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GROWING AGAINST THE ODDS: CLIMATE CHANGE CHALLENGES AND ADAPTIVE APPROACHES IN PERUVIAN AGRICULTURE

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Abstract
The Indonesian retail sector is experiencing rapid growth, but the development of the furniture retail sector is hindered by supply chain-related problems. Supply chain management (SCM) is a business strategy that integrates the flow of materials, information, and finances through the entire supply chain. The successful implementation of SCM can improve the relationship between upstream suppliers and downstream customers, thus improving customers' satisfaction and company performance.

Keywords: Supply chain management, Retail sector, Furniture, Indonesia, Business strategy,Performance improvement

Introduction

Peru is among the three most vulnerable countries in the world in terms of climate hazard risks and has highly heterogeneous climatic variations across regions. Some of the areas of predominant rice cultivation are lowlying coastal areas that are predicted to face increased precipitation, others are on the edges of fragile mountain ecosystems and forest regions were drought frequency is predicted to increase disproportionately. This high and heterogeneous climate variability is imposed on producers who already face critical and diverse challenges for their economic survival. The two main agro-ecological regions where rice is predominantly grown - coastal and forest areas - have historically faced several distinct biophysical and socioeconomic constraints to rice production. Including highly arid terrain, low precipitation in the Coast, and low availability of improved varieties and other technologies, as well as limited access to important commercialization channels in the Forest.

Rice cultivation in Peru exemplifies the complex nature of the interaction between changing climatic conditions and households' decisions on how to cope with these changes in the face of multiple constraints. In this study, we examine how climatic conditions affect these decisions. We account for the fact that this relationship is mediated by the perceptions that individuals have about climatic conditions, which can be highly heterogeneous at the local level. We focus on small-scale household farmers in Peru who depend on rice production for their livelihoods. We first examine men's and women's perceptions of climatic changes and compare them to aggregate and weather station information regarding changes in climatic indicators. Beyond examining climate warming, which is the most widely known climatic stress factor, we also study perceptions on changes in rainfall frequency, quantity and seasonality, in the level of water in the rivers, and on the frequency of droughts and floods. We show that farmer perceptions provide a nuanced picture of climate change predictions in Northern Peru. Furthermore, official climate information often does not reach farmers in the countryside, who are more likely to base their behavior on their climate perceptions. As such, information about perceptions and coping behavior provides a unique view into the heterogeneity of households' exposure to climate risks and related livelihood stresses, as well as into the causal links between climatic stress factors and adapting or coping behavior. We then examine the various adaptation practices used by rice farmers to cope with climate change, and what determines these practices. Our empirical analysis uses multivariate probit regression analysis, in order to understand patterns of coping behavior and the factors associated with them.

Preliminary findings show that, while climate change studies predict generalized increased temperature, there is a coastal area in Peru where the majority of farmers perceive a drop in temperature over the course of the last 5 years (2007-2012).

Similarly, while aggregate predictions determine increases in precipitation in northern Peru, farmers' perceptions show a large degree of heterogeneity, with the coast facing most of the precipitation increase and the forest more floods and droughts. We also find that perceptions on the level of water in the rivers do not follow the same pattern as precipitation perceptions, likely because the level of the water in the rivers is affected by other factors. Regarding the adaptation to climate change, we find that households adopting new rice varieties as a coping strategy use this option in contrast to other households who rather ask for credit, reduce the cultivated area or diversifying away from the crop. Furthermore, non-agricultural strategies such as migrating, mortgaging the land and pawning assets are complements of asking for credit, reducing area or diversifying the crop, and relying on the help of family and friends. Furthermore, households with male managed and female managed plots are less likely to adopt a coping strategy in comparison to households with joint-managed plots.

The document is organized as follows: The second section presents an overview of the rice challenges related to climate in Northern Peru. The third section describes the climate indicators in the region. It includes the patterns and the forecasted behavior of temperature and precipitation in the Andean region and Peru, particularly. The fourth section presents the literature review on gender and climate change. The fifth section briefly describes the Peruvian sample data and the methodology. The sixth section is dedicated to the results. It provides information about climate indicators from weather stations in our study site, the comparison of farmer's perceptions and aggregate weather data, the perceived impacts of climate change and the coping strategies used by farmers, and the estimation results. The document ends with a conclusion section and some policy implications of the findings.

Rice Challenges related to Climate in Northern Peru

Rice is an important component of the Peruvian agricultural sector. It represents roughly 9.4% of the gross national production and occupies almost 20% of cultivated areas. In the rural areas, it is a source of employment and the livelihoods of many farmers depend on its cultivation. It also plays a vital role

in food security as one of the most important staple foods in the country. Rice consumption in Peru is the third-largest in South America, where the average Peruvian consumes 48.7 kg of rice per year
Rice cultivation is located mainly in the north of the country, in the valleys, forest rim, and forest region. Our study focuses on the departments of Amazonas, Cajamarca and San Martin, in the forest region, and La Libertad, Lambayeque and Piura, in the coastal area, which concentrate 70% of the national production according to Escobalet al. (1994). The study area is shown in Figure 1.
Figure 1. Study area

Source: University of Texas Library Online (2006)

This area is characterized by high climatic heterogeneity and is subject to a number of constraints. The coastal climate is characterized by very little rainfall. The mean temperature is 18.1 Celsius, and a wide range of daily fluctuation between 8 and 30 Celsius.
In the Forest, depending upon the location, mean temperature ranges between 25 and 28 Celsius, rainfall varies between 1,500 and 3,000 or more mm per year distributed over a period of 9-11 months (Vera 2006).
The challenges that rice production in Peru faces are already considerable and the threat of climate change will add to these challenges. Rice cultivation is vulnerable not only to higher temperatures, water scarcity and drought (especially during the growing season) but also to excessive flooding (in particular during the ripening phase). Rice flowers can become sterile due to higher temperatures, meaning that no rice grains are produced. Water scarcity and drought due to lack of rain can have a significant negative effect on rice yields as well. Excessive flooding, in turn, forces the plant to be submerged underwater for a long period with a high likelihood that it will not be able to survive. Fluctuating climatic conditions also generate severe disease outbreaks, which significantly reduce rice grain production and quality (CIAT 2013).

The arid and dry nature of the coastal area has resulted in widespread and increasing irrigation use to supply the high water demand for rice production. Irrigation in the country depends largely on the water regulation capacity of Andean ecosystems (where almost all river systems in the North originate), which are being negatively affected by climate change (Hofstede et al. 2014). Additionally, the widespread use of irrigation has caused significant problems of soil salinization, which in turns has triggered that many fields become useless for cultivation and farmers have to move to new soil (CGIAR Research Program on Rice 2017).

In spite of the arid nature of the soil in the Coast, larger market accessibility in this region have provided for larger adoption of mechanization and improved rice varieties. As such, production in the coastal area tends to be more predictable and has larger productivity. While rain-forest production puts less stresses on the hydric resources, it has had a tendency towards lower profitability, partially due to the lower availability of improved varieties and the more rudimentary methods used for production (Dirección General de Competitividad Agraria 2012).

However, the heterogeneous impacts of climate change across the country may be altering production conditions in ways that could merit the reformulation of government goals. If precipitation increases in the coastal areas are generalized and sustained, or if, to the contrary droughts are occurring more frequently in the forest areas, then the emphasis of the government to shift rice production form the coastal region towards the more humid forest area may be inappropriate. In general, policymakers may have to consider devising alternative strategies for rice production in order to confront increasing uncertainty in production conditions.

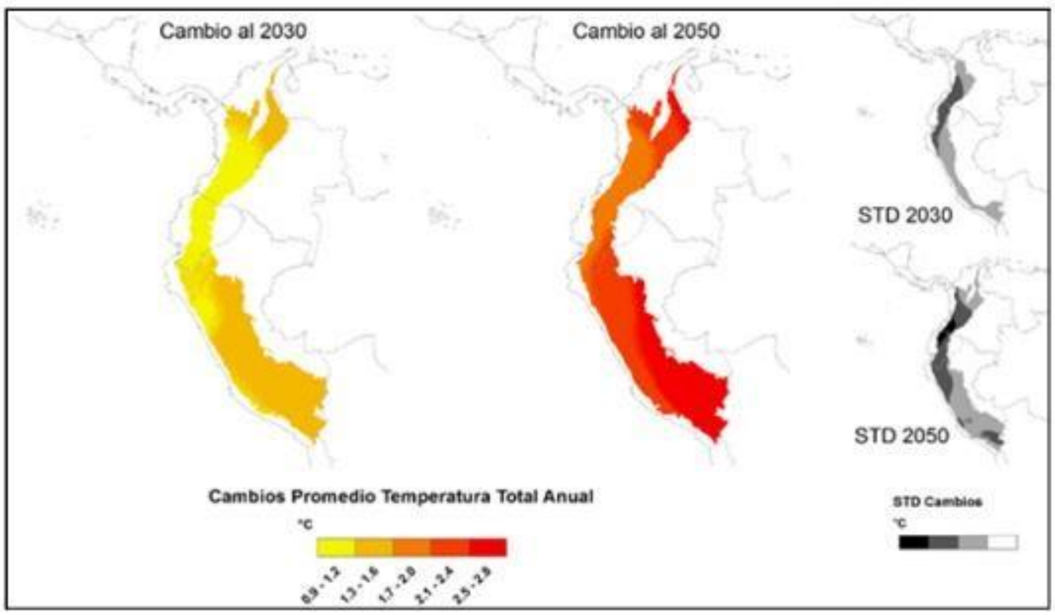
Climate change in the Northern Andean Region

The trend of mild average annual temperature increases in the Northern Andes (Venezuela, Colombia, Ecuador, Peru) documented since 1939 tripled over the last 25 years of the 20th century; going from decadal increases of 0.11 ^{o}C to 0.34 ^{o}C(Marengo et al. 2004; Vuille and Bradley 2000). Recent studies have suggested that this pattern of change in the climate is generating increased variability in the cycle of Pacific Ocean surface water warming and cooling (Cobb et al. 2013; Fedorov and Philander 2000), which is associated with warm and wet weather in April–October along the coasts of northern Peru and Ecuador. This, in turn, causes heavy rain and flooding whenever the event is strong (University of Illinois 2010).

As the average increasing trend in air temperature has been established, it has been difficult to establish trends with regard to precipitation, not only because of the different periods considered and methodologies used in the studies but because of the high annual and decadal variability. Specifically for Peru, strong regional differences in precipitation have been observed in weather stations. Towards the west of the Andes mountain range, systematic precipitation increases have been evidenced. However, in the central and eastern areas reductions may be occurring (SENAMHI 2009).

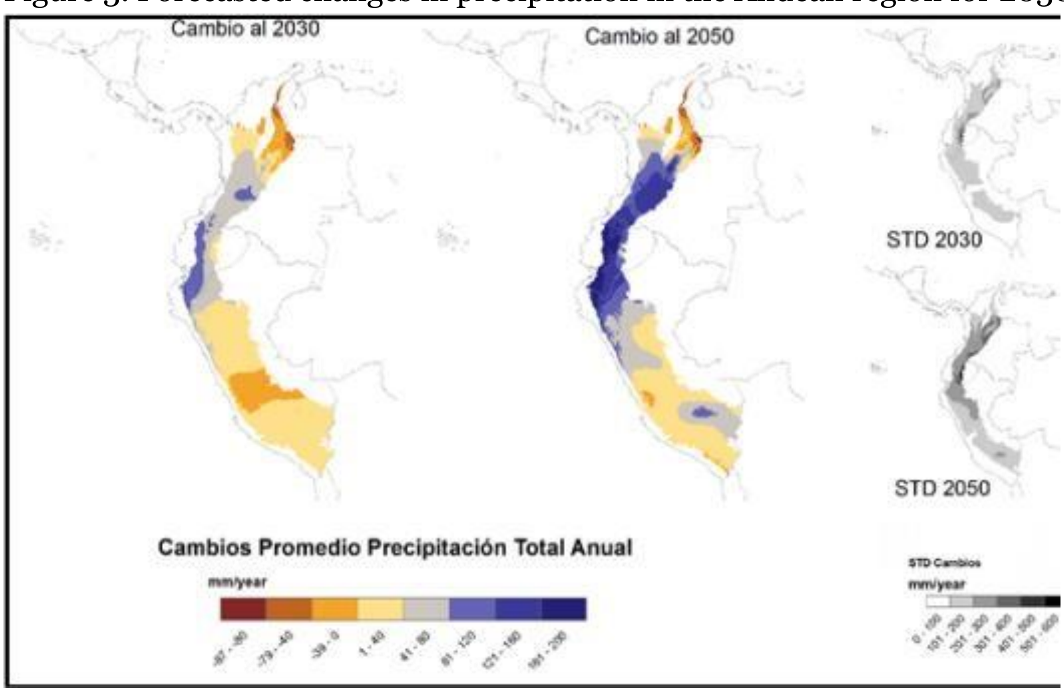
Climate projections suggest that most of these trends will continue in the coming decades. A general increase in temperature over all the Andes is forecasted (an annual mean increase of 1-1.4C in 2030 and larger for 2050). Increases in precipitation are predicted in the central area that includes Southern Colombia, Ecuador, and

Northern Peru. Reductions in precipitation are expected in areas of the South and North –to the south of Southern Peru and in the North of Colombia (CIAT 2014). Figures 2 and 3 reproduce the maps from the International Center for Tropical Agriculture (CIAT) study, which enables visualizing these changes.
Figure 2. Forecasted changes in temperature in the Andean region for 2030 and 2050.



Source: CIAT (2014)

Figure 3. Forecasted changes in precipitation in the Andean region for 2030 and 2050.



Source: CIAT (2014)

For Peru in more detail, the study by CIAT forecasts a general increase in the annual average temperature of 1.6 degrees Celsius by 2030 and 2.8 degrees Celsius by 2050. It also predicts a strong increase in annual precipitation in the North (up to 80 mm per year in 2030), but weaker or even reductions in the South (max 40 mm/year). Similarly, the Met Office Hardley Center (2011) projects an overall increase of up to around 3 to 3.5 degrees Celsius over most of Peru. In the North, they expect a 5 to 10% increase in precipitation whereas projected increases in the south are slightly lower, at around 0-5%.

The National Meteorological and Hydrological Service of Peru (SENAMHI) coincide with these temperature trends by 2030 and further details that the largest increases would occur in the northern coast, and in the northern and southern forest. In the case of maximum precipitation by 2030, there would be a decreasing trend in most parts of the country and only in certain locations there would be an increase in reference to current values. In particular, reductions of 10 to 20 percent were projected for the mountains region, yet the northern coast and southern forest could see some increases of similar magnitude (SENAMHI 2009).

Overall, the lack of climatic records or regularity in their collection in ample areas of the Andes prevents researchers from establishing more precise average and extreme trends(Marengo et al. 2009; Trenberth et al. 2007). As we will illustrate later, the larger the scale (more localized) of the analysis, the harder it is to find accurate and regular climate observations. Thus, information by local dwellers may be key to develop maps of climatic variation for specific micro-regions in the Andes and to capture more accurately the climatic heterogeneity in these areas.

Watershed-river water level is importantly related to the previously described climatic factors, however, we did not find studies examining it systematically, perhaps because it is more complicated to explain and predict since it depends on a number of factors beyond the climate (the region where the watershed is located, the vegetation cover surrounding it, the type and quantity of anthropogenic intervention in the area). In the Andes, several watersheds provide for hydroelectric power, which reduces the water levels in lower altitudes. In times of high precipitation, where water is abundant the risk of floods and landslides may increase.

Data and methodology

Data for this study comes from a survey of 497 rice producers in northern Peru (85% men and 15% women) administered by the Peruvian Institute for Agrarian Innovation (INIA) and the International Center for Tropical Agriculture (CIAT). This research was conducted in order to determine adoption rates of improved rice varieties and to gain knowledge on women's roles in rice production in the main rice-producing departments in the country (Amazonas, Cajamarca, La Libertad, Lambayeque, Piura and San Martin). The fieldwork was carried out between October and December 2012 in both coastal and forest regions. The questionnaire consisted of 38 questions divided into 12 modules and was directed to rice farmers with less than 10 hectares that produce using irrigated systems. Table 1 shows the distribution of the sample across departments and agro-ecological zones.

Table 1. Departments and Agro-ecological zones

Departments	**Number of Farmers**	**Agro-ecological zone**
Amazonas	52	Forest
Cajamarca	87	Forest
San Martin	99	Forest
Lambayeque	91	Coast
Piura	93	Coast
La Libertad	75	Coast
Total	497 (422 men, 75 women)	

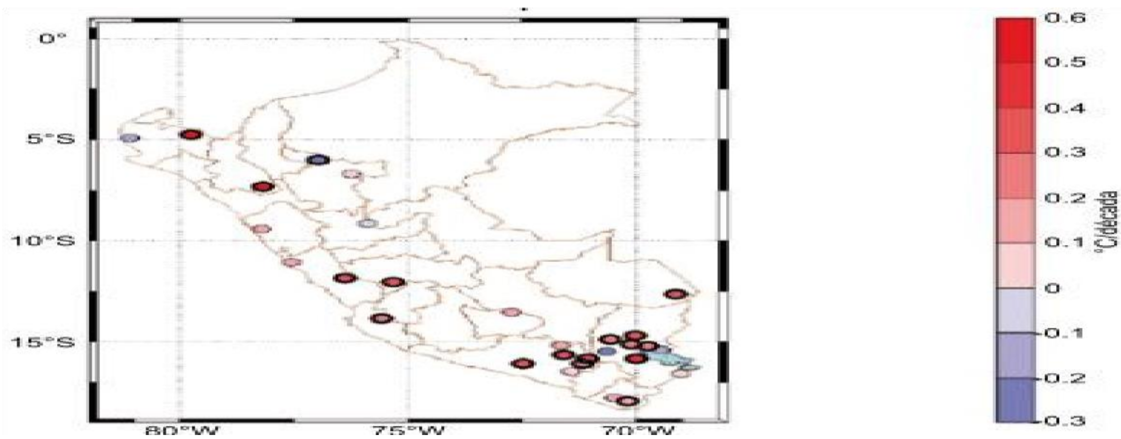
Using this household survey data, we examine how men and women perceive changes in temperature, rainfall, and water level in the rivers that feed irrigation channels. This analysis is informative in understanding the level of awareness of Peruvian rice farmers. It also allows us to compare men's and women's perceptions regarding climate variability and how they perceive the impacts of climate change on rice farmers' livelihoods.In order to validate the farmers' claim of perception against actual weather data and forecasts, we use available aggregate observations and information about changes in climate indicators from weather stations in our study site.

Finally, to have an in-depth understanding of the various adaptation practices used by rice farmers to cope with climate change, and what determine these practices, we rely on econometric technics and estimate a multivariate probit model. In addition, we test different ways to measure gender that go beyond the sex of the respondent or the head of the household. Specifically, we include the gender of the manager of the plots which allows us to differentiate between households with plots that are only male-managed versus jointly-managed.

Results Weather Station Information

According to SENAMHI (2009), the average temperature in Peru has increased by 0.2 degrees Celsius over the last 40 years. Average rainfall has increased on the coast and in the northern Andes and decreased in the northern Amazon (SENAMHI 2009). Below we reproduce some maps from SENAMHI report, which show the distribution of weather stations with reliable data for annual maximum mean temperature estimated for the period 1965-2006 (Figure 4) and the distribution for weather stations with reliable data for total annual precipitation (Figure 5). The latter figure shows the linear trend of total annual precipitation in percentage, relative to the multiannual average for the period 1965-2006.

Figure 4. Spatial Distribution of change in annual maximum mean temperature (°C/decade) estimated for the period 1965-2006.

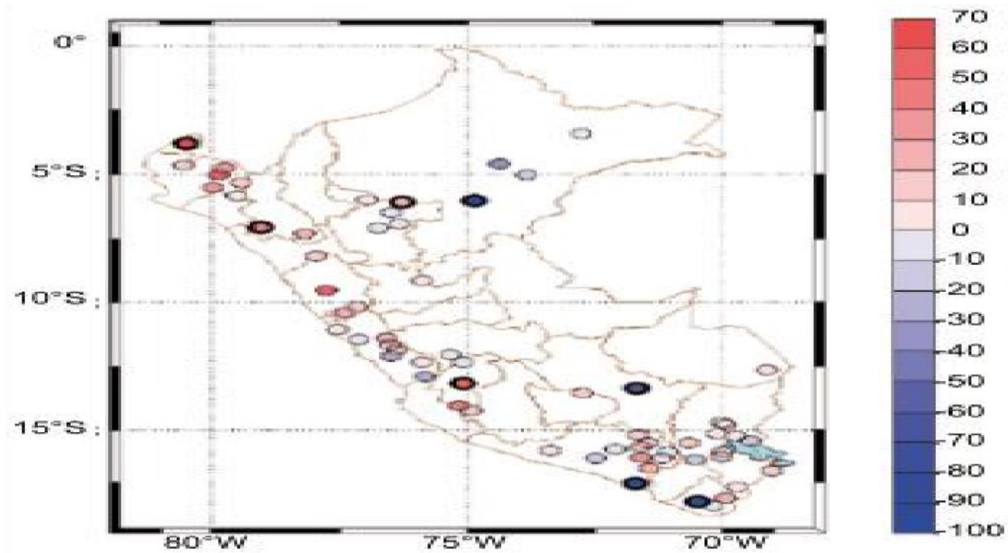


Source: SENAMHI (2009). The trends with statistical significance at 5% or less in Mann-Kendall Test are indicated in black circles.

There are two main aspects to highlight in the map for changes in annual maximum temperature. First, it can be observed that for Peru as a whole, weather stations report mostly positive and significant changes in temperature, with a few exceptions. Decreases in temperature were registered over this period in two of our study regions --the coastal zone of Piura and the forest zone of San Martin. The highest change value (0.52C) was in the northern locality of San Marcos (Cajamarca). Our second observation is that reliable and consistent temperature data from weather stations is very sparse. Overall, there are only 5 weather stations with reliable temperature data in our study area: two in the most northern coastal department of Piura, one in the northern forest department of San Martin, one in the border of San Martin with the northern forest department of Amazonas, and one in the central high forest area of Cajamarca (near border with La Libertad). No reliable weather station data was available for Lambayeque, La Libertad and Amazonas. The most significant trends for these data are the strong temperature increases in Cajamarca and the higher altitude Piura western area, and a significant drop in the northern San Martin (Moyobamba Station) area near Amazonas. However, the other weather stations in both Piura and San Martin do not provide such definitive evidence.

While precipitation data from weather stations (Figure 5) is more widely available, significant trends provide mixed results. Unlike temperature, there is not a clear majority of sites presenting increases or decreases at the national level. Overall, the weather stations in the northeast (coastal area) appear to present increases in total annual precipitation, while the ones in the forest areas of San Martin and Loreto show mostly decreases. Two caveats from these data observations are that most coastal weather stations appear to be located in the relatively higher altitude area of the coastal departments, which may not be representative of lower altitude areas. The other is that no station data is available for the Amazonas and La Libertad departments (although the two weather stations in Cajamarca are located very close to the border with La Libertad).

Figure 5. Linear Trend of total annual precipitation in percentage, relative to the multiannual average (1965-2006).



Source: SENAMHI (2009). The trends with statistical significance at 5% or less in Mann-Kendall Test are indicated in black circles).

Having analyzed these observational data, we proceed now to study farmers' perceptions by department and gender in our study region.

Regional Farmer Perceptions vs. Aggregate and Weather Station Observations

The issue of a changing climate evokes the need to understand the perceptions and adaptation to climate change among rice growers in Peru. Maddison (2007)argues that adaptation to climate change is a two-step process. First, farmers perceive that the climate is changing and second, they respond to these changes through a series of adaptation strategies. In other words, the decisions to adapt to climate change are derived from their understanding and assessment of risk. Besides, there is a growing body of literature showing that men and women might adopt different strategies to cope with impacts of climate change (Lambrou and Nelson 2010; Ngigi, Mueller, and Birner 2017; Perez et al. 2015), depending on their capabilities, resources, information, knowledge, decision-making power, and roles.

Temperature Perceptions

Perception is a prerequisite for adaptation to climate change. In our survey, rice farmers were asked about their perceptions of climate change with respect to change in temperature, rainfall, and water level in the rivers that feed irrigation channels. This analysis is informative in understanding the level of awareness of Peruvian rice farmers. It also allows us to validate the farmers' claim of perception against actual weather data and forecasts, and to compare men's and women's perceptions. Given available aggregate climate forecasts, we would expect farmers to perceive an increase in temperature in the region as well as increases in precipitation in the Coast and decreases in precipitation in the Forest.

Indeed, we find that the majority of farmers in all departments perceive that the temperature has increased in the previous 5 years (2007-2012) and that this perception does not differ by gender of the farmer. Close to 100% of respondents agree in the South and West of our study region, yet there is a significant minority of farmers in disagreement in the coastal Lambayeque (and in Piura if the lack of reply is taken as no change perception). As Figure 6 shows, in Lambayeque, 68% of farmers reported perceiving an increase in temperature while 11% perceived a decrease, 7% saw no change and 14% did not answer the question. In Piura, 78% of farmers perceived an increase in temperature, 1% perceived a decrease, 3% saw no change and 17% did not answer the question. When asked whether they think that hot months are hotter, we see a very similar pattern emerges.

A significant proportion of farmers (90-99%) in most departments reply affirmatively but men tend to agree more with this affirmation than women do. However, in Lambayeque a larger proportion (19%) disagreed that it is hotter during the hot seasons (Figure 7).

These findings show a clear consistency with the mixed nature of information from the two weather stations in Piura, one showing significant temperature increases and the other insignificant temperature decreases. In our case, a large group of farmers in the department perceive a temperature increase over the last 5 years, yet about 20% of the farmers saw no significant change, with a small minority perceiving a drop in temperature. As pointed out above, the same pattern holds for the seasonally hot months.

Our data further complements the weather station data, showing that the most significant minority of the country perceiving temperature decreases is located in the Lambayeque department. A coastal area directly below Piura, where a significant minority clearly states perceiving drops in long-run average temperature.

When asked about colder months being colder, we see a clear difference in perception between farmers in the forest region and farmers in the coastal one. More than 72% of farmers in the coastal departments perceive that the cold months are colder than usual. In the Forest, only between 34% (Amazonas) and 62% (San Martin) of farmers concur with that perception (Figure 8).

Figure 6. Change in temperature.

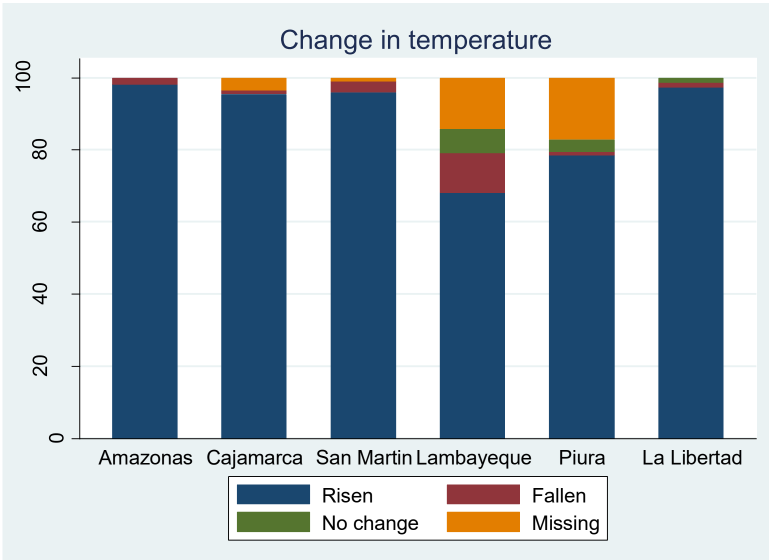


Figure 7. Hotter during hot seasons

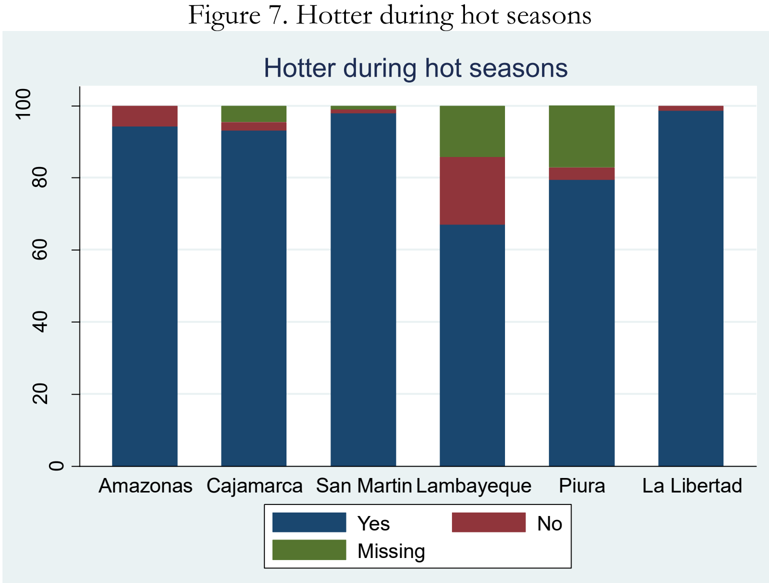
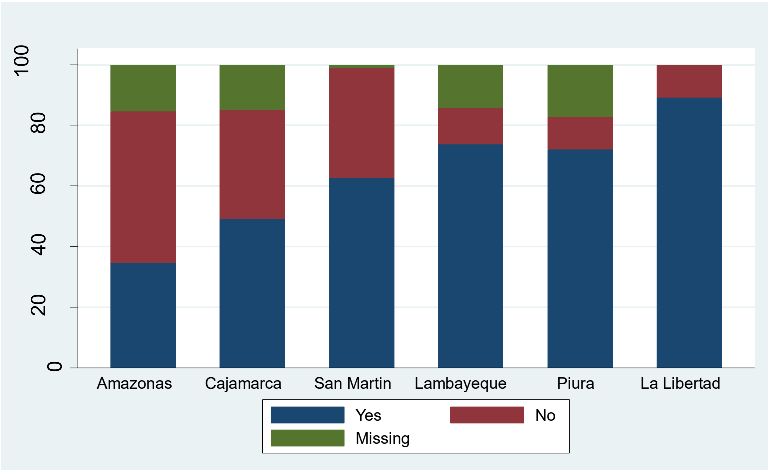


Figure 8. Colder during cold seasons.



Colder during cold seasons

Precipitation perceptions

Aggregate predictions for Peru suggest an increase in precipitation in the northern region and weakeror a decrease in precipitation in the south. Answers regarding perceptions of whether it rains more show that in most departments, the majority of farmers, regardless of gender, perceive less frequent rain. In most departments though, there are also between 15 and 24% of farmers reporting that they perceive an increase in rain frequency. Importantly, in Lambayeque the majority of farmers perceived an increase in rainfall. Thus, while weather station observations suggest generalized increases in precipitation in coastal departments, farmer perception data show that a majority of farmers perceive rainfall frequency decreases in two of the three coastal departments, with a not-insignificant minority perceiving decreases also in the third one. We believe this difference may be based on the fact that weather stations tend to be located at higher altitudes and further to the east, while the majority of our data points in coastal departments are located on the western side of these departments, further away from the mountains, where rain may be more frequent.

Perceptions in the forest departments are better explained by weather station data, since a majority of farmers in these departments perceive precipitation decreases, just as the weather station annual total precipitation data suggests. However, there are important minorities within the forest area, for which weather station data would not be representative of their frequency perceptions, since a significant group of farmers perceive higher frequencies (22% in San Martin, 20% in Cajamarca and 15% in Amazonas – Figure 9).

Comparing rainfall frequency with rainfall quantity perceptions (Figures 9 and 10), we find that overall, majority of individuals perceive quantity reductions as well. However, while the distribution pattern of the answers or quantity and frequency is very similar for Amazonas, La Libertad and San Martin, in Lambayeque, Piura and Cajamarca the number of individuals perceiving quantity increases is significantly larger (individuals who did not perceive rainfall frequency increases, but did perceive quantity increases for a given rainfall event, were 15% in Cajamarca, 14% in Piura and 10% in Lambayeque)

Figure 9. Frequency of precipitation.

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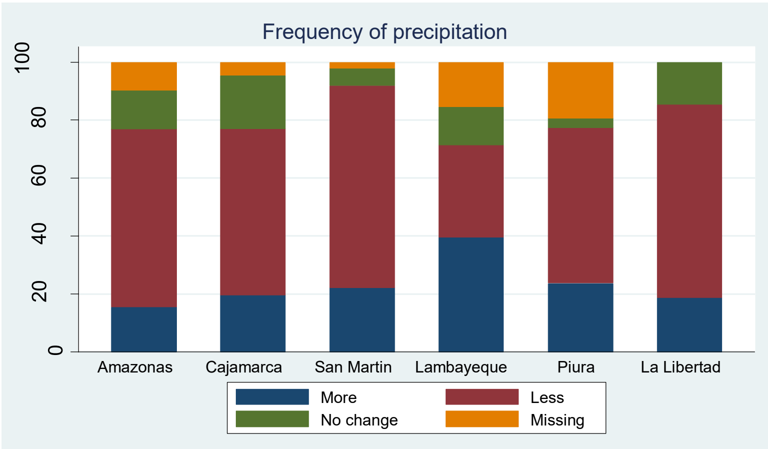
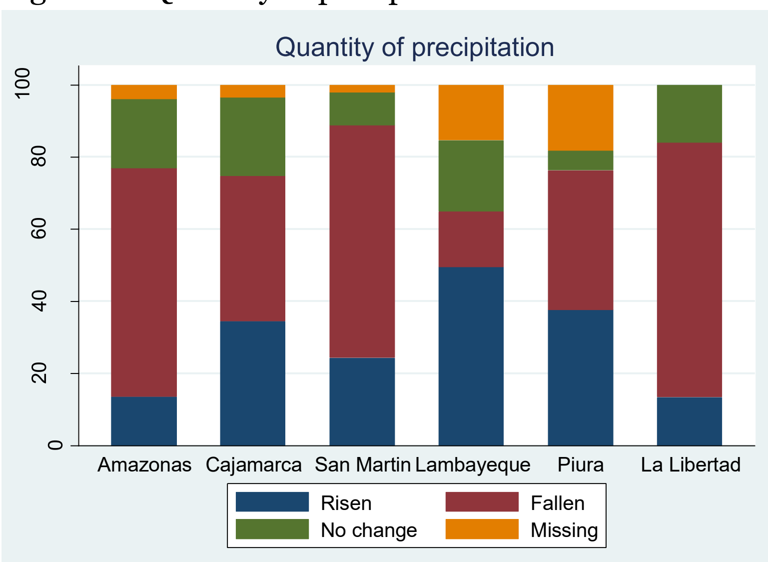


Figure 10. Quantity of precipitation.



Floods, droughts and wind perceptions:

Respondents also provided information on climate extremes' perceptions. Frequent floods were perceived to have occurred almost exclusively in the Forest during the previous 5 years: San Martin (49%), Amazonas (17% of respondents) and Cajamarca (16%). Examining more closely the case of San Martin, the department with the most frequent floods and droughts (Figure 11), we compare the frequent flood with precipitation perceptions and find that decreased precipitation concentrates in the South, while precipitation increases are in the North (matching weather station data). This means that the flatter areas of the North that tend to be heavily affected by floods, are the ones where precipitation increases may be worsening conditions the most. On the contrary, in the South, lower levels of precipitation may be reducing the flooding frequency and magnitude (both quantity and frequency precipitation perceptions are lower in this area).

In the case of Amazonas, the other department relatively heavily affected by floods, we are not able to establish whether flood frequency may be increasing or decreasing. While the rainfall increases in

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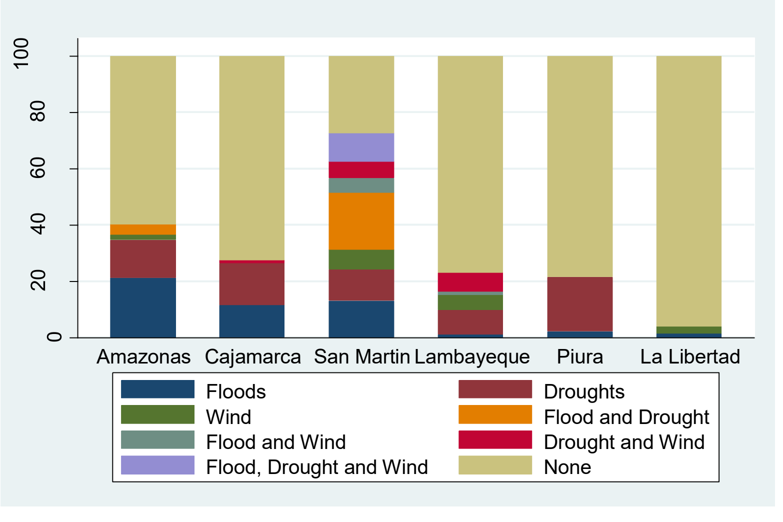
Cajamarca -- a higher altitude area through which the Maranon river passes that feeds smaller tributaries in the Amazonas--, maybe generating flood increases, the reduction in precipitation in higher areas could be reducing floods. However, since the majority of those perceiving frequent floods simultaneously perceived decreases or no change (73%) in rains, we suspect that floods may be decreasing in the Amazonas area.

Floods' perceptions are also consistent with perceptions of the water level of the rivers that feed irrigation channels and precipitation perceptions. In Amazonas, Cajamarca and San Martin almost all farmers perceive decreases or no change in the level of these rivers as well as less or no change in the frequency of precipitation. The majority of households perceiving increases in the water level are located in Lambayeque --which is the department with most farmers reporting more precipitation frequency-- and, in a smaller proportion, in Piura.

Droughts were perceived by a high number of farmers in San Martin (47%). All other departments had between 15% and 19% of farmers perceiving frequent droughts, except for La Libertad, were no farmer perceived a drought in the past 5 years. A significant number of farmers also report frequent strong winds in San Martin (28%) and Lambayeque (13%). Of those farmers who perceived more frequent droughts, 99% also perceived increased temperatures. Thus, droughts may be exacerbated by the increased temperatures across the Peruvian northern territory, except for the Northern region of La Libertad (our data points are not representative of the whole department), were temporary precipitation occurs due to Humboldt streams and the ENSO phenomenon.Also, dry winds hit the lower western slopes of the Andes creating a low-level cloud (locally called ―Garua‖), which blocks out the sun for the cooler six months of the year.

Figure 11. Frequent floods, droughts, and wind.



Frequent floods droughts and wind

In sum, the majority of farmers in all departments have perceived an increase in temperature over the last 5 years; which is consistent with observed data and climate change predictions. Precipitation perceptions are highly heterogeneous and hard to predict based on weather station or aggregate data. For precipitation, except for farmers in Lambayeque, most farmers have noticed less rain. This is not as consistent with aggregate predictions and observations that average rainfall has increased on the coast as a whole and in the northern Andes, and decreased in the northern Amazon(SENAMHI 2009). Overall, the department of San Martin presents the most generalized extreme weather changes, with a high proportion of farmers perceiving all long-term temperature increases, higher heat during hot seasons, colder temperature during cold season, decreased precipitation, frequent droughts, floods and winds. In addition, no gender differences were found on climate perceptions related to temperature, precipitation, floods, droughts, and strong winds.

Climate Change Impact Perceptions and Coping Strategies

As explained earlier, rice is highly sensitive to the quantity and timing of rainfall. Rice thrives on wet conditions during the growing season followed by drier conditions during the ripening phase. Thus, small-scale rice farmers that depend on rice production for their livelihoods can be highly vulnerable to changes in both temperature and precipitation. When farmers perceive that climate change is having some impacts on their livelihoods they will be more likely to adopt coping strategies (Ngigi, Mueller, and Birner 2017).

Rice farmers in our study site were asked about the impacts of the changes in the weather on yields, food availability, indebtedness, and crop growing. Table 2 provides the percentage of farmers that report having impacts on each of those. Most of the farmers (77%) report that climate change had led to reduced crop yields, 34% percent perceive crop loss, 31% less food and 25% report that the indebtedness has increased due to changes in the climate. Women are significantly more likely than men to report that crop yields are negatively affected by climate change. But overall, men perceive more negative impacts than women.

Table 2. Perceived impacts of climate change by gender.

Impacts	**N**	**%**	**Male**	**Female**
Low yields*	384	77%	77%	80%
Less food	156	31%	32%	25%
Increased indebtedness	124	25%	26%	19%
Crop loss	168	34%	34%	31%
Total farmers	**497**		**422**	**75**

*Differences between men and women are statistically significant.

Rice farmers werealso asked about the strategies that they have used in order to moderate harm or to cope with the consequences of climate change in the past 5 years. They were allowed to report more than one coping strategy. Table 3 provides a list of these strategies and the percentage of farmers that adopted them. We group the coping strategies into two main categories: agricultural and non-agricultural strategies.

Thirty-three percent of the rice farmers adopt agricultural strategies, and among these, 54% chose to change the rice variety to cope with climate change. Many others chose to practice other agricultural strategies such as cultivate less area and diversify crops. Around 9% of the farmers adopt non-agricultural, and a significant percentage (31%) use both, agricultural and non-agricultural options.

Table 3. Coping strategies by gender

Coping strategies	**Total**	**Male**	**Female**
Agricultural Strategies			
Change rice variety	54%	54%	51%
Cultivate less area	9%	9%	7%
Diversify crops	14%	15%	13%
Non-Agricultural strategies			
Seek wage jobs	15%	15%	13%
Acquire credit	22%	22%	23%
Pawn assets	6%	6%	7%
Rely on family and friends	16%	16%	17%
Mortgage land*	7%	7%	3%
Migrate	4%	5%	3%
Total farmers	**497**	**422**	**75**

*Differences between men and women are statistically significant.

From table 3 we see that farmers' coping strategies to detrimental climate events vary from relying on family and friends, asking for formal loans or simply resigning to cultivate smaller areas, to more drastic strategies like leaving farm work to seek wage jobs or even to mortgage their land, pawn their assets or migrate. Even though there are no discernible differences between men and women with regard to coping strategies, men tend to adopt more agricultural strategies while women adopt more non-agricultural options. It is therefore important to have an in-depth understanding of the various adaptation practices used by rice farmers to cope with climate change and what determines these practices. The following section presents our empirical approach to address this issue.

Determinants of adaptation practices

We use a multivariate probit model (MVP) to examine the determinants of various adaptation measures while allowing for the correlation across error terms due to unobservable explanatory variables. MVP is a normal discrete choice model to simultaneously examine the relationships between each adaptation option and a common set of explanatory variables. It simultaneously models the influence of independent variables on each adaptation measure while allowing errors to be freely correlated(Lin, Jensen, and Yen 2005). This model is superior to univariate and multinomial models because it explicitly recognizes and controls for potential correlation among adaptation strategies and gives a more accurate picture of the relationship between each adaptation option and its explanatory variables. Younget al. (2009) show that, compared to the MVP model, the multinomial logit model (MNL) --which is the empirical approach that is commonly used in studies of adaptation decisions involving multiple choices-- is a poor approximation of outcome probabilities because it assumes that the adaptation practices must be mutually exclusive, which is not the case for the adaptation choices in our study. A single household can adopt multiple strategies to cope with climate change and may use them as complements or substitutes. This fact may be the source of correlations between error terms, modeled using a multivariate probit model.

For each strategy type i we will simultaneously estimate a set of binary logistic regressions as follow:

$$\begin{cases} y_{1h} = X\beta_1 + \varepsilon_J \\ \quad \dots . \\ y_{Jh} = X\beta_J + \varepsilon_J \end{cases}$$

Where y_J is equal to 1 if the farmer h chooses the strategy type j and 0 otherwise. X is a vector of covariates, β_J is a vector of coefficients to be estimated for strategy j. ε_J is normally distributed with mean 0 and variance 1 and the covariance matrix V

Where V has values of 1 on the leading diagonals and correlations $\rho_{JK} = \rho_{KJ}$ for strategiesj and k for instance. The correlation coefficient ρ_{JK} indicates if strategies j and k are used as substitutes or complements.

Model variables

We hypothesize that the rice farmers' choices of strategies are not determined solely by climatic variables or geography; households' socioeconomic characteristics, farm characteristics, perceptions, and institutional factors also play an important role in choosing a set of adaptation strategies. We select a series of independent variables based on a review of the literature and location-specific characteristics as factors that explain households' choices between the following four strategies: changing rice variety, reducing cultivation area or diversifying crop, obtaining credit, and using non-agricultural options.

First, we consider household size, measured as the number of working adults between the ages of fifteen and sixty-four in the household. According to the literature, the size of the household can have a positive impact on the propensity to adopt certain farm-based coping strategies, especially those that are considered to be laborintensive (Tazeze, Haji, and Mengistu 2012; Gbetibouo 2009). Large households are also more likely to divert part of the labor force to non-agricultural activities in order to earn income to ease consumption pressure (Silvestri et al. 2012). In our sample, each household has in average 3 members between 15 and 65 years old.

Farming experience measured as years of experience in rice cultivation also has a positive effect on the likelihood to adopt coping strategies to cope with climate change. It is hypothesized that households with more farming experience have more knowledge of changes in climatic conditions and therefore are more likely to adopt adaptation practices. Several studies have shown a positive impact of farming experience on the likelihood of adopting diverse coping strategies(Nhemachena, Hassan, and Chakwizira 2014; Silvestri et al. 2012; Gbetibouo 2009). The average years of experience in rice cultivation of the respondents in our sample is 23 years.

Farm size positively influences adaptation of coping strategies. Several studies have shown that farmers with large farms are more likely to adopt coping strategies. In Nepal, Piya, Maharjan, and Joshi (2013) show that larger farms are more likely to adopt all the adaptation practices except the traditional strategies. Gebrehiwot and Vand der Veen (2013) find similar results in Ethiopia. Tazeze et al. (2012) argue that large-scale farmers are more likely to adopt coping strategies because they have more capital and resources. Farmers who own large farms also tend to adopt faster than farmers who own smaller farms (Gbetibouo 2009). The average farmer owns 3.6 hectares of land in our sample.

Receiving financial assistance or being part of a farmer's association can also positively impact adaptation. Households might be more willing to take on risk associated with adopting new technologies if there is a social safety net in place to help them financially in the event of a shock. Membership in associations is considered to be a good source of information and extensions service for the community. Piya et al. (2013) find that being part of NGO enable households to adopt more modern strategies and deviate from traditional ones. In our sample, only 9% of households belong to a rice farmer's association.

The literature provides mixed results on the gender differences in adopting coping strategies. Some studies have concluded that gender is an important variable affecting decisions to adapt (Tenge, De Graaff, and Hella 2004; Newmark et al. 1993; Nhemachena and Hassan 2007; Deressa et al. 2009; Bryan et al. 2013; Ngigi, Mueller, and Birner 2017). Other studies do not suggest a clear-cut effect on the gender factor (Bekele and Drake 2003; Kristjanson et al. 2017; Lambrou and Nelson 2010).Two things might be responsible for this ambiguity. First, many of these studies rely on the sex of the head of the household or the respondent. This variable might not perform well since it may not tell us who participates in the decision-making process. Second, many studies do not take into account couple-headed households and classify them as either female-headed or male-headed households, couple-headed typically being classified in the latter. Along with a measure of the ratio of women to men in the household, we include the sex of the managers of the plots instead of the sex of the head of the household in our analysis. This allows us to differentiate between household with plots that are male-managed only and plots in which women participate in the managing, either individually or jointly with men. The majority of households have plots managed by men individually (84%), 8% have female-managed plots and 8% have plots managed by men and women jointly.

In the literature, the impact of the age of the household head on adaptation decisions is ambiguous. The literature has shown both positive and negative propensity to adapt to climate change by farmers. Some would argue that age is associated with more experience and more experienced farmers are more likely to adapt to climate change. However, older farmers might be more risk-averse and less likely to be flexible compared to younger farmers (Gbetibouo 2009). In a study of Ethiopian farmers, Tazeze et al. (2012) show that due to experience age affects adaptation to climate change positively.

However, in Nigeria, Sofoluwe et al. (2011)find younger farmers to be more knowledgeable about modern practices and may be more willing to adapt to better techniques. The effect of age might be dependent on the location of the study and the type of coping strategy adopted. Similar to our gender variable, we use the average age of the managers of household plots instead of the head of the household.

The education of the head of households or members of the household is expected to have a positive influence on adaptation strategies. Education is linked to information on improved technologies and bestpractices. Farmers who are educated are expected to have more knowledge about climate change and the practices that they can use to cope (Hassan and Nhemachena 2008). It is also expected to increase the ability of decisionmakers to receive, decode and interpret information that is relevant for decision making. In Kenya, Silvestriet al. (2012) finds that farmers with higher levels of education are more likely to take adaptation measures. Piya et al. (2013)find that households headed by more educated heads are less likely to depend on traditional strategies and more likely to adopt more modern strategies to cope with climate change in Nepal. The average education of the plot managers in the householdis used instead of the education of the head of the household

Farm and non-farm income are indicators of wealth, and in many instances, the technologies required for the adaptation of strategies requires sufficient financial well-being (Silvestri et al. 2012). The wealth of the households reflects its capacity to tolerate risks and deal with climate change. Additional income can help farmers overcome financial constraints and allow them to adopt agricultural practices that might not have been available to them. Gebrehiwot and Vand der Veen (2013)find that higher farm and non-farm income impact positively farmer's perception and adaptation to climate change. Farmers' additional income is captured in our analysis by other cultivation income, animal income, wage, and government assistance (*bono*).

Access to information and extension services can be critical determinants of adaptation to climate change. Extension services provide important information on climate change and management practices. The availability of climate information can help farmers make comparative decisions among different management practices(Hassan and Nhemachena 2008). In Ethiopia, the degree of access to information that the farmer from agricultural experts was found to significantly influence conservation decisions(Bekele and Drake 2003). Gbetibouo (2009) finds that access to extension increases the probability of uptake of adaptation options in South Africa. Farmers in our survey received technical assistance, assistance in using machines, certification in the use of modern varieties, information on varieties, information on agricultural practices and information on climate change.

Farmer's perceptions have been shown to have an effect on the probability of adopting a coping strategy. We expect farmers who notice climate change to be more likely to take up adaptation measures to help them mitigate losses associated with those changes. Hassan and Nhemachena (2008)show that farmers who are aware of climate change take up adaptation to help them reduce losses. However, all will depend on the variable used for perception. Piya et al. (2013)notice that the perception of temperature changes does not have the expected effect on adaptation, but the ability to perceive rainfall facilitates adaptation practices in Nepal. We measure farmers' perception of change in temperature, rainfall, and water level.

Table 4 presents the descriptive statistics of selected dependent and independent variables for our sample of 497 households. Almost all rice farmers have perceived changes in temperature, rain, rainfall, rain season and water level. But only 22% reported having received information on climate change. As stated previously, in 16% of the households the women participate in the managing of the plots. But, on average each household has more women than men.

Table 4. Descriptive statistics.

Variable	**Type**	**Mean**	**Std. Dev.**	**Min**	**Max**
Demographic characteristics					
Number of working adults (15-65)	Continuous	2.68	1.56	0	8
Years of experience	Continuous	23.26	12.53	1	70
Rice association	Binary	0.09	0.29	0	1
Farm size (ha.)	Continuous	3.59	3.56	0	44
Amazonas	Binary	0.10	0.31	0	1
Cajamarca	Binary	0.18	0.38	0	1
San Martin	Binary	0.20	0.40	0	1
Lambayeque	Binary	0.18	0.39	0	1
Piura	Binary	0.19	0.39	0	1
La Libertad	Binary	0.15	0.36	0	1
Women to men ratio	Continuous	1.05	0.80	0	5
Male managed plots	Binary	0.84	0.37	0	1
Female managed plots	Binary	0.08	0.27	0	1
Joint managed plots	Binary	0.08	0.28	0	1
Average age of manager(s)	Continuous	55.34	12.84	19	91
Average education of manager(s)	Continuous	6.79	3.68	0	16
Income					
Other cultivation income	Binary	0.19	0.40	0	1
Extension services					
Technical agricultural assistance	Binary	0.37	0.48	0	1
Assistance in the use of machines	Binary	0.22	0.41	0	1
Receive training	Binary	0.36	0.48	0	1
Certification	Binary	0.07	0.26	0	1
Information on varieties	Binary	0.52	0.50	0	1
Information on agricultural practices	Binary	0.28	0.45	0	1
Information on climate change	Binary	0.22	0.41	0	1
Climate change perceptions					
Change in temperature	Binary	0.98	0.15	0	1
Change in rain	Binary	0.88	0.33	0	1
Change in rainfall	Binary	0.84	0.37	0	1

Change in rain season	Binary	0.78	0.41	0	1
Change in water level	Binary	0.78	0.41	0	1

Model results

Table 5 presents the results of the multivariate probit regression. Larger households and plot managers with more farming experience are more likely to adopt all the coping strategies except change in rice variety. Being part of a rice association has no significant effect on adaptation. As expected, farm size is positively associated with changing rice variety, acquiring agricultural credit and adopting non-agricultural strategies as ways to cope with climate change. We control for regional effects by adding department dummy variables. Households in all departments are more likely to change rice variety as a way to cope with climate change relative to households in La Libertad. Households in Amazonas are less likelyto acquire credit as an adaptation strategy in comparison to La Libertad.

Households with a high women-to-men ratio are less likely to adopt a coping strategy. The same is true for households with male managed and female managed plots in comparison to households with joint-managed plots. Other cultivation income is negatively associated with change rice variety as an adaptation strategy, but households receiving income from other cultivation are more likely to focus on other agricultural options such as crop diversification and reducing area of cultivation. The average age of plot managers seems to have a negative effect on adaptation strategies, while education has an insignificant positive effect.

Receiving technical assistance appears to be positively associated with non-agricultural strategies. Receiving certification increases the likelihood of changing rice variety while decreasing the likelihood of acquiring credit. Households that received information on varieties, agricultural practices, and climate change are more likely to adopt certain farm-based strategies while significantly less likely to adopt non-agricultural strategies.

Once we control for the above mentioned demographic characteristics, perceptions are not strongly correlated with the adoption of coping strategies. A few aspects of farmers' perceptions are significant, though. Households that perceive a change in raining seasons are more likely to change the rice variety they use. Whereas those who perceived changes in the river water level are more likely to diversify their crops or reduce the area of cultivation, acquire credit and adapt non-agricultural strategies.

As expected, changing rice variety is negatively correlated with acquiring creditand other agricultural and non-agricultural strategies (yet not significant). This means that households use these strategies as substitutes. However, all the other coping strategies are positively related to non-agricultural strategies meaning that households use sets of agricultural and non-agricultural strategies as complementary ways to cope with climate change.

Table 5. Multivariate probit results

	Change rice variety	Acquire credit	Reduce cultivation area or diversify crops	Use non-agricultural strategies
Number of working adults (15-65)	-0.097	0.129	0.255	0.171

	(1.67)	(2.14)*	(3.75)**	(2.73)**
Years of experience	-0.002	0.020	0.024	0.015
	(0.21)	(1.87)	(2.26)*	(1.60)
Rice association	0.071	0.598	0.278	-0.104
	(0.17)	(1.43)	(0.65)	(0.26)
Farm size (ha,)	0.104	0.038	-0.025	0.021
	(3.10)**	(1.49)	(0.73)	(0.67)
Amazonas	2.545	-4.038	0.400	0.178
	(3.79)**	(0.05)	(0.64)	(0.29)
Cajamarca	1.812	1.531	0.986	0.055
	(5.09)**	(3.60)**	(2.52)*	(0.16)
San martin	1.092	0.678	0.169	1.134
	(3.04)**	(1.43)	(0.39)	(2.96)**
Lambayeque	0.737	0.772	0.772	0.854
	(2.05)*	(1.63)	(1.69)	(2.24)*
Piura Base = La Libertad	0.977	0.826	1.192	0.334
	(2.25)*	(1.59)	(2.37)*	(0.71)
Women to menratio	-0.207	-0.053	-0.109	-0.113
	(1.67)	(0.42)	(0.87)	(0.93)
Male managed plots	-0.452	-0.573	-0.311	-0.602
	(1.29)	(1.62)	(0.91)	(1.71)
Female managed plots Base=Jointmanaged plots	-1.005	-0.122	-1.033	-0.192
	(1.92)	(0.23)	(1.43)	(0.36)
Average age of manager(s)	-0.007	-0.025	-0.020	-0.020
	(0.67)	(2.18)*	(1.69)	(1.95)
Average education of manager(s)	0.031	0.036	0.017	-0.013
	(1.12)	(1.26)	(0.58)	(0.49)
Other cultivation income	-0.499	0.143	0.589	0.423
	(2.19)*	(0.55)	(2.32)*	(1.78)

Technical agricultural assistance	0.035	-0.371	0.020	0.559
	(0.15)	(1.43)	(0.09)	(2.35)*
Assistance in the use of machines	-0.253	0.574	0.661	0.462
	(0.82)	(1.66)	(2.00)*	(1.29)
Received training	-0.177	0.510	0.372	0.000
	(0.82)	(2.15)*	(1.59)	(0.00)
Certification	0.785	-0.985	-0.708	0.354
	(2.10)*	(2.18)*	(1.65)	(0.95)
Information on varieties	0.588	-0.123	0.424	0.368
	(2.56)*	(0.46)	(1.63)	(1.61)
Information on agricultural practices	0.291	-0.127	-0.279	-0.783
	(1.04)	(0.43)	(0.94)	(2.75)**
Information on climate change	0.438	0.495	-0.142	-0.943
	(1.46)	(1.53)	(0.43)	(2.90)**
Change in temperature	-0.182	-0.039	-1.104	0.100
	(0.32)	(0.05)	(1.58)	(0.16)
Change in rain (frequency)	-0.467	0.121	-0.324	-0.155
	(1.34)	(0.31)	(0.88)	(0.45)
Change in rainfall (quantity)	-0.315	-0.270	0.408	-0.078
	(0.97)	(0.78)	(1.16)	(0.24)
Change in rain season	0.333	0.500	0.071	0.533
	(1.25)	(1.70)	(0.25)	(1.85)
Change in water level	-0.084	0.717	0.709	0.937
	(0.33)	(2.43)*	(2.39)*	(3.15)**
Constant	0.233	-2.123	-1.449	-1.734
	(0.25)	(1.95)	(1.39)	(1.76)
Number of observations	326	326	326	326

	P1	**P2**	**P3**	**P4**
P1 (change rice variety)	-	-0.115	-0.195	-0.072
P2 (acquire credit)	-0.115	-	0.300*	0.339*
P3 (reduce area/diversify crop)	-0.195	0.300*	-	0.257*
P4 (non-agricultural strategies)	-0.072	0.339*	0.257*	-

Conclusion

This paper examines Peruvian rice farmer's perception of climate change and the factors associated with their selection of strategies to cope with its impacts. Farm level data was obtained from 497 households in different departments in Peru. The choice of strategies is not mutually exclusive, farmers can report using more than one strategy. A multinomial Probit is used to study the determinants of adaptation choices. This study is the first of its kind to analyze the determinants of adaptation strategies to climate by farmers in Latin America. Evidence from official studies has revealed an increase in temperature in Peru over the last 40 years and a decrease in precipitation in certain areas of the country. The perceptions of farmers are consistent with the official findings.

Overall, weather station data and other aggregated data may not provide enough detail for policy design addressing climate change that is related to changes in precipitation.

More 90% of households have declared that they believe that the climate has changed and many have taken steps to cope with these changes. Farmers mainly change the rice variety that they plant in order to cope with climate change. The results from the MVP model indicate that the coping strategies adopted by small-scale rice farmers are sometimes complementary, while other times they substitute (or are negatively correlated) with other strategies. Moreover, the size of the household and of the farm, as well as the gender of the head, receiving extensions services, receiving information on varieties and climate change have a significant impact on the propensity of adopting a coping strategy. We also find that changing a rice variety can be negatively correlated with, for example, acquiring credit. This means that households use these strategies as substitutes. However, all the other coping strategies are positively related to non-agricultural strategies meaning that households use nonagricultural strategies with the agricultural strategies as complements.

Our analysis has important policy implications for the establishment of national rice production goals and recommendations on how to achieve these goals. Indeed, while a national policy goal was to shift rice production in the coast to the forest area because of the higher water availability in the latter region, our study shows that climatic variability warrants a re-examination of this objective. Hydrological patterns appear to have had wide variability in the years 2007-2012 within and across zones, with the most unique weather patterns in the Lambayeque coastal region. In this region, increases in rainfall and river water levels are significantly widespread. While precipitation decreases follow similar patterns in the rest of departments, the level of the river water, which feeds many irrigation systems for rice production, is heterogeneously affected, being higher in some areas and lower in others (in spite of similar reported decreases in rainfall). This aspect requires deeper study in order to regulate irrigation water use. The effect on irrigation of the widespread higher temperatures (through their effect on the glaciers that feed the rivers also deserves further attention).

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