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Chapter 17
Towards More Resilient Food Systems for Smallholder Farmers in the Peruvian Altiplano: The Potential of Community-Based Climate Services

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Abstract Experiences from the disastrous 2016 El Niño revealed that its forecast, although available, was not known, accessed or understood by a large part of agricultural communities living in remote rural areas. This is all the more striking since these population groups are particularly vulnerable to adverse climate events as their livelihoods heavily depend on climate-sensitive agricultural production. In the framework of Climandes, a twinning project between the meteorological services of Peru and Switzerland, we implemented and evaluated the impact of community-based climate services that were co-developed with the target smallholder communities of the semi-arid highlands of the southern Peruvian Andes, where small-scale farmers are especially exposed to adverse climate events due to high inter-annual climate variability and weak socio-economic capacities. In this chapter we analyse the project implementation through a socio-economic lens. Research results generated alongside the project indicate that the well-directed user engagement resulted in a strong increase of trust in the weather service SENAMHI Peru and led to improved consideration of the information provided in the respective decision-making processes. We highlight the key steps that proved to be indispensable for the implementation of meaningful and sustainable climate services. The project outcomes point to the great and widely untapped potential of community-based climate services to reduce vulnerability and strengthen resilience of smallholder farmers in the face of changing climate conditions.

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Introduction

Implementing the Global Agenda at the Local Level

Climate change constitutes a substantial challenge for developing countries and countries with emerging economies due to their often limited adaptation capacities. People and regions that are socially or economically marginalized are particularly at risk as climate-related hazards will further exacerbate their already constrained livelihoods (IPCC 2012). In the coming decades climate change is expected to amplify existing climate risks and create new ones for society.

In 2015, the international community set new global targets for the period 2015–2030 for disaster risk reduction (Sendai Framework), climate change mitigation and adaptation (Paris Agreement) and sustainable development (Agenda 2030). Climate services support the achievement of these three global agendas. For the Sendai Framework, weather and climate predictions on a broad range of spatial and temporal scales are a fundamental element of multi-hazard early-warning systems, which in turn are the basis for enabling proper disaster preparedness to safeguard lives and livelihoods. Under the Paris Agreement, improved communication of scientific information on climate variability, trends and extremes contributes to climate risk assessments and supports the promoted National Adaption Plans (NAPs). Finally, the majority of the 17 sustainable development goals (SDGs) are climate-sensitive, which renders climate services critical for achieving these goals.

Well aware of this cross-cutting importance of climate, the third World Climate Conference in 2009 decided to launch the Global Framework for Climate Services (GFCS) with the aim to improve availability, quality and access to climate services to better deal with climate-related risks. The GFCS recognized that developing countries and countries with emerging economies are often lacking even basic weather and climate information and, therefore, are given a high priority in the implementation of the Framework.

An innovative core element of the GFCS implementation strategy is the establishment of a User Interface Platform (UIP), designed to ensure effective dialogue and interaction between users and providers of climate services, helping providers to understand user needs and, correspondingly, allowing users to understand technical and scientific opportunities and thereby correctly interpret weather and climate information and services. Moreover, the GFCS proposes to set up this platform in a way that provides a structured process to foster the indispensable user-supplier dialogue and a managed method to define and reconcile user needs and provider capabilities, all with a view towards promoting effective climate-smart decisions.

In 2012, the Swiss Development Cooperation launched Climandes (*Servicios climáticos para el desarrollo*) as one of the first GFCS priority pilot projects under the Global Program Climate Change and Environment. This cooperation project between the Peruvian National Meteorological and Hydrological Service SENAMHI and the Swiss Federal Office of Meteorology and Climatology MeteoSwiss aimed at developing and providing climate services tailored to the agricultural sector of the Andean highlands with emphasis on food security and subsistence farming. As such, Climandes can be considered an innovative example of how to transform the GFCS into practical solutions at the local level and hence improve the resilience of agricultural communities in the Peruvian highlands. Climandes was performed in two phases periods 2012–2015 (Rosas et al. 2016) and 2016–2019 (Gubler et al. 2020), respectively.

The Importance of Small-Scale Agriculture and Enhanced Access to Weather and Climate Information

In Latin America, Sub-Saharan Africa or East and South Asia, small-scale farmers provide almost three quarters of food calories, hence playing an essential role in sustaining food security, jobs and income in rural areas of developing countries and countries with emerging economies (Samberg et al. 2016). However, smallholder farming is frequently exposed to socio-economic, cultural and environmental risk factors that affect the production system. In 2016, El Niño-driven weather patterns and political instability caused an intensification of global food insecurity in 2016 (FAO et al. 2017). An analysis of the 2016 El Niño event, which affected more than 60 million people worldwide, revealed that a major part of the exposed population was uninformed and unprepared for the pronounced climate anomalies (Frei et al. 2016). Tailored communication of weather and climate information is critical to reducing the impact of agro-climate hazards by enabling proactive action to reduce crop yield losses. While information on adverse events often exists, too often it is not known, accessible or understood by large user groups, particularly smallholder farmers in remote rural areas (Carr and Onzere 2017).

Indeed weather and climate information often fail to complete "the last mile" to reach large user groups, as for instance in the case of smallholder farmers in remote rural areas. For many national meteorological services climate information are not co-developed with and tailored for specific users or user groups, nor are they well anchored at the institutional level, especially in developing countries and countries with emerging economies. To address these shortcomings and following the GFCS guidelines, the Climandes project developed a prototype of a UIP designed to enable a strong engagement with key stakeholders. The implementation of such a UIP was probably the single most decisive factor in successfully bridging the supplier-user gap. The stakeholders involved encompass the information providers, intermediary users such as sectoral experts, and representatives as well as local communities and small-scale farmers.

Conceptual Framework

To plan an intervention that aims at strengthening climate resilience, it is paramount to understand the target populations' climate-related vulnerabilities. Socio-economic vulnerability to climate-related hazards on the one hand is given by a combination of the magnitude of typical weather and/or climate events, the exposure and sensitivities of people and assets to such events. On the other hand, the peoples' adaptive and coping capacities is determinant to how large an impact will result (Fig. 17.1). In the case of small-scale farming, extreme weather and climate events result in immediate short-term impacts such as crop losses, which depend on exposure, sensitivity of the agricultural production, but in a substantial way on the adaptive capacity to such events. As a matter of fact, significant weather and climate services can help the decision-making process for putting in place impact-mitigating measures to reduce the crop losses. A use case example for the mitigating effects of user-tailored climate services on the impact of a hypothetical frost event on the Andean highland quinoa harvest is given in Box 1.

Box 1 Frost example—Why do Juan and Pablo experience different quinoa losses from the same frost event? Juan's farmland lies in a shallow basin where a pool of cold air forms during the night (higher exposure to frost). Due to better yields, he uses a more productive but less frost-resistant crop variety (higher sensitivity). Furthermore, he lives in a remote area that has no radio signal. Therefore, he does not receive the frost warning from a local radio station and cannot trigger corresponding protective measures (low adaptive capacity). During a strong heavy frost night in February, Juan loses almost half of his quinoa production. Pablo lives in the same community as Juan, but his farmland lies on the slope (lower exposure to frost). Julissa, a friend of Pablo is working at an agricultural research institute and is developing new frost-robust resistance quinoa varieties that are less productive but more robust to frost and drought (lower sensitivity to frost). Julissa regularly sends text messages with specific agricultural advice based on information from the meteorological service and Pablo protects his cultures with foil in case of frost (high adaptive capacity). During the frosty night in February, Pablo does not suffer any quinoa loss. Luckily, Pablo is sharing a part of his quinoa harvest with other community members like Juan who would otherwise lack food (coping capacity).

For subsistence farmers, significant crop failures imply long-term consequences, typically including strained livelihoods and increased food insecurity. These consequences arise from a combination of the farmers' large dependence on home-grown food and insufficient capacity to recover from external shocks for a lack of savings and other social or financial protection. As a result, a single event can set in motion a negative feedback process (see Fig. 17.1) which pushes vulnerable people into poverty, and potentially propagates this status to keep them locked in a poverty trap

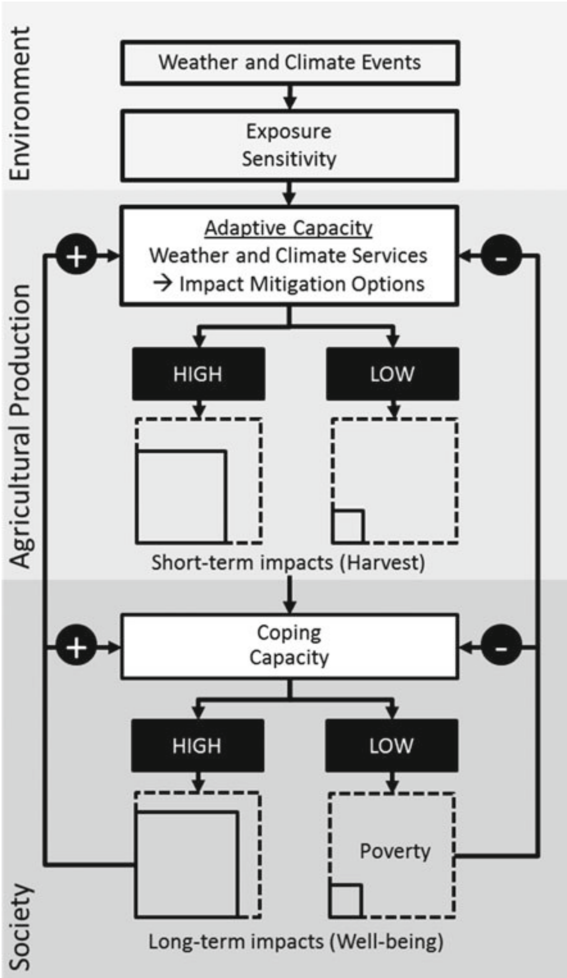

Fig. 17.1 Shows the underlying concept of socio-economic vulnerability to weather and climate events. Socio-economic vulnerability towards climate-related hazards is composed of an environmental and societal dimension. The environmental dimension comprises the magnitude of the weather and climate event, how often someone is hit (exposure) and how sensitive they are towards it (sensitivity). The societal dimension encompasses the ability of a specific population to prepare for an up-coming event (ex-ante adaptive capacity) and to overcome the associated impacts (ex-post coping capacities). For small-scale subsistence farming, severe weather and climate events may, depending on the adaptive capacity, translate into short-term impacts in form of partial or total harvest losses. Frequently ensuing long-term impacts on the population's well-being may, depending on their coping capacity, endanger their livelihoods and leading to poverty. Dashed/solid squares represent typical/reduced harvest and well-being. The larger the missing portion of well-being, the larger the risk for poverty. Note, that the feedback processes determined by good or poor adaptive and coping capacities can lead, respectively, to a sustainable livelihood or quickly into poverty

and thwart years of improved welfare. In the context of disaster risk management and adaptation planning, the nexus of poverty and vulnerability has recently gained much attention (Hallegatte et al. 2017). The Climandes project paid particular attention to this nexus by evaluating the smallholders' ability to manage climate-induced crop failures depending on their individual wellbeing. This information helps to better anticipate the social effects of the implementation of climate services in order to make these more inclusive.

In summary, both exposure and sensitivity to adverse weather and climate events can be reduced, for example by properly choosing the location of land to be farmed and using robust crop varieties, for instance. Climate services, for example in form of early warnings allow farmers to trigger preventive disaster-reducing measures. Additionally, an improved ability to recover from disasters can reduce the negative long-term impacts of events on the farmer's livelihood and welfare. Such recovery mechanisms include the enhancement of access to social and financial protection mechanisms like crop insurance, safety nets, savings and governmental aid, aspects which are beyond the reach of the present study.

Objectives

This chapter assembles the practical, user dialogue-related experiences of project Climandes. It outlines the project's approach and reports key findings and lessons learnt, with a particular focus on user participation and the presentation of pilot GFCS User Interface Platform (UIP). The chapter is meant to provide examples of "best practices," and give guidance for similar initiatives in developing countries or countries with emerging economies. It is not intended to be a comprehensive manual, but rather a description of essential steps, that emerged to be indispensable for the design and implementation of effective and sustainable climate services tailored to user needs.

The chapter is organized as follows: first, we describe the context for the implementation of Climandes and the project's approach; the following two sections present the project's key findings and insights from the project and illustrate applied research activities; we conclude with a discussion of our main findings and recommendations for practical applications.

A Two-Stage Approach for Evidence-Based Action

Climate Service Implementation as a Multidisciplinary Effort

In 2014, the GFCS stated that user dialogue and feedback is only just beginning and that gaps therein were impeding the process of moving from data to decisions. The

GFCS introduced an innovative concept—the User Interface Platform (UIP)—and encourages the development of UIP models that are not overly sector-specific, but instead identify and clearly articulate the common aspects of a UIP that make it sufficiently flexible to meet the needs of a wide range of climate-sensitive sectors. On the other hand, the GFCS recognized that, even though the geographical scope of the UIP is targeted to the global, regional, and national levels, possibly with multi-sectorial reach, actual implementation actions take place at the local level and often focus on a specific sector. There is an evident need to reconcile the scale gap between 'changing the world at once' and 'helping individuals'. This scale gap is exemplified in many regions where weather and climate information exist, but do not cover the 'last mile' to reach remote rural communities who are most in need of such information. All these issues make the design and implementation of climate services a very complex, inherently multidisciplinary challenge that involves a variety of stakeholders ranging from an individual smallholder farmer to national governmental institutions. It combines expertise from natural and social sciences as well as traditional knowledge in order to understand the decision-making processes of the users.

While the GFCS proposed guidelines to setup a UIP to address these challenges (WMO 2014), the specific activities of such a platform are not well defined or specified in any implementation-ready manner. In fact, a review of the GFCS recently concluded that 'the purpose and functioning of a UIP is not well understood by many climate service producers and users' (Gerlak et al. 2017). We responded to this inherent difficulty by setting up a pilot GFCS UIP in a way that reflected the needs of targeted groups, allowed regular interaction and training, built trust in the climate service provider and motivated users to engage in a monitoring and evaluation activity. In a nutshell, we found that a significant user engagement is a key element for implementing climate services and reaping their benefits.

The Climandes Two-Stage Approach of a User Interface Platform

In our quest to ensure that all relevant voices are heard and climate services respond to their needs, we implemented the pilot UIP in a structured two-stage approach (Table 17.1). The approach was set up to promote a close user engagement from the very beginning of the project that helped to design climate services that are in line with the users' demands. We conceived the first stage to provide the robust evidence necessary to plan subsequent interventions. In the second stage, we implemented climate field workshops to facilitate interaction with climate service end-users in two rural communities, along with the corresponding monitoring measures to evaluate the intervention's performance and impact. The first stage involved a mapping of stakeholders, aimed at identifying all relevant actors, integrating sectoral expertise and building strategic alliances. We further carried out a comprehensive assessment

Table 17.1 The two stage set-up of the prototype UIP implementation in Puno

Pilot GFCS User Interface Platform (UIP)	
Stage I: Evidence for action	Stage II: Translating evidence into practice
Stage I: Building blocks • Stakeholder mapping • Vulnerability assessment through a7 household survey • Socio-economic benefits estimation • Constraints to utilization of weather and climate information	Stage II: Building blocks • Building a continuous dialogue between provider and user • Establishing a feedback mechanism • Improving climate literacy • Monitoring and evaluation measures
To gain evidence for the intervention, we conducted a representative survey with 726 small-scale farmers in 15 districts in the Puno region. The investigation aimed at assessing the smallholders' climate vulnerability in terms of exposure, adaptive and coping capacities, as well as the current use of and prevailing barriers to weather and climate information	The intervention consisted of a series of monthly climate field workshops in the two agrarian communities Churo López (Aymara community) and Ccamara (Quechua community) during the growing season 2017/18. The workshops aimed at establishing a continuous feedback mechanism, sensitizing farmers about the use of weather and climate information, overcoming key factors limiting their use and evaluating the impact of the project

of vulnerability to climate-induced hazards through a household survey including a representative sample of more than 700 small-scale farmers (<10 ha) covering a total of 60 peasant communities in the northern (Quechua) and southern (Aymara) part of the Puno region (Fig. 17.2). The survey aimed at assessing the end-users' characteristics, knowing their major climate-related problems for agricultural production, evaluating their decision-processes and eliciting their needs for weather and climate information. Based on these data, we then estimated the potential economic value of improved access to information. Communicating potential socio-economic benefits in monetary terms to policy makers is expected to raise their awareness and foster sufficient and sustainable public investment in climate services. Finally, we identified major barriers to the utilization of weather and climate information among end-users.

The second stage of the intervention translated the previously generated evidence into practice in the form of climate field workshops. We paid particular attention to the development of a user-tailored service focusing on targeted communication and user involvement through the setup of a community outreach strategy (climate field workshops). These workshops were geared to facilitate effective uptake of the information provided, as well as to build trust among users on the weather and climate information offered. Workshops were designed as a pilot intervention to evaluate the potential for scaling-up effective user-driven climate services in the future. The number of farmers participating in the workshops did not change significantly, but the proportion of participants interviewed after the workshops to carry out an impact analysis was highest during the first session.

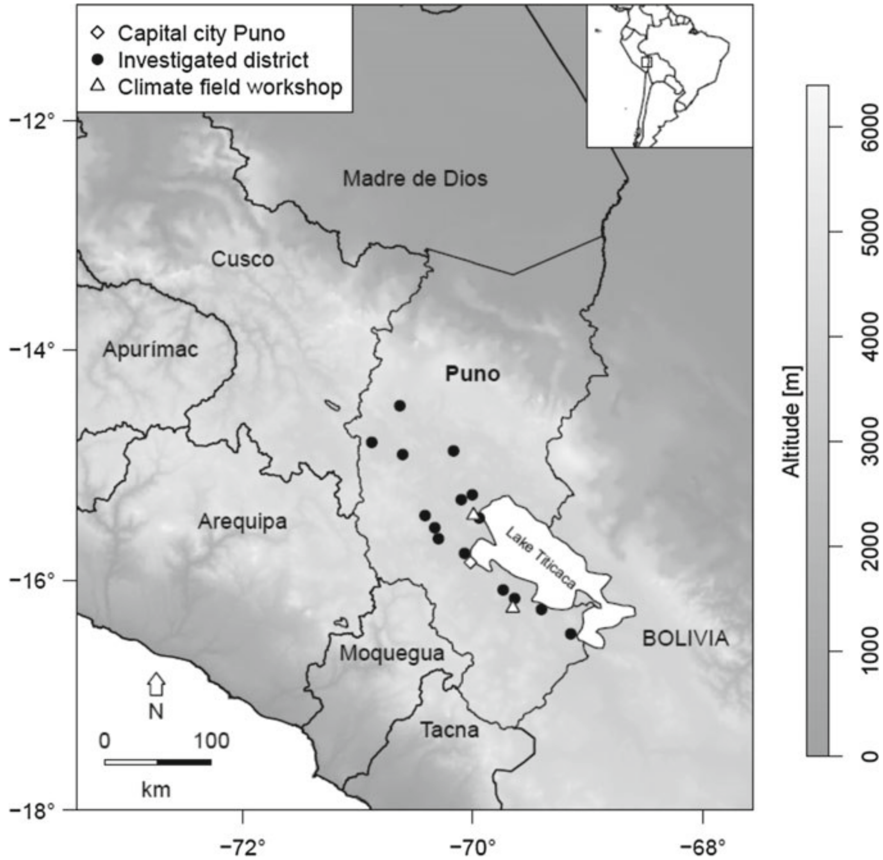

Fig. 17.2 The Climandes two-stage approach in the pilot region Puno. We implemented a GFCS pilot User Interface Platform (UIP) using a two-stage approach that is built around evidence-guided action with early involvement of the user community. The applied approach is generic and transferable to other regions and climate-sensitive sectors. The intervention took place in Puno, a semi-arid highland area in the southern Andes of Peru (grey shades denote topography) where smallholder farmers are especially exposed to the impacts of adverse weather and climate events due to high inter-annual climate variability and weak adaptive and coping capacity. The filled black circles indicate districts investigated, while the triangles denote the two pilot communities for which monthly climate field workshops were conducted. The regional office of SENAMHI Peru is located in Puno (diamond)

The workshops were built on the UIP guidelines proposed by the GFCS (WMO 2014). These guidelines include (i) the setting up of a mechanism to receive feedback from the user community, (ii) building a continuous dialogue between users and providers of climate service, (iii) improving the climate literacy of the user community and (iv) developing evaluation and monitoring tools to measure whether the implementation delivers the expected results.

Characteristics of the Implementation Context and Target Population

The pilot implementation took place in Puno, one of the two pilot regions of the project. Puno is located in the southern highlands of the Peruvian Andes with an average altitude around 4000 m a.s.l.

Its climate is characterized by dry conditions in the austral winter from May to September and wet summers from October to April, with occasionally occurring frost. ENSO influences both seasonal temperature and precipitation variability. El Niño (La Niña) is related to warmer (cooler) than usual temperatures. El Niño (La Niña) summers are also drier (wetter) than usual, although this relation is less robust (Lavado et al. 2013; Garreaud 2009). Future climate scenarios predict a decrease in precipitation and a growing risk of drought by the end of the 21st century (Neukom et al. 2015).

Puno has a population of 1.4 Million inhabitants, who account for 5% of the Peru's population. Puno is among the four Peruvian regions identified as having a very high level of food insecurity (INEI 2012). Although contributing only 15% to the region's GDP, 43% of the economically-active population works in the agricultural sector, with a majority of small-scale subsistence farms (INEI and MINAM 2013). Due to the short duration of the growing season (from October to April), the extensive nature and the low technological development of agricultural production systems and climate and soil constraints, agricultural productivity is below the national average. More than 96% of the population relies on rain-fed agriculture for their livelihoods, which makes the region especially susceptible to weather and climate events.

The main food crops are potatoes, quinoa and broad beans. Livestock farming provides an additional source of income. For quinoa, the demand on international markets has recently risen due to recognition of its nutritional value. For the majority of small-scale farmers in Puno, however, home-grown quinoa is still an essential food source. This crop has been grown for more than 7000 years, mainly using traditional cultivation methods without pesticides or mineral fertilizers. The cultivation of quinoa, in contrast to many other crops, is well adapted to the harsh climate conditions of the Altiplano. Due to the high importance of quinoa for the local population, it was chosen as a pilot crop for the project implementation.

Evidence for Action

Vulnerability to Hazards Depends on Farmers' Socio-economic Status

The household survey with 726 smallholder farmers in the Puno region allowed us to compare their actual harvest with their historical baseline and, therefore have a meaningful measure for production and yield losses among individual producers. First of all our analysis revealed that frost and drought events are the most frequent (*Exposure*) and damaging (*Sensitivity*) natural hazards which was also reflected by the farmers' perception (Fig. 17.3a).

Farmers were clustered into three income groups based on their possessions. Poor farmers seem to be more sensitive to crop losses due to natural hazards compared to their better-off counterparts. Unequal distribution of income within a community and exposure to frost negatively impacted relative harvest levels. The use of weather and climate information for production and the number of viable protection measures were positively associated with the actual harvest.

Considering that frost and drought are the two hazard types having the greatest impact, the majority of the study participants stated that they could make good use of early warnings to reduce crop losses by taking preventive measures (*adaptive capacity*).

Throughout all income classes, the ability of an individual farmer to recover from crop failure (*coping capacity*) is limited (Fig. 17.3). The largest share of farmers (53%) is forced to reduce their food intake due to lack of savings or stored crops (Fig. 17.3b). In the case of financial shortages, farmers switch to strategies that further increase pressure on their already constrained livelihoods: selling of livestock, stored food or other assets (86%) and engagement in casual external work (33%). Formal social and financial protection mechanisms are very limited: 2% of the farmers have crop insurance and 5% have access to bank credits (Fig. 17.3c).

Considering that a large number of the targeted actors practice subsistence farming, using up to two thirds of their production for self-consumption and due to the low coping capacities observed, crop failures directly translate into food shortages. In particular, poor households whose dependence on homegrown food is higher, exhibit significant problems of food insecurity which peaks in January, shortly before the next harvest starts (Fig. 17.3d).

The Evaluation of Crop Protection Measures for Effectiveness and Applicability

The survey also revealed that while farmers in the region apply preventive options to protect crops from extreme climate events, the effectiveness of such options remains largely unclear. In order to evaluate the viability of these measures, the method of analysis of real options was applied to evaluate the effectiveness and applicability of two viable management options that could potentially reduce crop losses due to extreme climatic events: (i) changing the variety of quinoa to one more resistant to frost and (ii) cultivation in elevated fields, called *Waru Waru* (in Quechua) or *Sukakollo* (in Aymara). The latter is an ancestral cultivation practice that increases yields and offers resistance to harsh climate conditions such as frost and dry spells.

Results indicate that switching to a more robust crop variety, offering higher yields, can significantly improve the farmers' revenues. However, adopting new quinoa

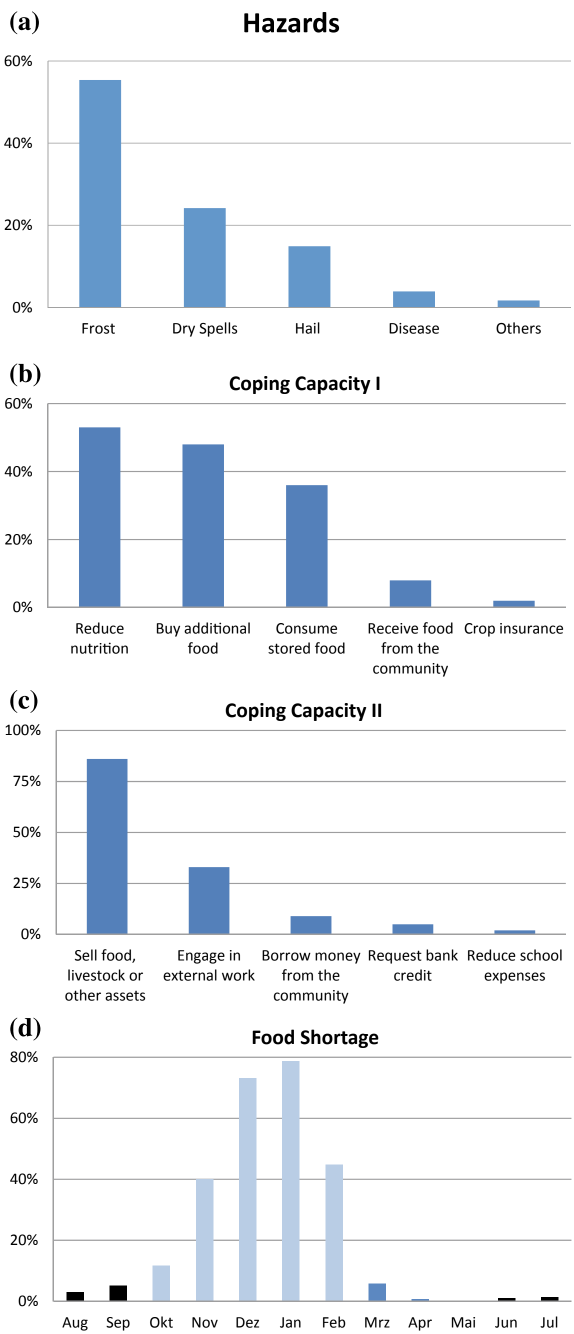

Fig. 17.3 The main results of the vulnerability assessment. These reveal the most severe climate hazards for production (panel **a**, in % of smallholders), the population's low ability to cope with shocks and their precarious livelihoods (**b** strategies for crop failures, **c** strategies for financial shortages) reflected in the form of food insecure periods. The percentage of households reducing meals for each month of the year is displayed in panel (**d**, light shading denotes growing period, medium shading the harvest period)

varieties is also associated with additional costs for new seeds and learning how to handle the new variety. In the case of the elevated fields, production is not worth undertaking for individual farmers, or the community, unless there is further evidence related to the increase in productivity of quinoa or subsidies from governmental or non-governmental institutions. This finding concurs with the fact that the occurrence of the technique remains low. Furthermore, it appears that even after implementation, raised fields have been abandoned in 3 out of 4 cases. Regarding these and other preventive measures to protect crops from weather extremes such as frost fires, water harvesting or specific irrigation systems, more investigation of their potential effects and benefits is required and results need to be mainstreamed to farmers and farmers' organizations.

A Frost Warning for Subsistence Quinoa Farming Potentially Values 2.7 Million USD for the Puno Region

The estimation of the socio-economic benefits (SEBs) of enhanced access to weather and climate information is essential to better understand the likely returns of public investment in climate services, as well as for the purposes of formulating public policies. However, such evaluations are particularly scarce for interventions in developing countries and countries with emerging economies. During the first phase of Climandes a pilot SEB study for the coffee growing sector yielded a very substantial benefit of an early warning system for conditions conducive to coffee rust (Lechthaler and Vinogradova 2017). In the second phase of Climandes the SEB study was done with a different approach. The estimate this time is based on a stochastic life-cycle model that builds on the relevant context information from the household survey and simulates a quinoa farmer's production and consumption decisions over a representative farming year. Based on the model, a specific frost warning is estimated to generate an increase of approximately 10% of their actual quinoa harvest. Translated into a monetary value and extrapolated to the total cultivated area of quinoa, this leads to a potential increase of 2.7 million USD per year for the Puno region (Brausmann et al. 2019).

Why Do Farmers not Incorporate Weather and Climate Information into Their Decision-Making?

The model we applied in the previous section assumes that a farmer correctly interprets and trusts the forecasted warning and knows how to apply the corresponding preventive measures. This is a strong assumption since the actual use of climate services by smallholder farmers in developing countries and countries with emerging economies remains a major challenge, as has already been shown in the context of

Sub-Saharan Africa (Carr and Onzere 2017). Even if climate services are available, they often fail to provide the information in a way that is meaningful to end-users. In order to properly design the climate services, the current barriers that limit the use of weather and climate information by the end-users were analyzed. Four aspects were especially evident and are described in Table 17.2. Firstly, the acceptance of science-based information is not complete. Secondly, access to information was not ensured for all farmers. Thirdly, farmers perceive the information currently disseminated as confusing and hard to understand. And finally, the information currently provided is insufficiently detailed for the specific location of their community.

Translating Evidence into Practice

Community Outreach: A Promising Strategy for Designing User-Driven Climate Services

The evidence generated in the first stage of Climandes unveiled the discrepancy between the weather and climate information currently provided and user requirements and expectations. This was manifested through low confidence in the information provided by the national meteorological service SENAMHI. It became clear that incorporating scientific weather and climate information into agricultural decision-making in remote rural regions like the Altiplano requires the active involvement of those targeted communities. In order to make available information meaningful for the end-users, we needed to overcome the four identified key constraints to utilization presented in the previous section, i.e. the lack of acceptance, lack of access, lack of comprehension, and lack of accuracy. To address this challenge, we undertook a community-based approach by conducting a series of monthly climate field workshops in two agricultural communities in Puno during the growing season 2017–2018. These workshops were organized and carried out by a multidisciplinary team, among them meteorologists and agronomists from the regional office in Puno and the headquarters of SENAMHI in Lima, as well as local non-governmental and governmental stakeholders interested in climate resilience and agriculture. The objectives of these workshops were to sensitize farmers to the use of weather and climate information, overcome key factors limiting their use, monitor and evaluate the impact of the intervention, as well as establish a continuous feedback cycle between the user and provider community.

Monitoring and evaluating the outcome of the intervention constituted a central part of our approach. To this end we developed a monitoring and evaluation approach that helped to continuously adapt the climate service to the user's needs and measure the impact of the intervention. The approach consisted of two elements:

(i) After each workshop, the facilitator responsible provided feedback on the workshop using a standardized form aimed at documenting the content and development of a given session;

Table 17.2 A community outreach through climate field workshops

Stage I: Evidence	Stage II: Evidence-based action
1. Lack of acceptance	Combining weather and climate information with traditional knowledge to enhance acceptance
Preference for environmental predictors One out of two farmers in the region favor traditional indicators over science-based information and considers these methods as sufficient for decision-making	Local traditional knowledge was widely used for predicting weather and climate by farmers in the study region. This knowledge served as a crucial entry point for discussing the information provided by the meteorological services. Each workshop started with a comparison between the previsions of a local community representative based on environmental predictors and a forecast presented by a meteorologist from SENAMHI. This activity served to illustrate the potential complementarity between scientific information and the traditional indicators in order to gain a robust foundation for decision-making. In order to value and preserve this ancestral traditional knowledge, Climandes made great efforts in documenting the natural indicators currently used in practice and published a book titled "Willay", using the Quechua expression for *reading natural signs* (Willay—Midiendo el Tiempo sin Instrumentos)
2. Lack of access	Improving the distribution channels to provide access to climate data and information
Lack of and unequal access to forecasts and warnings Almost 20% of the farmers are uninformed of upcoming weather and climate events. Low access is particularly prevalent in poor, less educated and female farmers	In the initial workshop, farmers were asked to present their preferred communication medium for receiving weather and climate information. In response to farmers' requests, we established two distribution channels to better reach the target population Local radio stations enable isolated communities to receive weather and climate information and agricultural advice. Thus, the first service consisted in transmitting the daily forecasts through two local radio stations in the pilot areas (*La Decana* in Juliaca and *Onda Azul* in Puno) in local languages Quechua and Aymara as well as in Spanish As the coverage for mobile phone networks is high and sharply increasing in rural regions (every other farmer in the target group owned a mobile phone), Climandes established, as second service, a text message service (SMS). The messages included weekly weather forecasts and early warnings of frost and drought events. According to feedback from farmers receiving these messages, they passed the information on to another four people on average in their community. In order to strengthen credibility of information and communication with farmers, it was essential that the SMS were disseminated by specialists from the SENAMHI regional office

(continued)

Table 17.2 (continued)

Stage I: Evidence	Stage II: Evidence-based action
3. Lack of comprehension	Improving climate literacy for a better comprehension of weather and climate information
Forecast is poorly understood 42% of producers perceive the information currently disseminated as hard to understand. These comprehensive issues are particularly prevalent in less educated and female respondents	A core element of the climate field workshop was the capacity-building of the user community. Local SENAMHI meteorologists covered weather and climate aspects such as the general principles and limitations of scientific forecasts, characteristics of the local climate, the El Niño phenomenon, cloud types, as well as causes of high-impact events like frost, drought and hail. Local agronomists complemented this input with corresponding measures to protect crops from agro-climate hazards. Farmers were shown how to interpret the weather and climate information they receive via radio and text messages. Users gave feedback on the information provided which led to modifications of the content and distribution of the information
4. Lack of accuracy	Discussing local implications of weather and climate information to address the accuracy issue
Forecast not accurate at local scale Information currently provided information is not accurate enough for the specific community to take decisions	All weather and climate information is by nature uncertain with the level of uncertainty typically increasing with forecast lead time. The highly complex terrain of the Puno region makes localized forecasts very difficult, even on short-time scales. This difficulty is also associated with the low density of available weather stations. To avoid unrealistic expectations by the farmers, the limitations of weather and climate information were regularly discussed with participants during the UIP workshops. With this in mind, the implications of the most recent forecast for their specific area was analyzed and discussed. Also, the choice of the kind of weather and climate information communicated to the users has to be adapted in a smart and careful way to the specific user groups. For instance, long-term information such as seasonal forecasts or even climate scenarios is not appropriate for individual smallholder farmers, as they are usually characterized by a high degree of uncertainty. Delivery of such information, typically communicated in a deterministic way, is potentially counterproductive, as it will inevitably lead to many false or missed alarms and counteract the increased trust in the national meteorological service

The identified main constraints of weather and climate information utilization for small-scale farmers were directly and specifically addressed in the monthly climate field workshops organized in two agrarian communities in Puno

(ii) Over the workshop series, we repeatedly tracked specific indicators reflecting farmers' acceptance, comprehension, accuracy and trust through a structured questionnaire. The resulting indicator values were used to quantify the impact of the climate field workshops. This analysis was carried out with 68 farmers after the initial, 32 farmers after the midterm and 37 farmers after the final workshop. Only 4 farmers were interviewed after all of the three workshops.

The results of this procedure are summarized in Fig. 17.4. They indicate that the workshops fostered a strong increase of trust in the meteorological service (SENAMHI) and in the weather and climate information they provide (Fig. 17.4). This was not only reflected by a growing credibility for the institution (panel d, *credibility*, an important attribute of information) but also by the perception that the information provided coincided with reality (panel c, *accuracy*). Farmers reported that they considered this information in their decision-making (panel b, *adoption*) and that, in doing so, it actually improved their prospects for production. The understanding of weather and climate information was still a critical point in the user community we worked with and did not improve significantly over the period of intervention (panel a, *comprehension*).

The fact that the adoption of climate increased from below 50% to around 80% but the comprehension stayed basically the same is not very intuitive and deserves some discussion. Why would the users progressively base their decisions on forecasts they did not have a better understanding of? On the other hand, the uptake of the services can occur while understanding still remains poor. For example if the awareness of the existence of services is low, utilization can simply be increased through better information on existing offers, independently of how well they are understood. Alternatively, many farmers may have understood the information, but did not know where it came from. Also, the credibility of the services improved after the first workshop almost to the maximum value possible. This could have been the case because the explanation given by the technicians was very convincing, or because the users were impressed by the novelty of the kind of services. It is fair to say, especially given the users' noticeable reservations about modern climate and weather information and their prior lack of experience in interpreting this information, it will probably require longer interventions to enhance the overall acceptance of new information. That credibility it is built by using the products consistently over an extended period of time. So that the benefit becomes tangible, but the results of the monitoring point in the right direction.

Beyond Climate Service Implementation

Through the results of our study and the experience gained during the project implementation, we have learnt that—besides the fundamental necessity of weather and climate information—there are critical factors which are beyond the scope of the

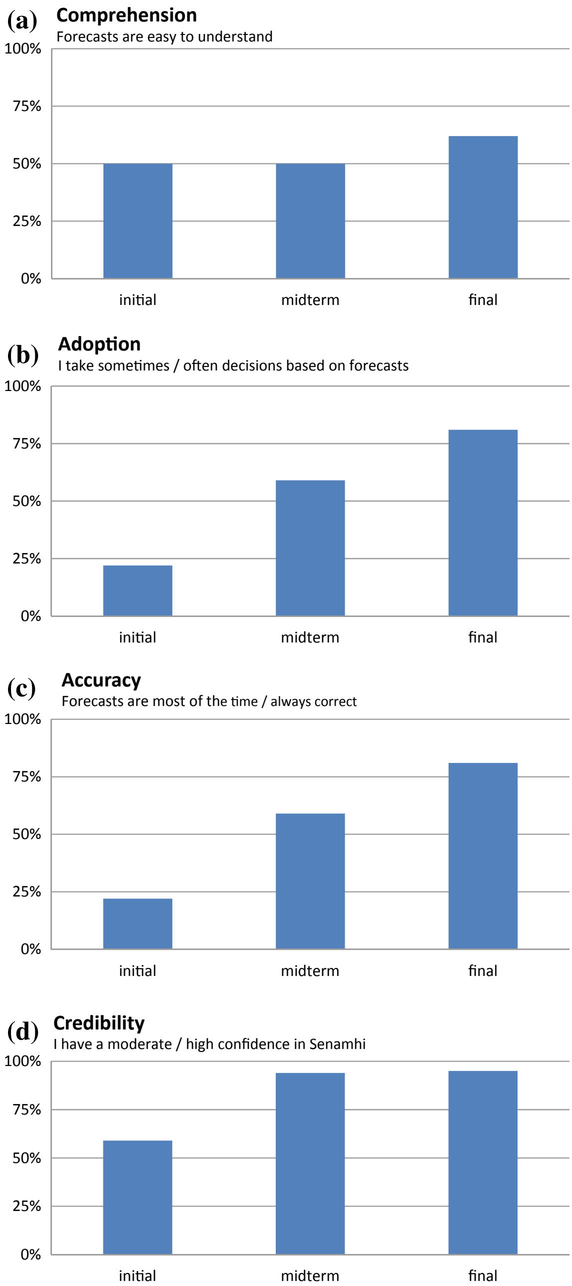

Fig. 17.4 After the initial, midterm and final workshop held in the two communities, we asked farmers to fill out a survey. The results demonstrate some of the benefits of our pilot UIP. While comprehension only slightly increased (**a**), farmers report that they more often integrate forecasts in their decision-making (**b**), perceive forecasts to be more accurate (**c**) and have more confidence in SENAMHI (**d**). Bars on the left of the plots denote results from initial workshop (sample size n = 68), bars in the middle from midterm workshop (n = 32), and bars on the right from final workshop (n = 37)

project mandate to enhance the resilience of the most vulnerable populations. Nevertheless, we would like to discuss complementary issues to climate services that became evident. A key finding of this project is the target population's low capacity to overcome shocks such as high-impact weather and climate events. The evidence brought forth by the project made clear that access to formal financial services, crop markets, social protection and governmental aid have to be strengthened in order to mitigate the negative long-term consequences arising from these events. As a matter of fact, these results highlight the very low access to formal insurance against crop losses with only 2% of the households being insured. Risk transfer would prevent farmers from selling their livestock and other assets, abandoning their farmland to find alternative work elsewhere and borrowing money or reducing nutrition. Therefore, micro-insurance services based on weather indices have gained increasing attention in recent years in the framework of development cooperation.

An additional prominent vulnerability factor was found to be the low incomes compared to other sectors and hence the lack of savings necessary to recover from the effects of a high-impact event. Smallholders could benefit from better access to market systems to receive better market prices. Although the majority of production in the project region Puno is extensive, only a very small share of the smallholder farmers certify their production as organic, even though prices are significantly higher for certified crops (+33%). The main reason for not certifying the products is lack of knowledge (84%) and—to a lesser degree—the high administrative burden (13%). Farmer cooperatives like Agrobosque in the Peruvian region Madre de Dios, for example, help their members sell their quality products for better market prices, by providing direct market access and organic certification.

Summary and Conclusion

Climandes was performed from 2012 to 2019 in two phases as a twinning project between SENAMHI Peru and MeteoSwiss to implement user-tailored pilot climate services for the agricultural sector, more specifically for the smallholder farmers of the Peruvian Andean highlands. The main findings can be summarized as follows:

- Climandes provides a proof-of-concept for the relevance of the UIP concept as a basis for user tailored climate service implementation. We implemented a GFCS pilot UIP using a two-stage approach that is built around evidence-guided action. This approach turned out to be a key factor for the success of the Climandes project, which is mainly due to the involvement of the user community at a very early stage. This community not only includes small-scale farmers as end-users, but also involves intermediary users such as private and public partner institutions that transformed the climate data and information into agro-climatic advice. As exemplified by this user-supplier interaction, the project confirmed the importance of incorporating sectoral, and hence transdisciplinary expertise in order to provide meaningful end-to-end climate services.

- Although Climandes focused specifically on smallholder farming in the Andean highlands, the proposed two-stage approach to set-up a UIP involves a number of generic elements that can be transposed and applied to other sectors with quite different user profiles, while continuing to ensure a user-driven process. We therefore provide a summary of these key elements of the process in form of a checklist for the proposed two-stage approach for designing user-driven climate services (Table 17.3). These comprise the participation of the user communities, the tailoring of the climate information and communication, on the supply side the provider capacities, and finally, for the sustainability of the results most importantly, a dialogue at the policy making level. Overall, the checklist highlights the importance as well as the necessity of a substantial user-supplier engagement, in whatever form effective.
- Community outreach requires decentralized resources, i.e. the regional office of Peru's meteorological service proved to be the mainstay for effective provision of climate services. Not only were the personnel responsible for the production and distribution of the weather and climate information but, more importantly, it had the hands-on knowledge of the hazards to which local communities are exposed, as well as the ability to reach out and engage with the local population. Thus, our experience made it clear that the implementation of a UIP based on community outreach is resource-intensive and requires enhanced capacities of technical staff in meteorological offices in peripheral regions. Particular attention must therefore be paid to the decentralization of meteorological services in the implementation countries.
- We deem that the twinning approach chosen for the Climandes project implementation was a recipe for success. The main focus and effort of the intervention has been in the development of capacities in the climate and user communities. All activities were developed in a partnering collaboration between the regional and national offices of SENAMHI Peru and MeteoSwiss, and can be seen as an effective peer-to-peer, on-the-job training and also as a means of building personal professional networks. Capacity development was complemented with a series of both online and classroom courses covering all themes of the project and providing training on specific climate-service related topics. The courses were attended by international participants, also fostering the exchange between professionals of the weather services of the region, for example through monthly online briefings on seasonal forecasts. The course material remained available upon registration on the platform for online courses from the Peruvian meteorological service.

Although this chapter mainly focused on the user's perspective of climate services specifically the UIP, Climandes made great efforts and progress in the other technical and provider-oriented components of the GFCS framework. We put particular emphasis on the quality of observational data because spatially and temporally complete, high resolution climate data are required for climate services to be reliable (Gubler et al. 2017; Hunziker et al. 2017). We also developed daily gridded datasets of precipitation and temperature, as these are necessary for analyzing the past climate in more spatial detail and for increasing the spatial resolution of the statistical forecasts, which are carried out operationally at SENAMHI. We investigated the skill of SENAMHI's seasonal forecasts using statistical and dynamical forecast models. Besides temperature and precipitation, parameters tailored to the phenological cycle were analyzed (e.g. frost days or dry days during the growing season), yielding significant skills for some temperature-based parameters and only marginal skills for

Table 17.3 Checklist for the design of user-driven climate services based on expertise gained in the Climandes project

Stage I: Setting the scene by providing evidence	Stage II: Establishing a user-driven climate service prototype
User community participation	
• Identify and evaluate key stakeholders and users relevant for climate services (stakeholder mapping) • Assess socio-economic vulnerability of the target population including the characterization of key hazards (exposure and sensitivity) as well as socio-economic characteristics (adaptive and coping capacities) • Identify vulnerability factors such as gender, socio-economic status, income inequalities, etc.	• Establish a continuous interaction mechanism e.g. through workshops targeted to directly address the identified constraints to the use of weather and climate information • Improve the climate literacy of the target users
Tailored information and communication	
• Identify key constraints to utilization of weather and climate information • Assess cultural aspects regarding climate service utilization (e.g. indigenous knowledge, traditional farming practice) • Understand how target population can be reached (e.g. radio stations, mobile phone distribution)	• Develop a distribution strategy • Establish information tailored to the users and delivered through identified distribution systems • Establish a feedback mechanism to verify that forecasts and warnings are received and understood with the aim to continuously improve the service
Provider capacities	
• Identify scientific, technical and operational gaps regarding climate service provision (e.g. low station density, lack of technical capacities, insufficient data and product quality, missing human resources at peripheral level)	• Rectify the scientific, technical and operational gaps on the provider side to improve data and product quality • Increase awareness in the climate community to guarantee an appropriate user commitment to the consideration of user needs for climate data and products
Policy dialogue	
• Evaluate potential socio-economic benefits of planned climate service to facilitate policy engagement • Implement a monitoring and evaluation process to measure the impact of the intervention	• Hold a policy dialogue with local, regional and national policy-makers to help them understand the return on their current and future investments in climate services

(continued)

Table 17.3 (continued)

Stage I: Setting the scene by providing evidence	Stage II: Establishing a user-driven climate service prototype
Striving for sustainability	
• Bring all developed services to operation • Upscale the prototype service to a wider user community	• Share lessons learnt and key experiences with other organizations and practitioners

We provide this checklist for the proposed two-stage approach for designing user-driven climate services. These stages encompass an accurate assessment of the implementation context (setting the scene by providing evidence); base the implementation processes on this assessment (establishing a user-driven climate service prototype) and ultimately, an operationalizing and scaling-up of the implementation to a wider region (striving for sustainability)

precipitation and parameters based on the latter. Given the substantial uncertainty at the seasonal range level, these forecasts do not seem to be of direct use for individual farmers. Rather, we see a potential value at a more institutional level, where seasonal forecasts can raise the awareness for releasing humanitarian funding, trigger risk-reducing actions, enhance preparedness and response and thus make disaster risk management overall more effective.

In summary, the Climandes project demonstrated that improved access to weather and climate information for the most vulnerable people significantly enhances their disaster preparedness and therefore contributes to protecting their livelihoods. The estimated potential socio-economic benefits of enhanced use of climate and weather information are likely to exceed the costs of developing and maintaining the provision of that information. However, the project testified to the great challenges in climate service implementation in developing countries and countries with emerging economies.

Through the user-participatory approach, we managed to overcome identified key constraints in the utilization of weather and climate information. In fact, our experience suggests that the co-developed climate service implemented enhanced the user communities' trust in scientific information and improved their adoption in agricultural decision-making in order to tap the potential socio-economic benefits that climate services provide.

In the face of the global climate change challenge, Climandes caters to the great need for climate service interventions in developing countries and countries with emerging economies. As such, it is well in line with, and can be seen as a significant contribution to the GFCS. Climate services are public assets, for which unrestricted and unlimited access should be guaranteed for the entire population. In other words, we should strive to make climate services more inclusive, by paying particular attention to the needs and constraints of the most vulnerable and marginalized population groups, which encompass the poor, the low-educated and women, as underlined by the evidence gained in this project.

Our study had some limitations. Most importantly, only a subset of the workshops participants were included in the data collection. Producing a more in-depth impact evaluation of improved access to weather and climate services would require an experimental design including a larger sample and a control group. Furthermore, field experiments could potentially quantify the impact of weather and climate services and corresponding management decisions on the yields and socio-economic status. However, such a study design could not be carried out within budget and time horizon of this project.

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Glossary

Climate services A climate service is a decision aide for governments, organizations and individuals and seamlessly derived from information about the past, current and future climate. Design and implementation of a specific climate service requires in-depth and iterative engagement with the users in order to tailor it to their key characteristics and needs. Effective climate services support climate-smart decisions and in this way lead to increased social and economic resilience to climate variability and change (WMO 2013).

User Interface Platform The User Interface Platform is one of the five main pillars of GFCS necessary for a functioning climate service system. It is the mean of interaction for users, researchers and climate service providers to bridge the gap between the science and user community and to guarantee the climate services meet users' needs. The design of a UIP can vary sector-specifically, but importantly, its design is based on evidence of the users' needs.

Resilience Resilience describes the capability of a system or part of a system to absorb or recover from the effects of a hazardous event and return to its former functionality. This can happen through preservation.

Hazard A hazard describes the potential occurrence of a natural or human-induced physical event that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources. Climate-induced hazards are hazards from atmospheric phenomena, that have the potential to affect humans, their structures or activities adversely. This includes all kind of events that deviate strongly from the mean climate, such as cold waves, dry periods or heavy precipitation events. More specifically, agro-climatic hazards are climate hazards with adverse effects for the agricultural system.

Exposure Exposure describes the exposition of people, livelihoods, resources and infrastructure to environmental hazards. The exposure matters, as an environmental hazard only becomes a risk if people or infrastructures are exposed and vulnerable to this hazard.

Sensitivity Sensitivity describes the degree to which a system (a community or an ecosystem) reacts and responds to a climate change or event. This includes both beneficial and problematic responses, resulting for example in food insecurity due to unfavorable climate conditions and yield loss.

Adaptive capacity Adaptive capacity describes the ability of an individual, community or society to prepare for a coming hazard and take actions to alleviate its adverse impacts. The adaptive capacity to mitigate damage depends upon the available resources (e.g. financial), decision options as well as available information.

Coping capacity The coping capacity is the ability of people, organizations, and systems, using available skills, resources, and opportunities, to address, manage and overcome adverse conditions; in the case of climate an extreme event such as a drought, a frost or an extreme precipitation.

Vulnerability This refers to the predisposition of a community, system or asset to be susceptible to the damaging effects of a hazard through a set of characteristics and circumstances. This can include for example a low adaptive capacity relative to a hazard or a high sensitivity towards it.

Risk transfer Risk transfer describes the process of shifting the financial consequences of a risk from the asset at risk to another, in many cases, less vulnerable party. A risk transfer can occur formally through insurance or through governmental aid.

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