTING OF FLASH FLOOD IMPACTS

At the moment, a system that quantitatively predicts flash flood impacts with blanket-coverage does not exist. My research produced a prototype of a real-time flash flood impact forecast method to fill this void. This is achieved by automatically combining hazard forecasts (based on radar rainfall measurements with information about socio-economic exposure and vulnerability, such as land use and population density maps.

To ensure a high practical value, the method is designed along the following principles:

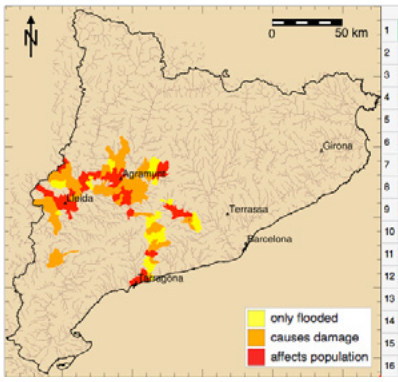
1. **Flexibility**
   The method allows impact products to be tailored to different groups of end-users. Apart from the benefits for civil protection operations, the outputs can also be provided to water agencies and (re-)insurance companies.

2. **Transferability**
   The first prototype was developed for the region of Catalonia, Spain. Due to the minimal data requirements, the method can be transferred and extended easily to other regions and spatial scales.

3. **Collaboration with end-users**
   Participation in the EU research project ANYWHERE-H2020 (http://anywhere-h2020.eu) allows close cooperation with potential end-users to develop the approach in a practice-orientated way. The Catalonian Civil Protection Agency and the Water Agency of Catalonia are partners involved in the project.

APPLICATION IN THE FIELD

The impact outputs from the prototype are manifold and produced every six minutes, with a forecast horizon of three hours. A severe flash flood that occurred in the evening of 2 November 2015, in Catalonia, illustrates the ability of the method.



	Unit	Population	Damage_k€	Infrastr.
1	Catalonia (total)	822 - 2736	20954 - 51261	3 School;
2	Balaguer	0 - 1115	0 - 4945	
3	Agramunt	663 - 812	10363 - 13931	2 School;
4	Tàrrega	152 - 397	2693 - 6168	
5	Igualada	0 - 147	0 - 1640	
6	La Pobla de C...	0 - 71	0 - 2079	
7	Lleida	0 - 47	0 - 1879	
8	Tarragona	0 - 44	0 - 735	
9	Preixens	0 - 29	0 - 932	1 School;
10	Santa Margari...	0 - 25	0 - 1609	
11	Montgai	0 - 12	0 - 1644	
12	Torà	0 - 6	0 - 91	
13	Anglesola	2 - 6	2062 - 3707	
14	La Sentiu de Sió	0 - 5	0 - 247	
15	Vilanova del ...	0 - 4	0 - 244	
16	Guimerà	3 - 4	112 - 179	

Modelled impact summary in Catalonia in the evening of the 02.11.2015. Impacts in 80 municipalities are identified (the 15 most severely affected are listed).

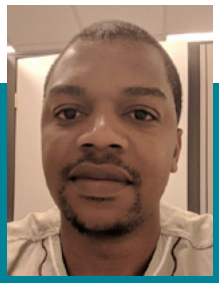
The four columns in the above table represent from left to right: the spatial unit (that is, the region in its entirety and the individual municipalities), and quantitative estimates of the following impact classes:

1. Number of people in the flood zone
2. Economic damage in thousands of euros
3. Affected critical infrastructures

Impacts for each spatial unit are presented as a range to account for uncertainty in the models. Produced during an event, this output allows end-users to identify which regions may be impacted. The system can then zoom into an area at risk and provide detailed images at 25 meters resolution for each impact class. These high-resolution images can, for instance, be used to coordinate firefighters and other emergency services in the field.

When comparing the results of the system to the impacts reported after the Catalonian flash flood, it became clear that the locations of highest impact (such as Agramunt, where four casualties occurred) were correctly identified. However, the model overestimated the economic damages, an issue that will be addressed in future work.

WEATHER SHOCKS, LABOR ALLOCATION AND INCOME



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BIOGRAPHY

Kelvin joined the Department of Agricultural and Resource Economics at the Colorado State University as a Fulbright Scholar in fall of 2016. Before enrolling as a Ph.D. candidate, Kelvin completed his MSc in Agricultural and Applied Economics with specialization in environmental economics and natural resources management. He published several research papers in development and practice journals. His areas of expertise include agricultural productivity, gender dynamics and climate change role in household labor allocation decisions.

THESIS TITLE

Weather variability and labor allocation: impact on income

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Innovative small-scale interventions could make a dramatic difference to African farmers in times of extreme weather shocks.

Throughout much of human history, farming has been a hardscrabble activity – and still is in large parts of the world. In Africa, where farmers lack the subsidies and safety nets that lessen the impact of weather-related catastrophes, farming is a precarious existence.

Close to 70% of Africa's population is involved as smallholder farmers working on small parcels of land. Yet, although farming is the backbone of Africa's economy, there is much that is not known about how farmers and rural communities respond to situations of death and drought.

In particular, we do not understand how responses to communitywide shocks vary by shock size (intensity) and by wealth as indicated by ownership of capital inputs such as land. Understanding such responses is important to plan interventions to help farmers cope with future weather shocks.

Climate models indicate that rainfall patterns will become more unpredictable in the future and that there will be an increased frequency of extreme events. The aim of this study is to understand how climate risk, posed through rainfall variability, affects rural farming households.

Specifically, the study examines the effect of extreme rainfall (flood or drought) on labor allocations between agriculture (crops) and the collection of non-timber forest products (NTFPs), such as caterpillars, edible insects, mushrooms, wild honey, etc. It also investigates the difference in response to a mild rainfall shock compared to a severe shock by farm size and the impact on income.

ZAMBIAN DATASETS

The focus was Zambia, a landlocked country in southern Africa. Rainfall data from the Zambia Metrological Department for the 2010/11 and for 2011/12 agricultural seasons was used. This was matched to rural livelihoods data for 2011/12.

The rural livelihoods data contains information on household labor allocation to different NTFP collection activities. The dataset also provides information on production and how labor was allocated to each agricultural activity.

A Standardized Precipitation Index (SPI) was calculated from the rainfall data. This index was used to categorize rainfall into "normal," "mild drought/flood" (mild weather shock) or "severe drought/flood" (severe weather shock).

Landholding or farmland was used as a proxy for wealth. Farmers possessing small land parcels (below five hectares) were categorized as small-scale or poor. Those with 5-20 hectares were categorized as medium-scale or well-to-do.

IN TIMES OF NEED

From the study, it emerges that a severe shock results in a reduction in the labor of all households to agriculture and an increase to the collection of NTFPs. This is different to mild weather shocks. Then medium-scale farmers reduce the collection of NTFPs and increase their focus on agriculture, while the small-scale do not respond in any significant way.

Further, a mild weather shock has no impact on the income of small-scale and medium-scale farming households, while a severe weather shocks reduces the incomes of both groups. Finally, the previous year's weather does not affect labor allocation decisions for medium-scale farmers, but does affect those of small-scale farmers. Neither group experiences an impact on the current year's earnings.

SOCIAL MECHANISMS

Both small and medium-scale households respond to severe weather shocks by reducing agriculture labor and increasing the collection of wild products. This underlines the critical role of community-shared forests as the option of last resort and has implications for the conservation of forests and other common property resources such as rivers and lakes.

Since both small and medium-scale producers resort to wild products collection in severe conditions, the amount collected per household reduces as more people are competing for limited resources (a tragedy of the commons scenario) leading to a reduction in income.

During a mild weather shock, there is weak evidence of a socially optimal collective equilibrium – a cooperative outcome in which no group is made worse off. Medium-scale households respond by withdrawing from collecting NTFPs and allocating more labor to agriculture, while small-scale operators increase the collection of NTFPs. This leaves the poor (small-scale) collecting more NTFPs per household and the medium-scale earning more from agriculture.

Results suggest that the incomes of both groups do not fall in the face of a mild weather shock (it actually increases for medium-scale farming households). This has implications for policy measures in times of severe weather. If medium-scale producers were supported with financial capital (for example, subsidies targeted at the "vulnerable but viable"), they could be more productive in agriculture and withdraw from NTFPs, which would benefit both groups.

There is also an insurance consideration based on the type of households and the severity of the weather shock. Practically, it is possible to initiate microinsurance for medium-scale producers who are compensated when there is a mild weather shock. This would draw them away from NTFPs, leaving the collection to small-scale farmers.

SALTING THE EARTH

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BIOGRAPHY

Catherine earned her Ph.D. in Development Studies in 2018 at the University of the Philippines Los Baños and has 19 years of teaching experience at the Xavier University, Ateneo de Cagayan. Currently, she is actively engaged in various research projects conducted at various levels, locally and internationally, in multidisciplinary and multi-sectoral groups.

THESIS TITLE

Innovative adaptation to varying condition of saltwater intrusion in northern Mindanao, Philippines

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Saltwater intrusion is forcing Filipino farmers to fight the problem or flee. Well-constructed intervention policies and training can support the decision to stay and create stronger communities.

The abandoned farms near the shoreline of Northern Mindanao silently testify to the ravages of climate change. Saltwater intrusion has driven local Filipino farmers from the land. As the salt remains in the rivers and canals and slowly progresses inland, it confronts progressive waves of farmers with a decision to either find ways to combat it or leave.

This is economically devastating for the farmers. Yet, because the damage is incremental, a slow-onset hazard like saltwater intrusion does not receive the same attention as the more spectacular effects of climate change. My research on Mindanao investigated the context-specific, local-level abilities of farmer to adapt. Specifically, it analyzed how farmers make adaptation decisions and how this adaptation can be measured quantitatively.

What emerged is that the knowledge of farmers concerning adaptation is insufficient for them to make informed choices. The measures currently being implemented often provide short-term benefits, but do not address the complex hydrological conditions present and could result in greater risks in the future.

However, the approaches of the farmers could form the basis of government policy to support adaptation. But, more innovations will also be needed for effective adaptation, as the chances of crossing critical ecological, physical and social thresholds increase.

In the study, spatial data analysis was used to identify rice producing barangays (Filipino term for a village, district or ward) that require effective interventions. This spatial technique could be combined with other databases, such as socio-economic indicators, soil characteristics, farming practices and infrastructures. Such a geographical presentation of these development indicators will be valuable for designing and planning strategies to improve overall welfare.

INNOVATIVE ADAPTATION

Innovative adaptation means, above all else, improving the economic status of rice farming households. This is crucial as it will influence adaptation diversity and improve the overall adaptation index.

Financial viability is the major concern of farmers in choosing adaptation measures. Increasing their income in the short term will motivate farmers to adapt relatively costly measures to combat saltwater intrusion. Measures that increase their income would also ease the liquidity constraints farmers face and encourage their adoption of new technology.

Long-term innovative adaptive transformation will, however, mean investments that most farmers cannot afford and so this will require assistance from the government and agencies. This may involve innovative technology such as developing salt tolerant rice suitable for the biophysical characteristics of the coastal farms.

One way to encourage technology-based adaption is to improve access to the inputs necessary for the implementation of these measures. This would be especially effective if more farmers can be convinced this would have positive effects on their families and their community. Increased investment in human and social capital should also complement adoption.

Innovative adaptation measures should be developed based on community needs and capacities. Policies should not only be based on the ecology but also on economic factors, especially the financial plight of vulnerable rice farming households. The findings support the design of measures to create off-farm livelihoods, so farmers can supplement their income in the face of saltwater intrusion.

These off-farm livelihoods should build new skills and capabilities and reduce dependence on natural resource extraction. Tailored programs that encourage adoption of specific measures may be highly effective not only for improving the ability to combat saltwater intrusion but also for reducing vulnerability.

At a lower level, innovative adaptation implies the timely delivery of climate related information to increase preparedness in planting. This means meteorological information should be collected and the biophysical characteristics of the rice fields monitored to provide an accurate basis for assessing the likely impact on production.

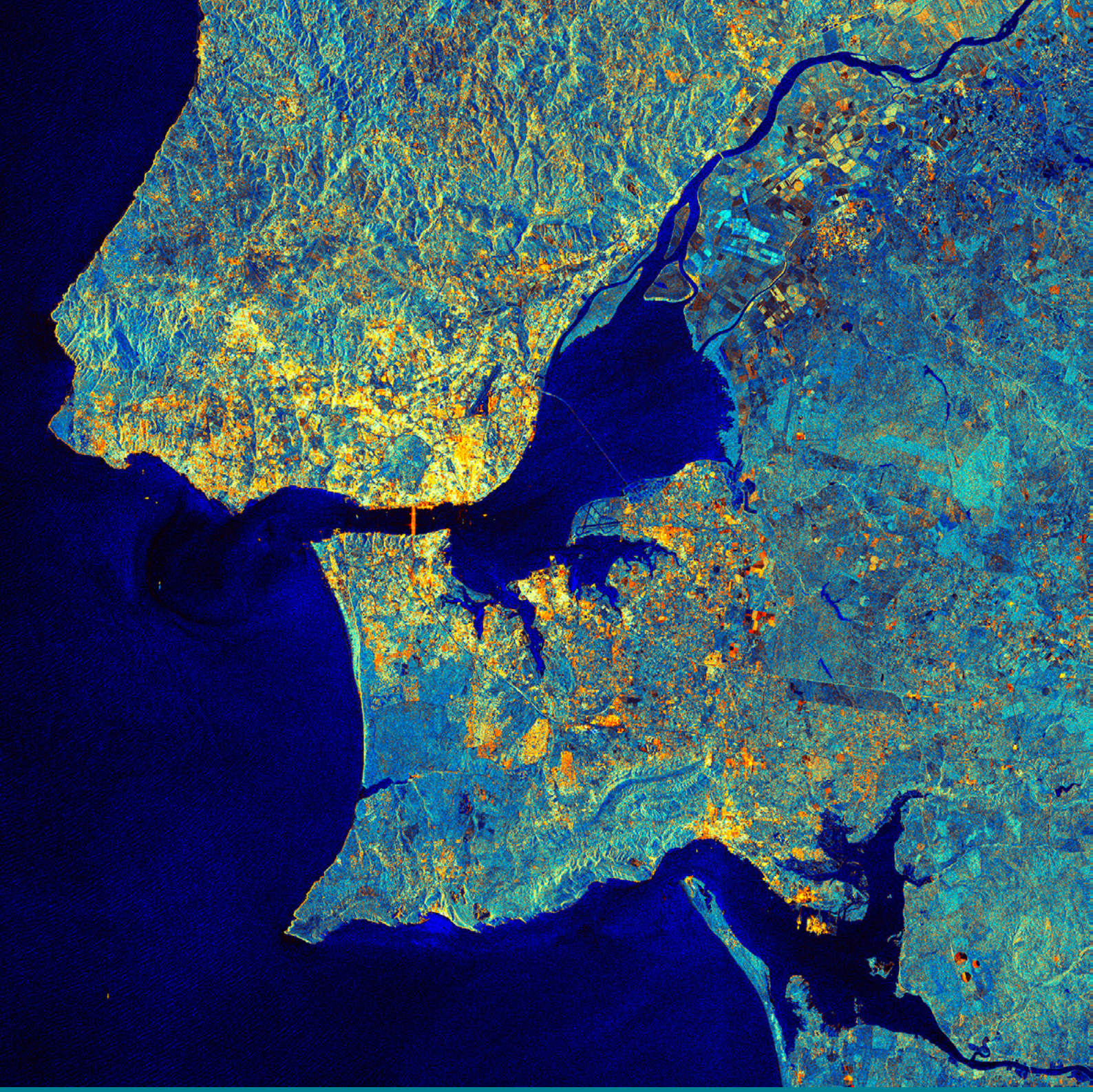
TRAINING AND SOCIAL SUPPORT

My research recommends a transdisciplinary approach that links data and results with biophysical data sets. Knowledge communication and transfer from scientists must be complemented with analysis from multi-disciplinary experts that can be translated into appropriate facts for local decision-makers and the farmers.

Providing farmers with training against saltwater intrusion significantly influences their decisions to take up adaptation measures. Equally important will be policies that generate incentives for active participation in farmers' groups if the efforts to boost the adaptability of coastal rice farmers and their livelihoods prove successful.

Communal water systems require adaptive cooperation, so labor and other resources can be pooled to construct and maintain canals and channels, allocate and share water, and regulate and monitor the provision and use of water. The cooperation of the farmers for irrigation plays a significant role in shaping responses to issues of social trust, reciprocity, competition, conflicts, equity and other mutual concerns related to water access. Effective social organization and rules for collective action are crucial to coordinate cooperation for irrigation use.

Lastly, group and labor collaboration activities manifested by the labor pooling system widely practiced by farmers may be effective to incentivize participation in groups. When farmers perceive they are supported from within their groups, this may strengthen sharing of indigenous knowledge, experiences and exchange of information about new technologies. Group membership can, therefore, enhance social learning and knowledge spillover on adaptation to saltwater intrusion.



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