



***Socio-Economic Benefits of  
User-Tailored Climate Services:***

**A Case Study for the Coffee  
and Maize Production in Peru**

***Valuing Climate Services***

#### Imprint

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# Preface

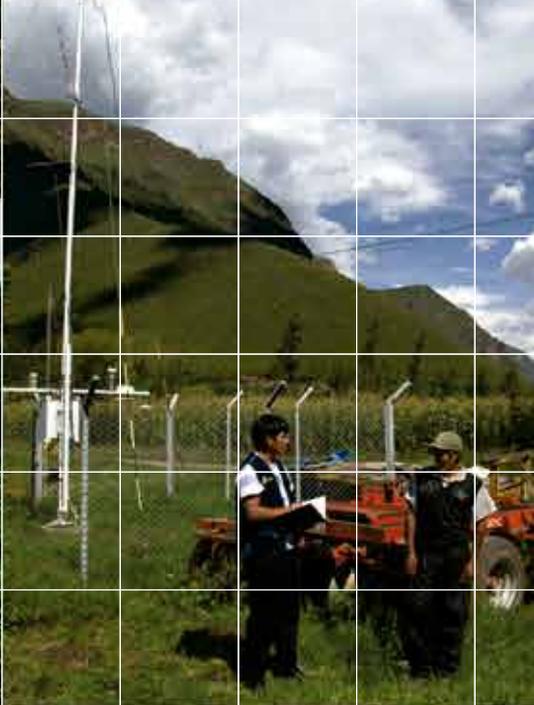
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Climate services are a fundamental element for national climate change adaptation strategies in climate-sensitive sectors. Widely considered as “public goods”, one would think that such services should be financed publicly. Quantitative evidence of the socio-economic benefits (SEB) coming from user-tailored climate services constitutes a necessary building block for public policy making which helps mobilizing the required financial resources.

Bespoke climate services meeting the needs of smallholder farmers carry the potential for building resilience to climate change. As such they contribute to developing a climate-smart agriculture and thus, ultimately, enhancing food security and reducing poverty, especially in rural and mountainous regions. This booklet presents the results of a first pilot case study for the coffee and maize sectors in the Peruvian region Cusco. They hold good promise that efforts of this kind replicated in other sectors will confirm the potential value that flows from public investments into user-tailored climate services.

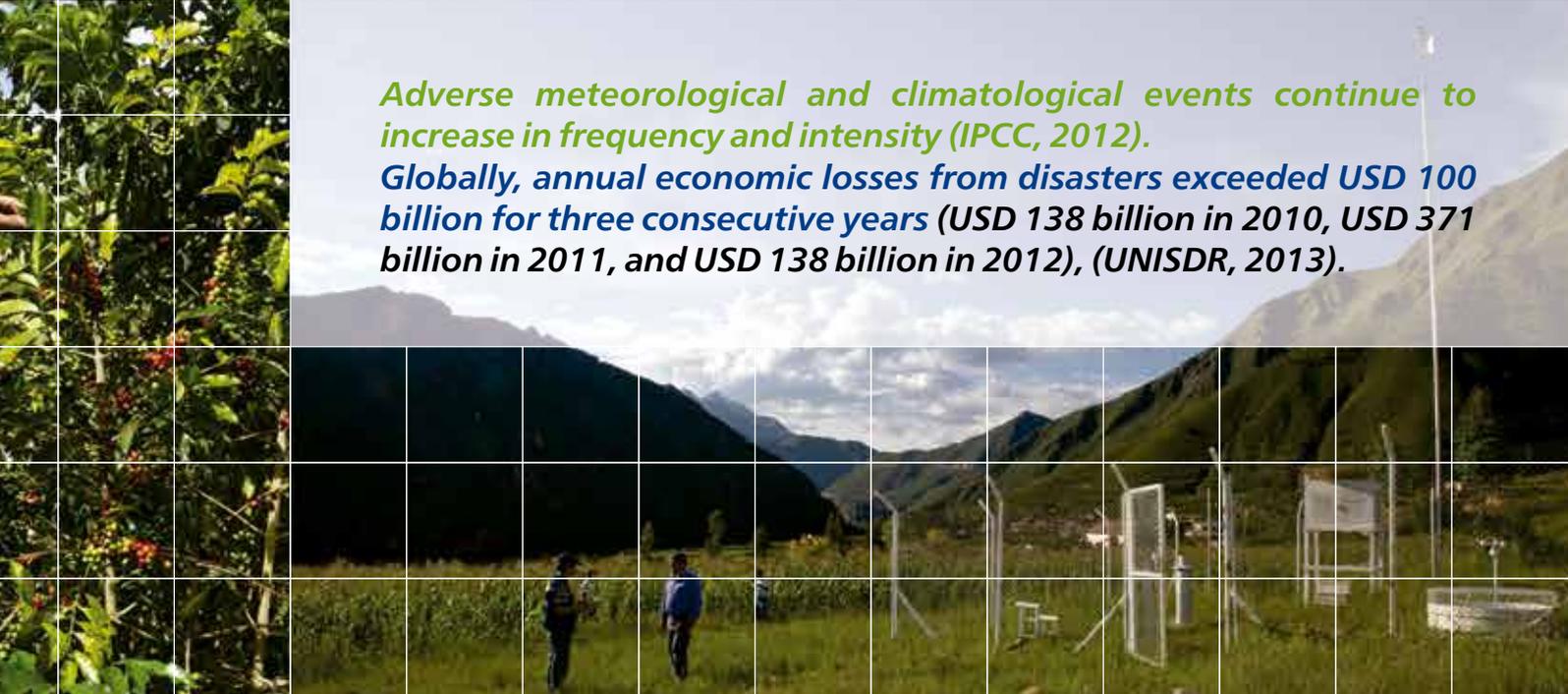
Through the CLIMANDES project, SENAMHI and MeteoSwiss join forces to generate the required climate services. This innovative collaboration between two high-mountain countries forms part of the WMO-led Global Framework for Climate Services (called “GFCS twinning”). The GFCS program seeks to promote science-based, user-tailored climate information and prediction in four priority areas – among which agriculture and food security. Fed into planning, policy and practice level, this enables better management of and adaptation to the risks arising from climate variability and change on the global, regional and national scale.

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Executive President of SENAMHI  
Permanent Representative of Peru with WMO





*Adverse meteorological and climatological events continue to increase in frequency and intensity (IPCC, 2012). Globally, annual economic losses from disasters exceeded USD 100 billion for three consecutive years (USD 138 billion in 2010, USD 371 billion in 2011, and USD 138 billion in 2012), (UNISDR, 2013).*



# *Index*

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Preface	3
Executive Summary	8
01. Introduction	10
02. Study Design & Methods	12
03. The Crops	15
04. Results & Discussion	17
05. Conclusions	21
Acknowledgements	23
References	24

Smallholder farmers peel harvested maize for sale.



# Executive Summary

Peru has 7.6 million hectares of cropland and 32% of the economically active population works in the agricultural sector, which is particularly climate sensitive. Climate-related problems such as diseases and high-impact weather events lead to significant crop losses which cause serious socio-economic consequences for farmers, as well as endanger food security. In addition, in a changing and more strongly variable climate, ancient techniques used by farmers as preventive measures do not show the expected results.

Impacts as these are challenging economic activities across numerous climate-sensitive sectors around the globe. Climate services such as early warning systems can provide essential, science-based information in support of national and international adaptation and mitigation strategies to reduce economic losses and negative societal impacts. This is particularly true for the agricultural sector where user-tailored early warning systems can support preventive measures to avoid, or reduce, yield losses and generate substantial socio-economic benefits by improving the farmer's decision making.

These potential benefits have been assessed by the Peruvian National Service for Meteorology and Hydrology (SENAMHI) and the Swiss Federal Office of Meteorology and Climatology (MeteoSwiss) on the basis of the farmers' willingness to pay for a hypothetical early warning system user-tailored for the coffee and maize production in Cusco. The analysis is based on a stated preference method applied to survey data from more than 60 interviews with smallholder farmers.

It is found that the socio-economic benefits of these enhanced climate services for the production of the two crops over a 10-year period amount to about USD 10 million for the region Cusco and well over USD 100 million for Peru as a whole. These results can be considered conservative estimates representing a lower limit of the benefits as a number of additional positive externalities are not considered in this study.

Socio-Economic Benefits (over 10 years operation time; discount rate 4%)			
<b>Region Cusco</b>		<b>Minimum</b>	<b>Maximum</b>
	Coffee	USD 9 million	USD 14 million
	Maize	USD 2 million	USD 3 million
	<b>Total</b>	<b>USD 11 million</b>	<b>USD 17 million</b>
<b>Peru</b>		<b>Minimum</b>	<b>Maximum</b>
	Coffee	USD 63 million	USD 93 million
	Maize	USD 29 million	USD 57 million
	<b>Total</b>	<b>USD 92 million</b>	<b>USD 150 million</b>

Own calculations.

These findings indicate a clear need for user-tailored climate services thus strongly supports the implementation of the Global Framework for Climate Services (GFCS). This is particularly true in the example of smallholder farmers in the Andean region who face concrete climate-related problems. For instance, an early warning system for coffee rust outbreak allows for targeted preventive measures and thus is a fundamental element towards climate-smart agriculture.

That said, interviews with the farmers in the study region reveal that agricultural decision-making is based on climate information to a small extent only. In order to realize a larger portion of the full potential, it is mandatory to raise the end users' awareness for the benefits that climate services can provide. This underscores the importance of the user-dialogue to meet the community's specific needs and requirements which can be considered of the GFCS User Interface Platform.

User-tailored early warning systems for the agricultural sector can enhance smallholder farmers' resilience against high-impact weather and climate events. The promotion of such climate services was recently emphasized in the Sendai Framework for Disaster Risk Reduction.

In conclusion, National Meteorological and Hydrological Services (NMHSs) can and should, play a central role in ensuring food security and reducing poverty and thus increasing a country's adaptation capacity to climate change. It is therefore key to generate public policies for mobilizing the required resources to enable NMHS to deliver the required climate services.

Coffee farmer in Santa Teresa (Cusco) shows coffee plant in the last growth period.



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# 01. *Introduction*

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The impacts of climate change and climate variability pose risks for natural systems, society and economic activities including agriculture, which is particularly climate-sensitive (IPCC, 2014). High-impact events such as droughts, heavy rainfalls, floods and frost can cause substantial negative consequences on crop and croplands entailing severe social and economic consequences for smallholder farmers. A recent example is the severe drought in Central America with yield losses in the maize production estimated at up to 70% (FAO, 2014).

Moreover, climate conditions favor the occurrence of certain plant diseases, leading to devastating impacts on productivity. In 2013, the severe outbreak of coffee rust in Latin America decreased production and boosted expenditures on additional pest control. In Central America, for instance, over 50% of the total growing area has been affected by the disease causing economic costs of USD 500 million in 2012/2013 (ICO, 2013b). The spread of the coffee rust disease in the various parts of Peru is shown in a figure on page 13.

More than half of global food production is delivered by smallholder farmers and, thus, contribute significantly to food security and nutrition (UNEP, 2013). Furthermore, smallholder farming is a substantial part of employment in rural regions where the agricultural sector plays a central role for the local economy. On the other hand, smallholder farmers are highly vulnerable to climate-related events since they often lack suitable warning services and are unable to apply preventive measures against negative impacts.

Early warning systems can mitigate and even prevent losses from high-impact events and constitute a cost-effective measure to build resilience of smallholder farmers to climate variability and change. This importance was recently emphasized in the new Framework for Disaster Risk Reduction adopted in Sendai earlier this year (UNISDR, 2015). Very much along this line, the Third World Climate Conference held in 2009, and extraordinary Congress in 2012 mandated the Global Framework for Climate Services (GFCS) where agriculture and food security was identified as one of the four priority areas established so far (WMO, 2014).

In general, due to high infrastructural investments, the development and implementation of early warning systems is very likely to be financed and provided publicly. It is therefore fundamental to generate public policies for mobilizing the required public financial resources to extend and maintain these systems. An essential tool towards reaching this goal are studies providing quantitative evidence of the socio-economic benefits (SEB) provided by such climate services. The importance of SEB case studies in the hydro-meteorological sector is stressed in the Madrid Action Plan in 2007 by the World Meteorological Organization (WMO, 2007).

SENAMHI and MeteoSwiss have carried out a case study to assess the socio-economic benefits of user-tailored early warning systems for smallholder coffee and maize farmers in the rural Andean region Cusco. The study is strongly linked to the Peruvian-Swiss GFCS-twinning project CLIMANDES (Servicios climáticos con énfasis en los Andes en apoyo a las decisiones), a strategic alliance between the World Meteorological Organization, the Swiss Meteorological Service (Meteoswiss), Meteodat, Berne University (Switzerland), La Molina University and the Peruvian National Meteorological and Hydrological Service (SENAMHI) which receives technical support and funding from Swiss Agency for Development and Cooperation (SDC). The project seeks to raise the decision-makers' awareness of the benefits of user-tailored climate services in the Andes region.

The case study is funded by the Swiss Agency for Development and Cooperation (SDC). The project is coordinated by the Federal Office of Meteorology and Climatology MeteoSwiss in close collaboration with SENAMHI and realized with the Swiss project partners Center of Economic Research at the Swiss Federal Institute of Technology in Zurich (ETHZ) and Meteodat GmbH.

Weather station in the maize production area of Paucartambo (Cusco) generates climate information needed for the cultivation of maize.



## 02. Study Design & Methods

The study focuses on the region Cusco, one of the two pilot regions of the CLIMANDES project. Cusco is located in the south-east of Peru characterized by the mountain range of the Andes with diverse agro-climate conditions. The study concentrates on the production of coffee and maize, cultures that are particularly climate sensitive (Tai, Val Martin, & Heald, 2014). Both crops are vital for Cusco's agricultural activities. Coffee is the most important cash crop supporting farmers' livelihoods while maize as subsistence crop contributes to food security (see boxes).

Similar to weather forecasts, early warning systems are usually treated as public goods (Freebairn & Zillman, 2002). A typical empirical challenge related to the economic valuation of public goods is that its value cannot be directly extracted from observing market activities, which means that there is no direct evidence on how much people are willing to pay for it. This willingness to pay, however, is required as it provides a monetary measure of welfare change induced by the public good serving as the basis for deriving the corresponding socio-economic benefits. The economic discipline provides different techniques on how to derive values for such unpriced goods and services. In this study stated preference methodology is applied in order to estimate the economic value of user-tailored early warning systems in Cusco. This survey-based approach has been widely used for the valuation of environmental goods in the economic literature (see e.g. Adamowicz, Boxall, Williams, & Louviere, 1998).

Interview with farmer in Santa Teresa (Cusco) during field work.



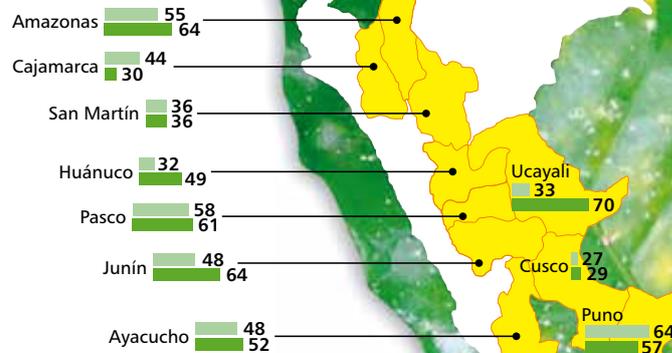
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## Effects of the yellow Rust on coffee

### Preliminary assessment By regions (%)

REF: ■ March ■ April

■ Affected regions



At national level  
In April It reached  
**51% infected  
With yellow rust**

In marchc  
it reached 43%

*Hemileja vastatrix*  
(Coffee rust)

### Ways of getting infected

The plant gets infected when there is high humidity and too much water on the leaves. It could be due to:

- Water from rainfall
- Wind, sprinkles or drags water
- Infected seeds
- Use of tools in different farms
- Animals

*The rust fungus quickly spreads due to constant climate changes*

### Symptoms:

It starts showing small yellow, orange and black spots.

At first the spots are small and round. They have almost 5 mm diameter and they can grow up to 10 times more.

The infections and sporulation or production of spores start to show on the underside of the leaf.

Source: Ministry of Agriculture

LA REPUBLICA

As user-tailored climate services do not yet exist in the study region, a survey scenario which describes a hypothetical market for early warning systems (*alerta\_roya* and *alerta\_maíz*) is developed. A sample of 63 smallholder farmers is asked direct and indirect questions about their willingness to pay for these products in order to quantify the economic benefit.

*Alerta\_roya* is designed as an early warning system providing coffee farmer with an alert in case of increased risk of coffee rust outbreak based on air temperature, humidity and precipitation measurements. Using this information and combining it with agronomic expertise, farmers can decide on preventive measures (e.g. use of fungicides) to mitigate the impact of the disease.

*Alerta\_maíz* is designed as early warning system that warns farmers of frost or heat waves. Depending on the phenological stage of the plants, these events can affect their growing process, deteriorate the leaves and roots and can alter the fructification process leading to a diminishment of quantity and quality. In a period with expected frost, the farmer has the opportunity to postpone the seedtime. In case of a heat wave, water management could be optimized to prevent water deficits.

The questionnaire consists of two parts. A general part elicits information about the farmers' socio-economic characteristics as well as their perception and use of existing climate services provided by SENAMHI. The second part is designed to extract the farmers' willingness to pay for the specific early warning system under consideration (*alerta\_roya* and *alerta\_maíz*). These climate services are described by the annual cost to the farmer's household and three attributes. Based on expert interviews as well as on experience from existing studies of individuals' value for weather forecasts (Lazo & Chestnut, 2002; Lazo & Waldman, 2011), three climate service attributes are defined: frequency of updates, geographic resolution and accuracy of the information.

For the estimation of the respondents' willingness to pay, the stated choice technique is applied. Respondents are confronted with a number of alternative climate services that include differences in attributes and costs. The alternative that the individuals prefer reveals information with regard to their underlying value for the service. The data generated by the questions are analyzed using the Random Utility Model (see e.g. Hanemann & Kanninen, 1996).

The described valuation methodology only allows deriving the economic benefit of the climate services at the individual farm level. In order to obtain benefits over the target population in the Cusco region and at national level, the economic benefit per hectare is linear interpolated to the related area under cultivation of the respective crop.

These producers expressed the need for climate information to know in advance the availability of water for their crops and are willing to pay for this service. Interview with maize farmers in Cusco. In the background, the drying process of peeled maize can be observed.



# 03. *The Crops*



## *Coffee production in Peru*

Coffee is Peru's most important agricultural export commodity. In 2012, coffee valued at roughly USD 1 billion was exported corresponding to 3% of the global coffee market (ICO, 2013a). Cusco is the fourth most important coffee-producing region in Peru with a cultivated area of roughly 59'000 hectares representing 14% of country's total area cultivated with coffee (2013) (MINAGRI, 2014a). Optimal conditions for producing high-quality coffee are located at altitudes between 1'200 and 1'800 meters above sea level (MINAGRI, 2014a). The climate regime of rainy and dry periods is important for flowering, proliferation and growth of the coffee plant.

Since 2013 coffee production in Cusco, as in other Peruvian regions and Latin American countries, has been enormously affected by a severe outbreak of coffee rust resulting in significant crop losses. Consequently, the Peruvian Ministerio de Agricultura y Riego declared the national state of emergency for coffee production in order to take immediate actions to combat and control the disease.

Coffee rust is caused by *Hemileia vastatrix*, a fungus affecting the leaves of the coffee plant leading to a premature drop of the infected leaves (further information on the disease can be found in the figure on page 13). As a consequence, annual yields and the quality of the coffee declined. This can result in serious economic consequences for coffee farmers since production costs simultaneously increase (e.g. additional expenditures for pest control, investment in plan renovation). Besides the direct economic impact on individual farmers, the outbreak of coffee rust also has societal impacts including job cuts because of decreasing demand for labor in the coffee plantations (Cintra, Meira, Monard, Camargo, & Rodrigues, 2011).

Even though, there is limited information available for the impact of climate change on tropical crops, studies have shown that specific, persistent hot and humid meteorological conditions stimulate the outbreak of coffee rust (Cintra et al., 2011)





## *Maize production in Peru*

Maize is one of the most important food crops in the Peruvian Andes. Peru's total production volume has reached more than 1.4 million tons in 2013 cultivated on a total area of 540'0000 thousand hectares (MINAGRI, 2014b)

Originated in the Andean region of Latin America, maize stands out through an enormous variety of different types, each one having adapted to specific altitudes, climatic conditions and soil structures (FAO, 2013).

In Cusco, maize is cultivated at altitudes between 2'000 and 4'000 meters above sea level, where the majority of the farmers depends on subsistence agriculture (MINAGRI, 2013). At these altitudes, crop production is significantly challenged by weather stresses such as droughts, frost, hail and heavy rainfall. Smallholders are particularly vulnerable to such high-impact events, because of their limited mitigation capacities. Reduced yields or even total crop losses have severe impacts on food security in affected regions and thus threaten livelihood of smallholders (Sietz, Choque, & Lüdeke, 2012).

Although maize types cultivated in Cusco are optimally adapted to the climatic conditions, they are sensitive to extreme climate conditions. The sensitivity varies according to the growth period. A frost during the seeding stage can significantly harm the crop. Furthermore, the water shortage during the flowering period at the time of pollination affects the grain yields negatively or can result in a total loss (FAO, 2013).

In order to avoid crop losses, farmers can take preventive measures. In some cases those actions are limited such as in case of heavy rainfall, hail or in the absence of water resource infrastructure.



# 04. Results & Discussion

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## 4.1 Farmers' perception and use of climate information

Most farms in the sample were smaller than 5 hectares which is consistent with results of the Censo Agrario 2012 showing that 80% of Peru's farmers cultivate an area smaller than 5 hectares (INEI/MINAM, 2013). Coffee farms were on average larger than maize farms. Interviews reveal that the Peruvian NMHS SENAMHI is generally well known among smallholder farmers providing them with useful information for decision-making. The most relevant information channels are radio and television. However, farmers' decision-making is based on climate information to a small extent only (on average services provided by SENAMHI are used once a month). Various farmers complement SENAMHI's products with traditional knowledge for decision-making.

Farmers report that most important meteorological parameters for the cultivation of coffee and maize are air temperature, precipitation and humidity. This is in line with the indicators described in the technical literature. Coffee farmers mention diseases (i.e. coffee rust) as the most important climate-related stress factor threatening the agricultural production. Like in other parts of Peru and Latin America, coffee production was heavily affected by coffee rust in 2013. Some farmers in Santa Teresa experienced significant yield losses between 60 –80% in 2013 compared to previous years. Drought and heat are further relevant climatic stress factors which

Seedlings in a coffee plantation in Santa Teresa (Cusco).



can be particularly harmful to the coffee plant depending on the phenological stage. Maize farmers mention frost as the most influential climate related stress factor followed by drought and hail. Similar to coffee crops, the occurrence of such an event can severely harm the maize plant if it is in a delicate phenological stage. In contrast to the coffee producers, maize farmers report diseases to be less of an issue.

## 4.2 Economic valuation of early warning systems

The Random Utility Model is used to derive monetary values that represent the farmer’s benefit of the climate services. The hypothetical early warning systems (*alerta\_roya* and *alerta\_maíz*) are characterized by annual costs and three attributes: frequency of updates, geographic resolution, and forecast accuracy. Data analysis reveal that these attributes have a plausible and expected impact on the farmer’s valuation: geographically more detailed information and lower annual costs of the climate services significantly increase the farmers’ benefits.

As the valuation is linked to the attributes of the hypothetical early warning systems, assumptions regarding accuracy and geographic resolution had to be made. Therefore, two types of hypothetical climate products of different quality are defined (a minimum (“min”) and a maximum (“max”) product) to reflect the uncertainty related to accuracy and geographic resolution. Accuracy is assumed to vary between 70% (min) and 90% (max) and the geographic resolution between 25 km (max) and 100 km (min). Since specific climate services for the coffee and maize sector do not yet exist in the study area, the baseline is assumed to be 0% accuracy and 140 km geographic resolution.

Table 1 reports that the annual value of the early warning system per farm is higher in the coffee sector with USD 54 (min) to USD 80 (max). The annual value per farm in the maize sector is USD 8 (min) to USD 16 (max). As coffee farms were larger than maize farms, it is useful to calculate the service value per hectare resulting in USD 19 (min) to USD 29 (max) for coffee and USD 6 to USD 12 (max) for maize.

**Table 1** Socio-economic benefits of the coffee and maize sector at individual farm level  
Socio-Economic Benefit - Individual level

	<b>Coffee (<i>alerta_roya</i>)</b>	<b>Minimum</b>	<b>Maximum</b>
	Annual per farm value	USD 54	USD 80
	Annual per hectare value	USD 19	USD 29
	<b>Maize (<i>alerta_maiz</i>)</b>	<b>Minimum</b>	<b>Maximum</b>
	Annual per farm value	USD 8	USD 16
	Annual per hectare value	USD 6	USD 12

Own calculations.

There may be several reasons for the higher valuation of the early warning system by coffee farmers. The outbreak of coffee rust in the sample region may be the main explanation for this finding. As mentioned before, this disease had a devastating economic effect in 2013 leading to higher expected benefits of the climate service. Moreover, further analysis shows that the farmers’ willingness to pay for the climate service is positively related to their educational background. This suggests that a higher education is associated with a better understanding and, hence, with a higher valuation of the climate service. In fact, average education level of coffee farmers in the sample is slightly higher. Furthermore, with coffee being a cash crop, the farmers may be more experienced in economic and monetary reasoning, again increasing their ability to optimize the production process with the hypothetical climate service presented to them.

Table 2 shows the socio-economic benefits in the coffee and maize sector aggregated over the region Cusco and over the whole country of Peru. Assuming that these hypothetical climate services are operated over a period of 10 years, the resulting benefits amount to USD 10 million for the region Cusco and well over USD 100 million for Peru as a whole. These estimates are discounted with an annual rate of 4%.

**Table 2** Extrapolation of the results into a broader geographical entity and discounting Socio-Economic Benefits (over 10 years operation time; discount rate 4%)

Region Cusco <sup>1</sup>		Minimum	Maximum
	Coffee	USD 9 million	USD 14 million
	Maize	USD 2 million	USD 3 million
	<b>Total</b>	<b>USD 11 million</b>	<b>USD 17 million</b>
Peru <sup>2</sup>		Minimum	Maximum
	Coffee	USD 63 million	USD 93 million
	Maize	USD 29 million	USD 57 million
	<b>Total</b>	<b>USD 92 million</b>	<b>USD 150 million</b>

Own calculations.

<sup>1</sup> Total cultivated area in 2012: 59'000 hectares coffee; 30'000 hectares maize (MINAGRI 2014b)

<sup>2</sup> Total cultivated area in 2012: 391'000 hectares coffee; 548'000 hectares maize (MINAGRI 2014b)

Considerations on potential costs of the implementation of alerta\_roya or alerta\_maíz are beyond the scope of this study, but to this end future analysis should incorporate the following factors: costs for improving the (agro) meteorological observation network for the data basis, labor cost for meteorological, climatological and agrometeorological experts implementing and maintaining the climate service, and expenditure for disseminating the information. It should be considered that additional observing stations, depending on their technical capabilities would also provide data for further meteorological or climatological purposes. In the light of the results obtained, it is safe to assume that the implementation and maintenance costs of the services are significantly lower than the expected benefits.

White maize plants - renowned for a solid demand on the market place - in Urubamba (Cusco)



Farmer and his son are harvesting coffee in Santa Teresa (Cusco)



# 05. Conclusions

The present case study aimed at estimating the socio-economic benefits of user-tailored early warning systems for coffee and maize smallholder farmers in Peru. The study is conducted in the region Cusco, in order to exploit synergies with the GFCS twinning project CLIMANDES. The analysis is based on the stated preference method, an econometric approach based on field survey data. The results indicate - over a period of 10 years - socio-economic benefits for the coffee and maize production of about USD 10 million for the region Cusco and well over USD 100 million for Peru as a whole. These results are conservative estimates and can be seen as a lower limit of the benefits, given a number of positive externalities not addressed in this study, e.g. by reducing public health costs due to more efficient use of agrochemical products.



The study results identify a clear need for early warning systems. This is especially true for farmers which face concrete climate-related problems and have the possibility to apply preventive measures as in the case of coffee rust. This finding demonstrates the potential value of early warning systems to improve smallholders' livelihoods by increasing their resilience against high-impact weather and climate events. Such climate services can build a fundamental element for disaster risk reduction as recently underlined in the Sendai Framework for Disaster Risk Reduction. In this context, NMHSs play an essential role in ensuring food security and reducing poverty and thus increasing a country's adaptation capacity to climate change.





However, this study also points out that agricultural decision-making is based on climate information to a small extent only. This underscores that the user groups' acceptance of climate services cannot be taken for granted and should be borne in mind when analysing the benefit of such services. Thus, improving the user-dialog and involving the end-user into the design of sector-specific products is a key element of climate service development. This insight is stressed out by the Global Framework for Climate Services (GFCS) that encourages the development of effective partnerships and dialogue between service providers and users of climate services.



This case study is a successful first step in quantifying the socio-economic benefits of early warning systems in the agricultural sector. As the mobilization of public resources is vital to extending and maintaining such climate services, further case studies are required in order to justify the corresponding public investments.



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Specialists are showing the varieties of maize plants in a research field in Cusco.



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# CLIMANDES

Climate services with an emphasis on the Andes to support decisions



Schweizerische Eidgenossenschaft  
Confédération suisse  
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