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Analysis and Mapping of Impacts under Climate Change for Adaptation and Food Security (AMICAF) project in Paraguay

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Contents

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Executive summary

The AMICAF project in Paraguay produced future climate projections at fine spatial scales, potential impacts of climate change on eight crops, hydrological information, and information on food insecurity and vulnerability to climate change.
The main results of the project are:

- Climate downscaling results suggest that precipitation will decrease, while temperature (maximum and minimum) will increase for both time frames (2010-2040 and 2041-2070).
- Water use at the basin of Tebicuary and Yhaguy Rivers has a potential risk due to the current increase in demand for water resources and projected reduction of precipitation and increase in temperature.
- Higher temperatures and reduced precipitation are expected to reduce agricultural productivity, farmers' incomes and thus increase their vulnerability to food insecurity, as a result of climate change.
- Simulations of crop yield responses to future climate are variable. Some crop yields show an increase while others show a decrease, depending on the geographical location and climate projections.
- All the Departments under the study present some vulnerability to climate change. Families that depend on agriculture in the Departments of San Pedro, Caaguazu and Alto Paraná will be the most vulnerable.
- Vulnerability analysis shows that education level of household members, community infrastructure such as piped water and access to transportation are positively related to agricultural productivity. Households with more children, especially under the age of five, consume less calories suggesting children in agricultural households may be particularly vulnerable to food insecurity.

Public institutions that were part of the AMICAF project acquired stronger capacity to analyse climate change impacts on food security. Those institutions include the Ministry of Agriculture and Livestock (MAG), the Meteorological and Hydrological Division (DMH/DINAC), the Environmental Secretariat (SEAM), the Secretariat of Technical Planning (STP), the Paraguayan Institute of Agrarian Technology (IPTA), the National Forest Institute (INFONA), the Faculty of Agrarian Science of the Asuncion National University (FCA/UNA), and the Faculty of Agrarian Science of the Catholic University (FCA/UC).
In order to strengthen capacity of adaptation to climate change, following recommendations are made in the fields of data collection, capacity development, national program and comprehensive research:

- Dedicate necessary resources among the different ministries/institutions to update the basic data collection in the field and collect new data.
- Build capacity and ensure the resources to strengthen the institutional and technical competences in terms of water management.
- Strengthen the national programs and plans such as National Plan for the Disaster Risk Management and Adaptation to Climate Change in the Agricultural Sector of Paraguay to support small-scale family agriculture and rural extension offices.
- Build synergies among universities, research centres and government organizations in order to implement lines of research that could include all dimensions of food security and promote adaptation to local conditions and climate change.

1. Context of the AMICAF project in Paraguay

Paraguayan economy is highly dependent on agriculture and livestock. Despite the country's relatively small population of approximately seven million people, Paraguay is the sixth largest producer of soy and the eighth largest exporter of beef in the world (FAO, 2017).

The Ministry of Agriculture and Livestock was the focal point of the AMICAF project in Paraguay. The project was developed in coordination with the Meteorological and Hydrological Division (DMH/DINAC), the Secretariat of Technical Planning (STP), the Environmental Secretariat (SEAM), the Paraguayan Institute of Agrarian Technology (IPTA), the National Forest Institute (INFONA), the Faculty of Agrarian Science of the Catholic University (FCA/UC), and the Faculty of Agrarian Science of the Asuncion National University (FCA/UNA).

The establishment of working groups and the capacity building activities carried out through the project have strengthened the technical knowledge of participating organizations, and encouraged the development of a collaborative inter-institutional framework. The outputs of the AMICAF project contributed to strengthen governmental program.

2. Climate downscaling in Paraguay

Climate Downscaling in Paraguay is based on the historical meteorological information from 12 meteorological stations for the entire country. Stations are selected according to data availability: only stations with 30 or more years of data are considered. Projections of precipitation and temperature (maximum and minimum) are obtained for two time frames:

- 2010 to 2040 (near future)
- 2041 to 2070 (far future).

The historical reference time considered is 1981 to 2010.

The models under analysis show that a reduction on precipitation is expected for both time periods up to 2070, while temperature (maximum and minimum) are expected to increase. The models show a range of possible decrease of precipitation, from 2.40 percent to 10.24 percent under the Representative Concentration Pathway (RCP) 4.5, while the possible decrease on precipitation for RCP 8.5 ranges from 3.27 percent to 15.92 percent.

Projected temperature increases range from 1.8 °C to 2.7 °C (for maximum temperature), from 1.8 °C to 3.3 °C (for minimum temperature) under the RCP 4.5, and from 2.3 °C to 3.3 °C (for maximum temperature), from 2.18 °C to 4 °C (minimum temperature) under the RCP 8.5 (see Table 1). The changes shown in Table 1 are calculated on averages over 30 years (1981-2010 and 2041-2070) for precipitation and temperature.

Table 1 | Results obtained at national level for the time frame 2041 to 2070 corresponding to three models

Models	RCP 4.5			RCP 8.5		
	Precipitation (%)	TMax (°C)	TMin (°C)	Precipitation (%)	TMax (°C)	TMin (°C)
CAN-ESM2	-10.24	2.7	3.3	-15.92	3.3	4.0
CNRM	-7.12	1.8	1.8	-3.27	2.3	2.2
MPI	-2.40	1.8	2.0	-3.82	2.8	2.7

3. Assessing the impacts of climate change on selected crop yields

The impact assessment of climate change on crops include the analysis of historical yields and projected trends for the future. The historical yield data are provided by the Ministry of Agriculture and Livestock. To estimate possible differences on crop yields between past and future scenarios, different models are considered using two RCPs (4.5 and 8.5).

The analysis is based on the following criteria for the selection of crops:

- crops which are important to small-scale family agriculture
- availability of historic yield data (at least 30 years of data)
- crops which are important as export goods
- relatively large surface area under cultivation.

Based on the mentioned criteria, the eight crops selected are: sugarcane, beans, cassava, corn, wheat, soybean, irrigated rice and non-irrigated rice.

The results show great heterogeneity in terms of future impacts on the yield of crops at the department level due to climate change, with both increasing and decreasing projections for different departments and crops. For several crops, no significant differences between historical and projected future yields are detected, or different GCM projections lead to inconsistent results. Only results for departments and crops that show statistical significance and models agreement are considered here.

The analysis of impacts of climate change on corn and wheat yield in 17 Departments shows no significant differences between historical and future modelled yields.

Results for soybean were mostly heterogeneous, with significant decrease on future yields projected in Misiones (MPI model, RCP 4.5), Alto Parana and Amambay Departments (CANES model, RCP 4.5 and RCP 8.5).

Upland and irrigated rice yields show a different behaviour: the most affected by climate change is expected to be the upland rice, with significant reduction in yields in the departments of Itapúa and Canindeyú. Irrigated rice shows instead positive changes in yields in the departments of Cordillera and Misiones, and negative for Paraguarí.

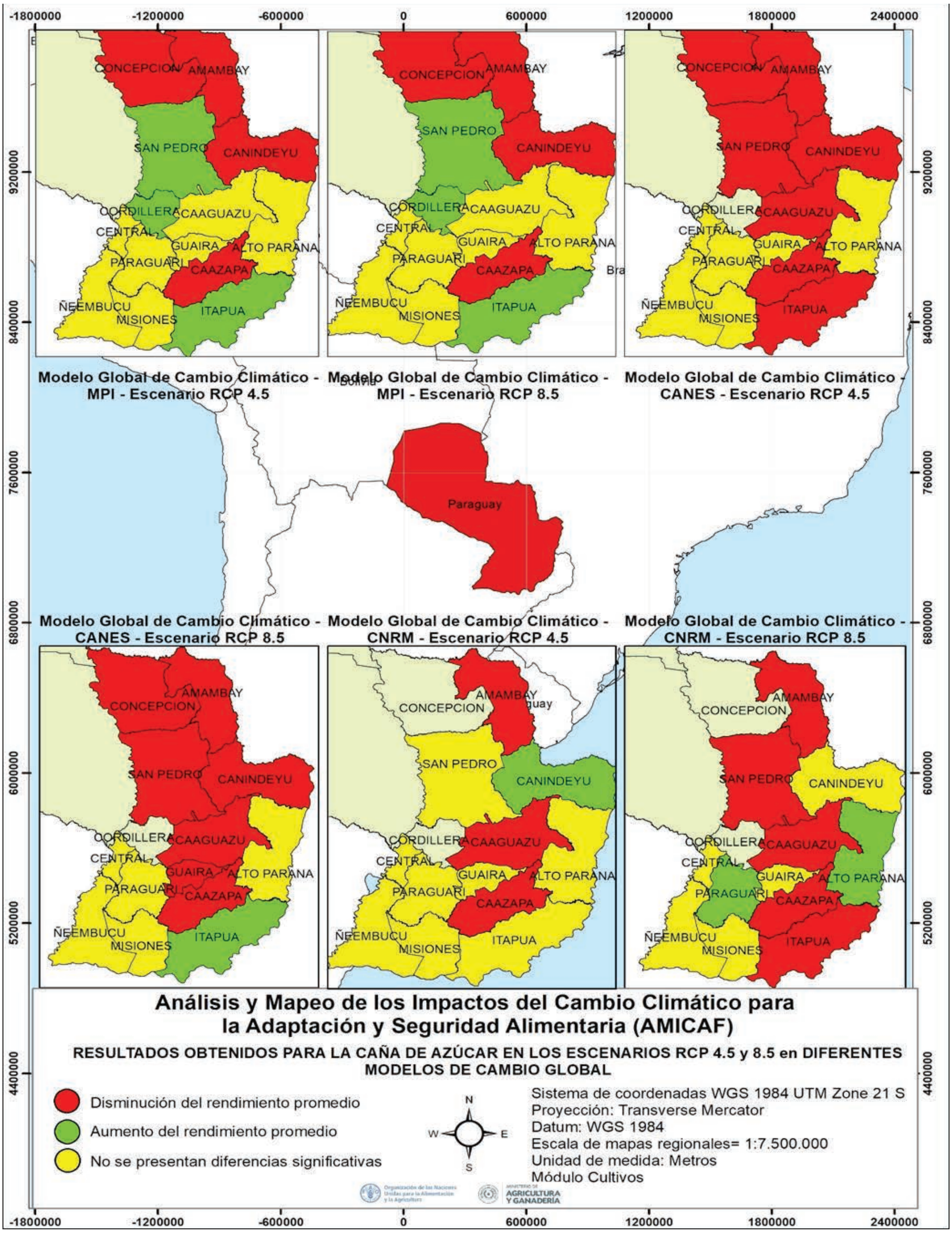
Sugarcane yield projections show widespread decrease, affecting significantly the departments of Amambay, Caazapá, Caaguazú, Canindeyú and Concepcion Departments under the RCP 4.5, while increment of future yield are expected for Paraguarí Department under the RCP 8.5 (see Figure 1).

Cassava ("mandioca"), a crop strongly associated with family small-scale agriculture, could significantly increase its yield in Alto Paraguay, Amambay, Canindeyú, Caazapá and Concepción. The yield increase is consistent in both scenarios RCP 4.5 and RCP 8.5 (see Figure 2).

The variability in yield responses to climate change mentioned above is also found for beans ("poroto"). Two out of three models show significant reductions on the yield of beans for Alto Paraguay, Alto Paraná and Amambay. The opposite result is found with CNRM model, which shows increase on the yield of beans in the Departments of Alto Paraguay and Alto Paraná.

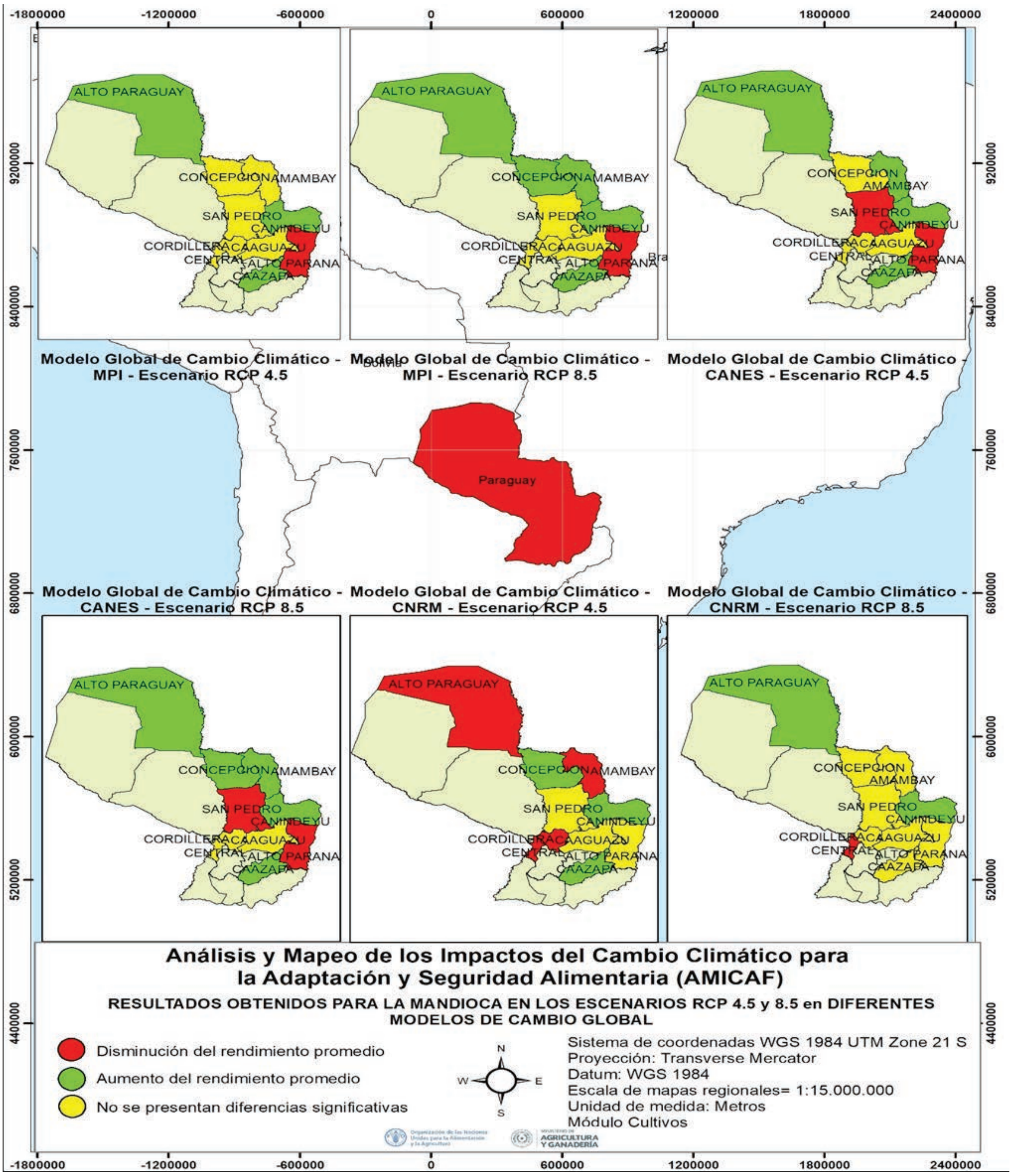
In summary, negative impacts of climate change are expected for sugarcane (in five departments), soybeans (in three departments), and upland rice (in two departments). Interestingly, cassava shows a positive impact of climate change on yields for approximately the same region for which negative impact is observed for sugarcane. We can conclude that the higher climate change risks concern sugarcane, soybeans and upland rice, while wheat, maize and beans show no significant changes, or both positive and negative changes. We can consider these crops as the most resilient, while cassava yields appear to mainly benefit of climate change effects.

Figura 1. | Projected changes of sugarcane yields according to three GCMs, RCP 4.5 and RCP 8.5



Source: Paraguay Ministry of Agriculture and Livestock, (2018).

Figura 2. | Projected changes of cassava yields according to three GCMs, RCP4.5 and RCP8.5



Source: Paraguay Ministry of Agriculture and Livestock, (2018).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4. Compilation of hydrological information and capacity building

Water availability and quality is important both for human consumption and for agricultural use. Currently, approximately 75 percent of the Paraguayan population has access to pipe water while only 15 percent has access to sewerage systems. There are also differences on access to water services between urban (87 percent) and rural areas (58 percent).

Farming in Paraguay is mainly without irrigation, although in recent years this situation is changing. Considering the future climate change, increase of the areas under irrigation system might be expected.

Tensions and problems related to water use at the basin of Tebicuary and Yhaguy Rivers have increased in recent years. Projected climate change for Paraguay includes reduction of precipitation and increase of temperatures, therefore, problems related water use might increase in the areas surrounding the basins if proper actions are not taken.

5. Analysis of household vulnerability to food insecurity due to climate

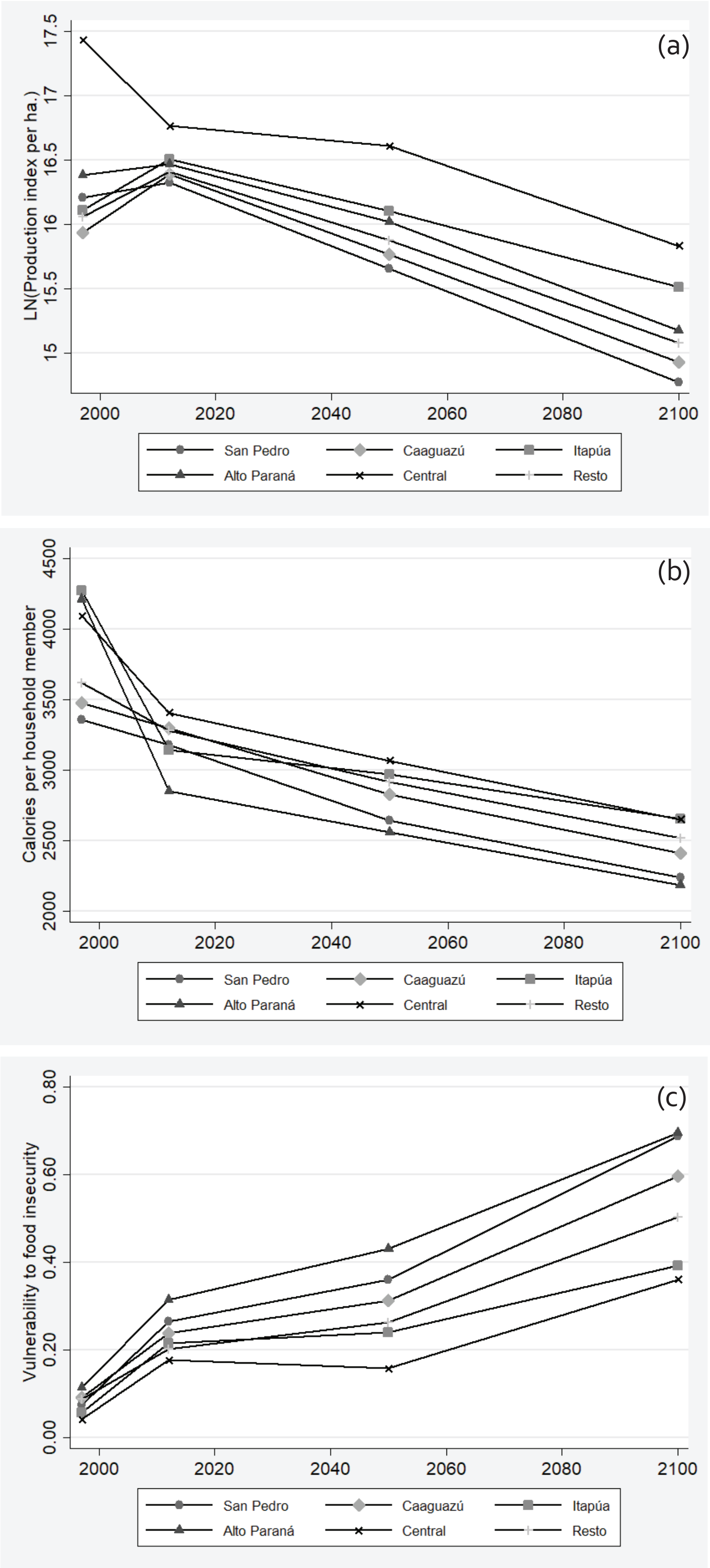
To assess the impacts of climate change on food security in Paraguay, the methodology recommended by Capaldo *et al.* (2010) and Karfakis *et al.* (2011), is applied. In these studies, the authors define vulnerability as the probability of facing food insecurity in the near future as a result of climate change. On these grounds, vulnerability to food insecurity is calculated through the impact that climate change has on agricultural production and income and through that, on food consumption in terms of caloric intake. In other words, the analysis estimates the probability of change on caloric consumption due to climate change impacts on household agriculture productivity. The results strongly indicate that increasing temperatures and reduced precipitation will reduce agricultural productivity. Specifically, a 1 percent increase in average maximum temperatures is associated with a 5 percent reduction in agricultural productivity (p-value < 005). A 1 percent reduction in rainfall is associated with a 0.58 percent reduction in agricultural productivity (p-value < 005). Reduction in agricultural productivity due to climate change translates into reduced household income, lower availability of calories, and an increase in average vulnerability to food insecurity. The result here is obtained through an econometric approach and refer to productivity defined as the value of agricultural production per hectare of cultivated land.

Nevertheless, a number of policy variables indicate possible pathways to reduce vulnerability to food insecurity. Variables that are proxies for community infrastructure, such as piped water and access to transportation are positively correlated with agricultural productivity. For instance, having access to water inside the house or on the property increases the productivity of the household by over 12 percent compared to households without access to water on the property. Having access to transportation (automobile, truck, or motorcycle) is associated with a 10 percent increase in productivity versus not having a means of transportation.

Socioeconomic characteristics of the household have different effects on agricultural productivity and food consumption. Households with more household members are more productive in agriculture, but consume less calories per capita. Households with more children under the age of five consume less calories and this effect is statistically significant, suggesting children in agricultural households may be particularly vulnerable to food insecurity. Education plays a positively important albeit differential role in household productivity and caloric consumption. Increasing the average years of schooling of male household members increases agricultural productivity, whereas increasing the average years of school of female members is associated with consuming more calories. The analysis assessed the medium and long term impacts (i.e. by 2050 and 2100) of climate change on food security under a business as usual scenario,[1] and the challenges are dire unless serious policy actions are taken. The results from the policy simulation scenarios indicate that agricultural productivity will monotonically decrease, as a consequence of variations in climate. The results shown in Figure 3(a) imply that if actions to adapt and mitigate the potential impacts of climate change are not taken, climate change will negatively affect agricultural production. Similarly, the effects of climate change are expected to reduce caloric consumption, due to the loss in agricultural productivity as shown in Figure 1 (b). Lastly, the simulation results indicate that the risk of food insecurity will increase as a result of climate change. These results represent the risk that households are expected to be exposed to, in the absence of interventions for adapting and mitigating the effects of climate change.

1 In the long term assessments of climate change impacts all climate variables follow a linear trend estimated for each season and department using climate data over the 1980 to 2015 period, up to 2100. The projected climate variables are used to simulate impacts on agricultural productivity and production, food consumption and vulnerability to food insecurity, while holding all the remaining variables in the model at their 2012 mean values and apply the parameter estimates from the baseline regressions.

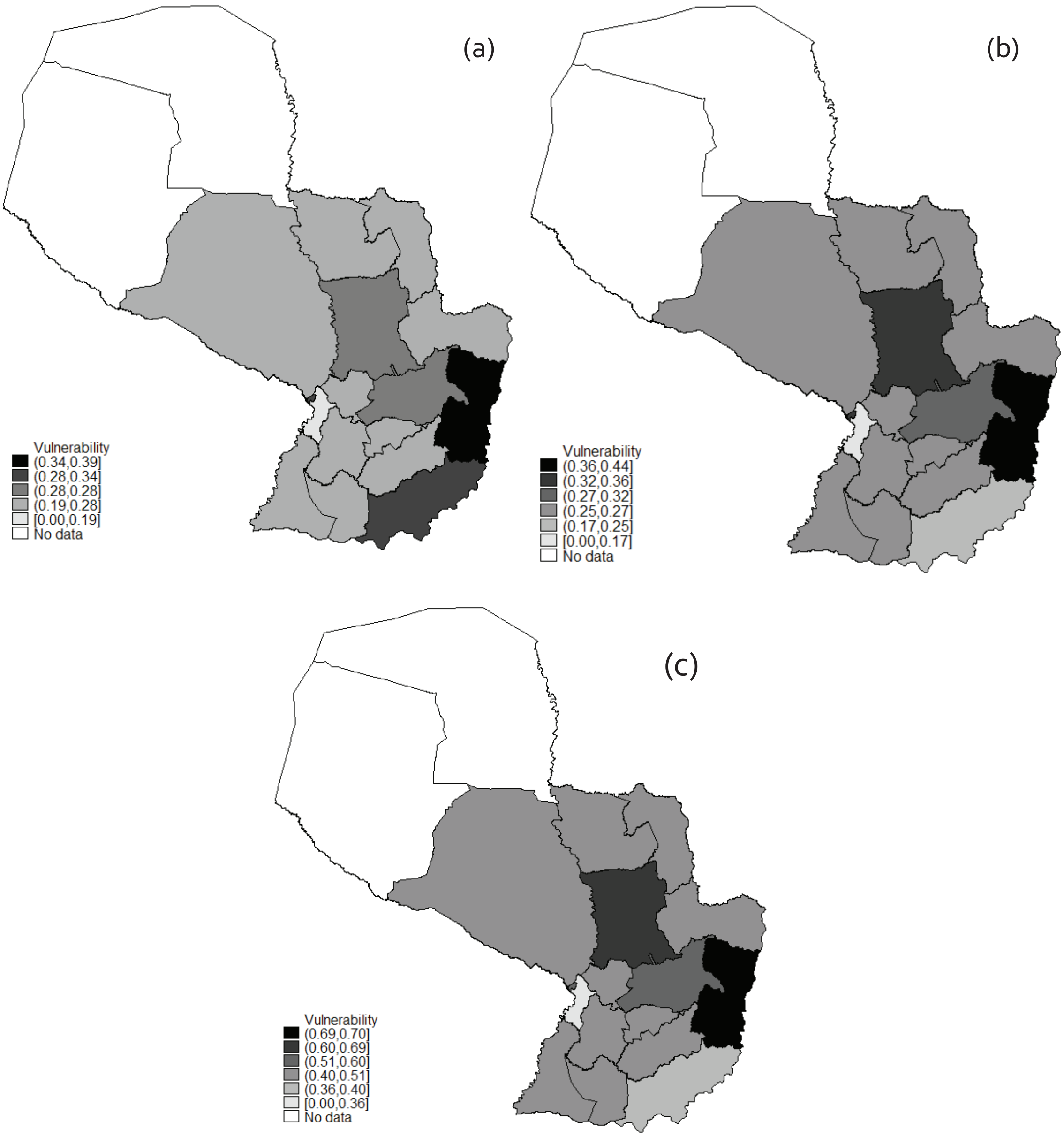
Figura 3. | Simulations results: agricultural production index (a), caloric consumption (b), and vulnerability (c)



Source: Ervin, P. and L. Gayoso de Ervin, (2019), Household Vulnerability to Food Insecurity in the Face of Climate Change in Paraguay, ESA working paper series, forthcoming, FAO, Rome

The analysis of the simulation results by departments indicate that weather patterns will result in differences in the intensity of the impacts of climate change. Figure 4 shows the maps of vulnerability for three years: 2012 (based on observed data), and estimations for 2050 and 2100. While all departments in the country are expected to see increased vulnerability to food insecurity due to climate change, the departments of San Pedro, Caaguazú, and Alto Paraná are expected to be the most affected, due to temperatures increasing faster in these regions. In the end, if no actions are taken, more than half of all agriculture producers in these departments are expected to suffer from food insecurity due to climate change. In addition, other agricultural households throughout the country are expected to face a significant increase in the risk of food insecurity due to climate change.

Figura 4. | Simulation results maps of vulnerability, for the year 2012 (a), 2050 (b) and 2100 (c)



Source: Ervin, P. and L. Gayoso de Ervin, (2019), Household Vulnerability to Food Insecurity in the Face of Climate Change in Paraguay, ESA working paper series, forthcoming, FAO, Rome

6. Policy recommendations

1) Strengthening data collection, processing and analysis

More accessible and reliable data is a fundamental part of the decision making process. In this context, it is important to mention that there has been progress in the country in terms of availability of data needed to analyse all the dimensions of food security. However, it is still necessary to strengthen the data collection and analysis. Some specific recommendations include:

- Build capacity at the local level staff of the Division of Agrarian Extension (DEAg) at MAG, which should be trained on data collection techniques. Although some crop yields showed an increased trend, such as cassava, and others showed a decrease trend, such as sugarcane, more robust data set is needed to draw conclusions about how each crop could be affected. Simple and standardized field data sheets should be designed.
- Use simple applications, which could increase the efficiency and reduce time and cost of collecting data.
- Ensure funding for data collection and analysis under the current programs, and include resources allocation for future development programs.
- Consolidate the multidisciplinary technical team that is working on data analysis related to climate change and adaptation.
- Strengthen the information systems in order to have an integrated database shared by the institutions.

2) Building capacity and strengthening the institutions in charge of managing water resources in the country

Information systems related to water resources need special attention. Water quality, availability, and use are essential information to implement climate change adaptation programs. SEAM and DMH/DINAC are implementing specific programs related to water resources. These programs should be strengthened. Taking into account the current situation of water resource management in the country, the following recommendations have been formulated:

- Strengthen data collection system and increase the number of automatic hydrometeorological stations in the country.
- Create an integrated early warning system for different water resources users (agricultural producers, boat sailor and ecosystems).
- Strengthen the national water resources' registry of users in order to improve the administration of water resources.
- Regulatory framework of the Law 3239/2007 of water resources should be issued. This regulatory framework is crucial to establish a clear mechanism for water resources management. The process to establish the regulatory framework started but a decree in this regard is still pending.

Considering the importance of water resources for the country and the necessity for allocating funds and other resources to ensure an integrated water management, it is advisable to create a government agency in charge of water resources management. This recommendation is based upon the experience of other countries. Currently, the revenues obtained by the electricity trade are used to fund the National Fund for Public Investment and Development (FONACIDE). Water management is essential for electricity generation in the country; therefore, using part of FONACIDE resources for water management will contribute to the sustainability of the whole system.

It is important to determine the ecological flow of the main watersheds,[2] in order to establish management guidelines and ensure proper quotas and water availability. This is convenient not only for economic activities but also for other services, including those in the environmental sector. Special attention should be paid to the Tebicuary and Yhaguy basins, considering current water use conflicts that could be exacerbated due to climate change.

3) Enhancing support programs for small scale family agriculture and agricultural extension

Negative impacts in terms of smallholders' income and welfare are a serious threat only if no action is taken against climate change. Farmers themselves undertake a good share of this action by observing and adapting to changing climate.

An equally important part refers to the public sector's responsibility to design evidence-based policies on adapting to or even mitigating the impacts. On this ground, climate smart agriculture policies have the highest potential for coping with climate change.

Additional resources should be invested in research and development for drought, flood or temperature resistant crops. Sustainable intensification practices have to be adopted and implemented on a wider scale.

Considering the impacts of climate change on agriculture, it is important to establish capacity building programs that include training on good agricultural practices which can enhance adaptation. In this sense, the identification and promotion of good practices for different crops should be vital.

Agricultural extension systems and agricultural training centres must be strengthened as these are the channels to reach out to farmers. Technicians should be trained and able to advise producers in the following priority areas:

- Water management, including techniques to harvest, store and sustainably use rainwater
- Management and conservation of soils and watersheds
- Good agricultural practices that facilitate infiltration, reduce erosion and potentiate carbon sequestration and storage such as agroforestry and silvopastoral systems
- Hydro-agrometeorological services that are available in the country
- Basic knowledge on the impact of climate change on agriculture in the country

[2] Environmental flows describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems, as pointed out during the tenth International River Symposium and Environmental Flow Conference held in Brisbane, Australia, in September 2007.

4) Creating synergies among research centres and institutions in charge of implementing development programs

Agrarian research centres play a fundamental role in identifying, documenting and improving good agricultural practices, which are important to ensure adaptation to climate change at the local level. In this context, development agencies should work closely with research centres to incorporate good practices into development plans.

The main actions needed to increase synergies are:

- promoting cooperation agreements in order to incorporate the assessment and monitoring of good agricultural practices into development programs;
- increasing and facilitating the participation of researchers and students on projects related to climate change; and
- strengthening the capacity of universities through the incorporation of students and lead researchers on the different development projects under implementation.

Currently most development projects contains monitoring and evaluation (M&E) systems. M&E activities are designed to be carried out by project staff or by independent agencies in order to increase the confidence on the data. The participation of research centres and university departments on M&E activities could be a good opportunity to build capacity at the local level. Furthermore, the incorporation of universities on M&E activities will ensure the dissemination and communication of lessons learned.

Climate change and food security have a complex interaction, therefore research is needed on all dimensions of food security. The following research topics were identified during the AMICAF project:

- Impacts of climate change on livestock
- Climate change impacts on distribution of vector, pathogens and crop pests
- Impacts from climate change on human health including vector-borne diseases
- The impacts of development programs on vulnerable populations

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