Food and Agriculture Organization of the United Nations

FUNDING PROPOSAL TO THE GREEN CLIMATE FUND

-IRES-CUBA-
INCREASED CLIMATE RESILIENCE OF RURAL HOUSEHOLDS AND COMMUNITIES THROUGH THE REHABILITATION OF PRODUCTIVE AGROFORESTRY LANDSCAPES IN SELECTED LOCALITIES OF THE REPUBLIC OF CUBA

APPENDIX 2.4 Baseline Study of Adaptation and Vulnerability for the Implementation of the Project

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ACRONYMS

AMA	Environmental Agency
AIP	Project Intervention Area
°C	Degree centigrade
CAI	Agroindustry Complex
CAM	Council of the Municipal Administration
CH4	Methane gas
CITMA	Ministry of Science, Technology and Environment
CO_2	Carbon Dioxide
CP	Popular Council
CPs	Popular Councils
CV	Coefficient of variation
D.STAND	Standard deviation
ENOS	El Niño/Niña Southern Oscillation
GEI	Greenhouse effect gases
GEPROP	Management of Prioritized Projects
GtC	Gigatons of carbon
hm^3	Cubic hectometers
ha	Hectare
Hr	Relative Humidity
INIVIT	National Institute of Tropical Food Research
INHR	National Institute of Hydraulic Resources
INSMET	Institute of Meteorology
IPF	Institute of Physical Planning
IPCC	Intergovernmental Panel on Climate Change
kg	Kilogram
km	Kilometer
km^2	Square kilometer
LADA	Evaluation of Land Degradation in Arid Zones
m	Meter
m^2	Square meter
m^3	Cubic meter

m/s	Meter per second
Mm^3	Millions of cubic meters
MINAG	Ministry of Agriculture
MP	Millions of pesos
NAN	Normal Water Level (Total capacity of the reservoir)
N_2O	Nitrous oxide
OACE	Organizations of the Central State Administration
ONEI	National Office of Statistics and Information
ppmm	Parts per million
$PPNcCO_2$	Net Primary Productivity of dry mass with fertilization by CO2 (T / ha)
PVR	Danger, vulnerability and risk
SIG	Geographic information system
SPI	Standardized Precipitation Index
SPI no LL	Standardized Precipitation Index of the non-rainy period
SPI LL	Standardized Precipitation Index rainy period
SST	Total Soluble Salts
t	Tons
t/ha	Tons per hectare
TMax	Maximum Temperature
TMin	Minimum Temperature
WOCAT	World Overview of Conservation Approaches and Technologies
W/m^2	Power density per square meter
W_o	Potential Volume of Water Resources

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EXECUTIVE SUMMARY

The Government of the Republic of Cuba, through its Ministry of Agriculture, requested the support of the FAO for the formulation of a Project Financing Proposal, "Increasing the resilience of vulnerable rural households and communities through rehabilitation of productive agroforestry landscapes in selected locations of the Republic of Cuba ", aimed at increasing the adaptation capacity of rural households and communities affected by climate change in seven municipalities of three selected provinces (Matanzas, Los Arabos, Villa Clara, Corralillo, Quemado de Güines and Santo Domingo, and Las Tunas, Amancio Rodríguez, Colombia and Jobabo) to be presented to the Green Climate Fund. In compliance with this request, FAO maintained intense contacts with the main institutions and actors involved and, in this sense, facilitated the formulation of a request for financial support to co-finance the formulation process of the Funds Proposal.

The present work aims to conduct a baseline study of adaptation and vulnerability to climate change for the three zones and seven municipalities selected by the project, integrating exposure, sensitivity, adaptive capacity of the population, in line with the impacts of climate change on their environment for their homes and productive units. In this sense, the context of Climate Change in Cuba is taken as a starting point, with emphasis on the variables of water resources, coastal zones, forests, agriculture, human settlements and land use and impact on the yields of selected agricultural production. Finally, vulnerabilities are identified and evaluated in each territory where the project will be implemented.

The processing and analysis of the databases show that the climate of the Central zone is drier and hotter than 37 years ago, with notable impacts on the vegetative cycle of crops and the thermal comfort of livestock. The average maximum temperature has increased between1978-2016 at a rate of almost 1.5% per year. While the average minimum temperature grows, in the same period, at 0.9 ^{0}C. Although the series of annual precipitation values for Cuba in the period 1961-2007 does not show a statistically significant trend, since the end of the 70s, there has been a slight but steady increase in positive anomalies, which are most relevant since the beginning of the 90s.

In the Eastern zone the average minimum temperature has increased by at least 0.8 ^{0}C between the 1970s and the present, confirming the tendency to rise in the average temperature. A hydrological study carried out in the reservoirs in the area, over a period of 34 years found that only in 8 of these, the filling volumes have behaved close to the nominal, the other years have been below 50% filling, evidencing that the rainfall parameters for which these dams have been designed have had a decreasing tendency, not forgetting that the only source of water in the country comes from rainfall. In this area, we can also see a tendency to increase the average values of positive anomalies, particularly in the period 1980-2007, with a reduction in the variation of the average values of precipitation.

Regarding the rainy season, the distribution of precipitation anomalies reveals a change in average values during recent decades, but contrary to the trend described for the non-rainy period, in this case there is a tendency to the predominance of negative anomalies. This behavior implies reduction of the range of variation of the average values of rainfall, particularly in the Eastern Zone. The most notable thing in this rainy period is the sharp decrease in the average values and variation in this Eastern Zone. The reduction of accumulated rainfall in the Eastern region is largely due to the more frequent occurrence of meteorological drought processes in recent years in that region.

The impacts of climate change on the yields of the main crops of the agricultural sector for vulnerable households in the AIP indicate a differentiated behavior in the Central and Eastern Zone, but in both areas, there is a tendency to decrease the yields studied.

The projected scenarios of an increase in average temperatures and a reduction in rainfall will have an impact on the reduction of pasture area yields, measured as net primary production, in the AIP. Also, the bio productive indicators of the cattle, will undergo considerable changes and the trends point to a lower birth rate, increase in the optimal age possible for the first parturition and increase of the general mortality. With the increase of temperatures in an increasingly prolonged period of time in the reference scenarios, the comfort conditions for cattle will be extremely unfavorable considering that as time passes and the number of months in which the temperatures Maximum and average air averages are higher than 27 ºC and 30 ºC respectively, the deterioration of the comfort conditions of cattle will increase. In the Reference scenario at 2100, average maximum temperatures will be higher than 30 ºC in more than 8 months of the year in all regions, while average temperatures will be higher than 27 ºC in more than 7 months of the year.

In summary, the agricultural sector in the AIP will develop in an environment affected by the increase in the frequency and intensity of droughts, the aridization of the climate, the reduction of the real evapotranspiration of the ecosystems and a pronounced water deficit.

The resources and edaphoclimatic potential in the AIP show differences between the central and eastern zones. The central zone in comparative terms has a moderate potential, while in the eastern zone it is low, in both zones the salinity, the erosion and the ago-productive potential of the soils are factors that limit the processes of adaptation to climate change in the AIP.

The projection of the uses and changes of land use in the AIP according to the climatic scenarios without the intervention of the project is estimated to correspond to the trends and trajectories experienced by the relevant uses and coverage studied (cane, crops, natural pastures, forests and idle lands) and with the impacts of climate change predicted on the yields of the main crops and livelihoods of vulnerable households, taking into account that there is a close interrelation between the impacts of climate change, changes in coverage and use of land and water resources, which in the case of Cuba and the AIP has a high dependence on the behavior of rainfall and the moderate to low edaphoclimatic territorial potential of both AIP zones.

The field zoning of the current uses in the areas in process and susceptible to the phenomena of desertification, degradation and salinization in the AIP shows that the Central zone has greater cultivated area (cane and several crops) and natural pastures in the category of very exposed, while in the Eastern zone the coverage of land use most exposed are occupied by forestry and idle land. There is therefore a significant difference between the Central and Eastern zones in relation to the use of the present land and its field distribution in the most prone areas and exposed to desertification, degradation and salinization, a relevant aspect that must be taken into account in the implementation of the agroforestry modules that the project promotes.

The changes in the patterns of precipitation behavior in particular from the decade of the 90s in the rainy season and its reduction, the increase in evaporation, together with the increase in saline intrusion as a consequence of the elevation of the mean sea level, will affect the availability and quality of the water resources of the AIP.

With the intensification of the drought in both areas of the AIP, and in particular the Eastern zone, the levels of salinity in soils and waters will increase remarkably; increasing the areas prone to desertification, degradation and salinization and the reduction of food production for the population among other negative incidents. In the AIP, reservoir filling levels, availability and access are affected by the recurrent periods of moderate and severe drought, and the tendency to decrease rainfall due to the progressive effects of climate change. The hyperaneous behavior of the reservoirs is evidenced in correspondence with the decrease of the precipitations and the affectation by intense droughts that the AIP has experienced, that in its historical behavior have extended for periods longer than 12 months in the Central zone and at 24 months in the Eastern zone.

The estimation of households and their livelihoods constituted, perhaps, the main challenge of this work. Avoiding double counting of households and population at risk is a requirement of the greatest importance in order to allocate funds for resilience in the face of the vulnerability of the different threats posed by Climate Change.

For this purpose, a numerical classification based on cluster analysis applied to the field data matrix composed of 55 popular councils, 4 threats and 3 variables was used. Cluster analysis allowed identifying five groups that synthesize the total vulnerability, allowing applying the following classification: very vulnerable, vulnerable, moderate vulnerability, low, and very low vulnerability.

In terms of land use, very different values can be observed between AIP, favorable to the Central zone, that is, 31% versus 20.6% in the Eastern zone, which must be affected by the amount of idle land covered by marabou (*Dicostrachys cinérea*) and that becomes more critical, precisely, in the AIP of the Eastern zone.

On the other hand, the area dedicated to the production of food presents a less unfavorable situation in the Center's AIP compared to the AIP in the Eastern zone. Certainly, the ratio cultivated area for food in relation to the agricultural area for the popular councils located in Groups I and II of total vulnerability, is double in the Central zone with respect to that obtained for the Eastern zone. In this sense, the higher incidence of the cultivated area of sugarcane within the cultivated area of these Vulnerability Groups, is what makes there less availability of cultivated area for food. Such situation could be understood as a reduction of the Capital of cultivated land of food for human consumption in the zones identified as having high Vulnerability. This capital is undoubtedly an important part of the livelihoods of the population, to which the project's actions focus primarily.

The households with high vulnerability in the AIP of the Central zone would be those belonging to Groups I and II, and would be in the order of 12 730 households. For its part, the population included in these amounts to 30 180 inhabitants. On the other hand, the households with high risk in the AIP of the Eastern zone, are in the order of the 30 639 homes, while the population ascends to 96 922 inhabitants. The number of very vulnerable and vulnerable households in the area of project implementation, both zones, amounts to 43 369, with an exposed population of 127 102 inhabitants.

INTRODUCTION

The accumulated anthropogenic CO2 emissions from 1750 to 2011 have been 555 GtC (375 GtC from emissions released from CO2 from the combustion of fossil fuels and the production of cement and 180 GtC from deforestation and other changes in land use). Of these emissions, 240 GtC have accumulated in the atmosphere, 155 GtC have been incorporated into the oceans and 160 GtC have accumulated in terrestrial natural ecosystems. In 2011, the concentration of carbon dioxide (CO2) was 391 ppb, methane (CH4) 1803 ppb and that of nitrous oxide (N2O) 324 ppbm. These values exceeded the pre-industrial levels by approximately 40%, 150% and 20%, respectively.

The increase in the concentrations of these GHGs is responsible for the radioactive forcing that has led to an absorption of energy by the climate system. The greatest contribution is caused by the increase in the atmospheric concentration of CO2 that has been produced since 1750. In the period 1951-2010, GHGs contributed to the global average surface heating in a range of 0.5 ° C to 1.3 ° C, while natural forcing contributed in a range of -0.1 ° C to 0.1 ° C[1].

For this reason, the Fifth Assessment Report of the Intergovernmental Panel on Climate Change states that: "The warming of the climate system is unequivocal, and since the 1950s, many of the changes observed have not been unprecedented in the past, the last decades to millennia. The global evidence indicates that the air temperature over the terrestrial and oceanic surface has experienced a warming of 0.85 ° C during the period 1880-2012. The 1983-2012 period is likely to be the warmest 30-year period of the past 1400 years in the northern hemisphere. For its part, the upper layer of the ocean, has also warmed, between 1971 and 2010, at a rate of 0.11 ° C per decade; while its waters have become 26% more acidic in relation to the beginning of the industrial age.

While, in the last two decades, the ice sheets of Greenland and Antarctica have been losing mass, and glaciers have continued to decline in almost the entire world. The average level of the sea, between 1901-2010, rose 0.19 meters. It is likely that there are many more regions where intense rainfall events have increased in contrast to those where these phenomena have decreased. Tropical cyclones in the North Atlantic basin have been most intense since 1970.

Future scenarios predict that climate change will amplify the observed risks, as well as the appearance of new ones in natural and human systems. For example, the risks of climate change related to freshwater resources increase significantly with growing concentrations of greenhouse

[1] Radioactive Forcing: Change in the flow of energy in W / m2 caused by an impeller. If it is positive, surface heating and cooling occurs when it is negative

gases. It is projected that climate change in the 21st century will significantly reduce renewable surface water resources as well as groundwater resources in most subtropical dry regions, intensifying competition for water between sectors.

Due to the increase in sea level projected for the 21st century and beyond, coastal systems and lower areas will gradually experience adverse impacts such as soil loss, flooding, salinization of water and soils, and coastal erosion. For major crops it is projected that climate change without adaptation will negatively impact production due to increases in local temperature of 2 ° C or more above the levels of the late 20th century, although some areas may benefit. All aspects of food security and food production systems are potentially affected by climate change, including access to food, consumption and price stability.

For its part, the climatic conditions of the Cuban Archipelago are determined by its geographical position, in the northern hemisphere. Cuba receives high levels of solar radiation throughout the year, which conditions the warm character of its climate; in turn, the proximity to the Tropic of Cancer presupposes the seasonal influence of tropical and extratropical atmospheric circulations. The data show convincingly that in the climate of Cuba there has been an increase in the surface temperature of the air; a reduction of the diurnal temperature range; greater frequency of long and severe droughts, especially in the summer; and an increase in rainfall totals associated with heavy rainfall events in winter.

The most notable changes experienced in the Cuban climate can be summarized in the behavior of the following climatic variables:

- The surface temperature of the air has increased by 0.9 ° C since half of the last century; conditioned by the increase in the average minimum temperature by 1.9 ° C; a decrease in the diurnal oscillation of the temperature occurs.

- The slight increase in positive anomalies of rainfall since the late 70's of the twentieth century with an increase in rainfall during the dry season (November to April).

- The tendency to diminution of precipitation in the Eastern Region, which since the decade of the 90s of the twentieth century has manifested significant deficits in the accumulated rainfall.

- The significant increase in drought events for the period 1961-1990 with respect to 1931-1960.

Endurance of these events in the eastern half of the country and the extraordinary event of drought between 2003 and 2005, which progressively spread throughout the country.

- Since 1996 began a new period of very active hurricane activity on Cuba. Between 2001 and 2008, the country was affected by nine hurricanes;
- The increase of the incidents of moderate and strong coastal floods during the last three decades.

The results of the 2050 and 2100 climate projections show that, towards the end of the 21st century, Cuba's climate will be hotter, drier and more extreme. It is expected that by the end of this century the climate will be characterized by: i) Increase of up to 4 ° C in the average air temperature; ii) annual precipitation decrease between 15 and 63%; iii) an increase in potential evapotranspiration and real evaporation, which leads to the progressive reduction of the net primary productivity of terrestrial and agricultural ecosystems, as well as the potential density of biomass; iv) dry sub-humid climates will advance in extension from the eastern region to the west; and v) dry sub-humid climates, susceptible to desertification, will be established in the eastern mountainous massifs.

Climate change influences strongly and negatively on almost all natural and human ecosystems. In the case of Cuba, such impacts have been identified and projected in agriculture, forests, coasts and human settlements and land use.

Agriculture is one of the human activities most dependent on climate and other environmental factors, so much so that we can talk about the conditioning of climate on agriculture (Rivero, 2002). Studies carried out by Rivero et al., 2002 and 2010, allow to affirm that the potential agricultural and irrigated yields of the main crops will progressively decrease over the next century between 10 and 25%; for sugarcane between 5 and 10%; and those of the tubers up to 50%. Total crop evapotranspiration will generally decrease except for potatoes, but irrigated water needs would rise progressively, between 40-55%, for short-cycle crops and 15-30% for long-cycle and perennial crops.

On the other hand, the effect of climate change on weeds would also affect pastures in livestock areas, which in the case of Cuba are predominantly gramineous, benefiting harmful invasive alien species such as marabou (*Dicostrachys cinerea*). According to climatic scenarios (increases of 1-2 ° C in the mean t), it is expected a greater aggressiveness of many of the existing pests and the emergence of new ones, giving the possibility of secondary species displacing the current primary species.

For the forestry sector the impacts derived from the increase in air temperature, the decrease in rainfall, the increase of the mean sea level, with the aforementioned floods and land losses, as well as the increase in saline intrusion in length and depth, the occurrence of more frequent and intense extreme events, and the increase of the atmospheric concentration of CO_2, will bring as a consequence, the modification of phenological patterns in coastal and mountain arboreal species, loss of biodiversity in forest formations of greater altitude, and acceleration of the reproductive cycles of pests, increasing their destructive potential.

On the other hand, as a result of the modification of the rainfall regime, the inversion of the annual distribution of resin yield of the male pine (Caribaea M, Caribaea B & G var.) will occur; affecting an important number of species in mountain formations, as well as the forest's regressive death.

The rise in sea level and the effect of tropical cyclones (more frequent and intense), would have negative consequences especially in the significant losses of timber volumes and forests ecosystem services in general, as well as severe impacts on its biological diversity. Finally, the increase in the concentration of CO_2 in the atmosphere would result in the expansion of the carbon-nitrogen ratio and the increase in foliage consumption by insects in some forest species; higher level of fuel products in forests increasing the danger of forest fires; increased incidence of insects and damage caused by diseases.

Regarding human settlements and land uses, the Second National Communication to the United Nations Framework Convention on Climate Change, made a broad and detailed assessment of the impact of climate change on the population, land use, the impact of the drought in human settlements, the impact of the rise of the mean sea level in coastal communities, tourism development, cities in general and the potentialities and realities of municipalities. Thus, it is estimated that climate change will have a negative impact on the quality of life of individuals and communities, which will be reflected in agricultural activity related to the production of food that is essential for the national diet; the augmented disaster risk in coastal areas; and the loss of territory in the low areas due to the risen mean sea level. In this sense, it is expected that the rise of the mean sea level with the scenarios estimated for years 2050 and 2100 (0.27 and 0.85 m) will signify a loss between 2.3% and 5.5% of the total surface of the mainland, likewise other surfaces in cays and islets of the archipelago (areas more sensitive and vulnerable to ascent), not yet estimated. The field distribution of human settlements in areas experiencing a transition to more severe drought regimes due to variability and climate change is a fact to which a growing population in the country is exposed.

The areas most affected by the increase in the mean sea level are those occupied by swamps with mangrove formations, grasslands, and low coastal territories, which causes increased salinization of farmland and aquifers. The lands located in the eastern region will be the most affected, with an expected aggravation of the drought phenomenon.

The Project Intervention Area (AIP) is made up of two zones: Central (Los Arabos, Corralillo, Quemado de Güines and Santo Domingo municipalities) and Eastern (Amancio Rodríguez, Colombia and Jobabo municipalities). The Central Zone covers a total area of 2818 km2, with a population of 120,929 inhabitants, for a population density of the order of 43 inhabitants per km2 (the smallest Los Arabos with 32.7, and the most densely populated, Quemado de Guiñes with 66.6 inhabitants per km2). All the municipalities are generally flat; only two of them have coasts (Corralillo and Quemado de Güines). This area is characterized by the presence of red ferralitic soils and carbonated brown soils (which, in the case of Los Arabos, make up almost 80% of the municipality's soils), although there is also the presence of humic and ferralitic soils, as well as clay soils in the zones of coastal marshes where there is an important forestry activity. The climate is tropical with two distinct hydrological periods: rainy period (spring and summer) and dry season (autumn and winter). The economic activity of the Central Zone is based on the production of sugarcane, various crops and livestock; In addition, others are added such as flake and shellfish fishing, tourism and wood (Corralillo and Quemado de Güines), and the production of twist tobacco in the municipality of Santo Domingo. The National Institute of Investigations of Tropical Food (INIVIT), of national importance and relevant in the field of the investigations of food and vegetables is located in this municipality.

The Eastern Zone covers an area of 2236 km2, with a population of 121,509 inhabitants, density of 54 inhabitants per km2. The topography is generally flat. Brown ferralitic soils, as well as reddish carbonated and non-carbonated are predominant in the region. The climate is tropical with relatively humid summers, with predominantly long periods of drought. There are two well differentiated seasons, the dry season from November to April, and the humid one from May to October. The economic activity includes the production of sugar cane, livestock, and various crops, although there are other activities such as fishing and forestry that are important in the municipalities of Amancio Rodríguez and Colombia; in the municipality of Jobabo there is metal work as well as construction materials

SECTION I. BASELINE STUDY OF ADAPTATION IN THE TWO ZONES OF INTERVENTION OF THE PROJECT

The future climate of Cuba "can be described as more arid and extreme, characterized by prolonged and intense processes of drought and severe water deficit. The dry landscapes of the eastern zone will intensify and advance progressively towards the west, producing a transformation from the current climate (humid tropical) to a dry sub humid one, with threats of desertification processes. The current climate trends and the scenarios considered (A2 and B2 of the IPCC) for the next 100 years, will produce a deterioration of the environmental quality in general, as a consequence of the reduction of the water potential, the loss of land in low coastal areas, the impoverishment of the soil, reduction of agricultural yields, loss of biodiversity (mainly in coastal areas), affectations to coastal settlements, the increase of communicable diseases and the consequent negative impact on economic activity ". (see Second National Communication), (Republic of Cuba, 2015).

I.1. CLIMATE CHANGE: EVIDENCE AND SCENARIOS

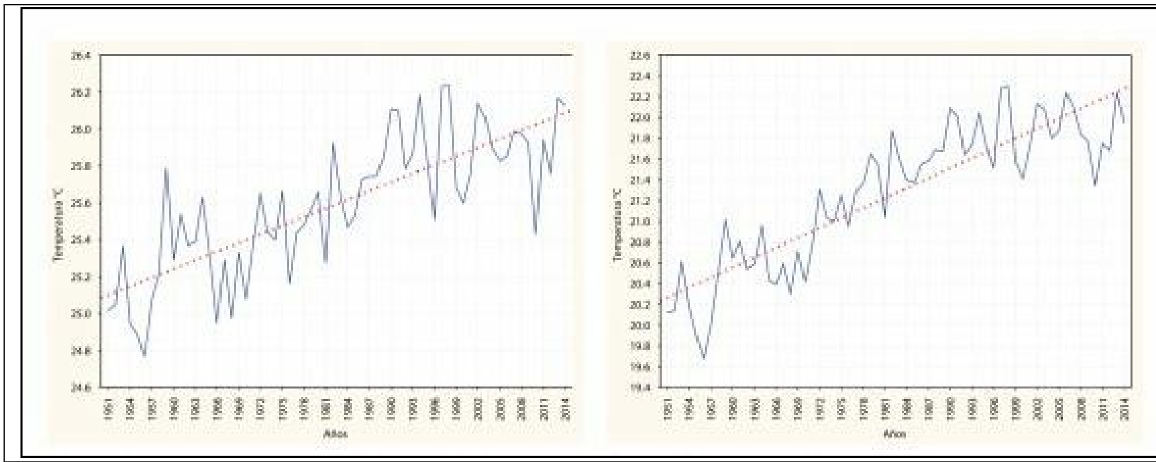
The climatic conditions of the Cuban Archipelago are determined by its geographical position, in the northern hemisphere. Cuba receives high levels of solar radiation throughout the year, which conditions the warm character of its climate; in turn, the proximity to the Tropic of Cancer presupposes the seasonal influence of organisms of both the tropical and extratropical atmospheric circulation. Among the factors studied that model the climate and its variation are the global atmospheric circulation, the sea surface temperature in the North Atlantic Ocean, the cold fronts and particular meteorological events such as tropical storms, hurricanes, as well as the incidence of the ENSO phenomenon / Southern Oscillation (known as "El Niño" and "La Niña").

I.1.1. Temperature

The surface temperature of the air has increased by 0.9 ° C since the second half of last century; conditioned by the increase in the average minimum temperature by 1.9 ° C; a decrease in the diurnal oscillation of the temperature occurs (see Figure 1).

Figure 1. Cuba, average temperature (a) and minimum temperature (b); and its trend

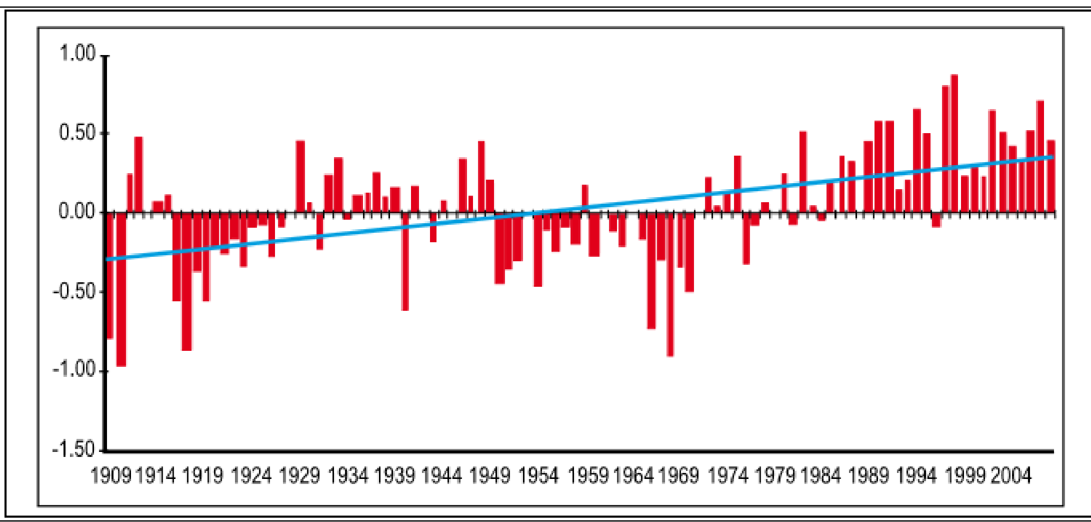
Panel (a) Panel (b)



Fuente: (Planos Gutiérrez et al., 2012)

The weather station of Casablanca has the longest temperature series available in the country, dating from 1908. The analysis of this series allowed us to state that since the beginning of the 20th century the average annual temperature of Casablanca has increased by about 0.6 ° C (Figure 2). This series clearly reveals the superposition of multi-year variations over the long-term trend. It highlights the existence of a period of relative cooling between 1950 and 1971, which gives way to a new stage of warming that lasts until the present. The period 1951-2008 has an increase of 0.9 ° C, similar to the average annual temperature of the country, and higher than the increases observed in the periods 1909-1949 and 1971-2008, which reach values close to 0, 5 ° C.

Figure 2. Annual anomalies of the Average Temperature for the period 1909-2004

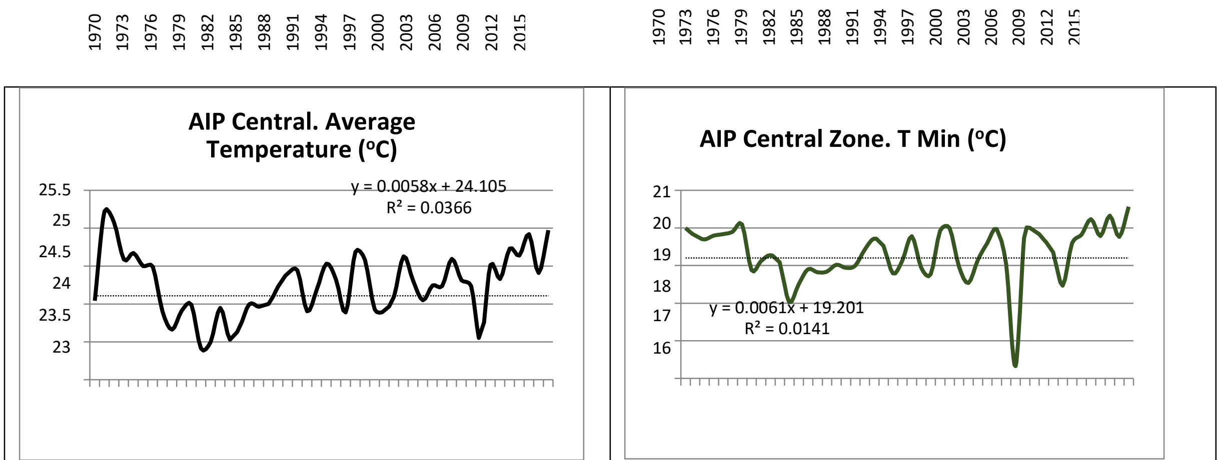


Source: (Planos Gutiérrez et al., 2012)

CENTRAL ZONE

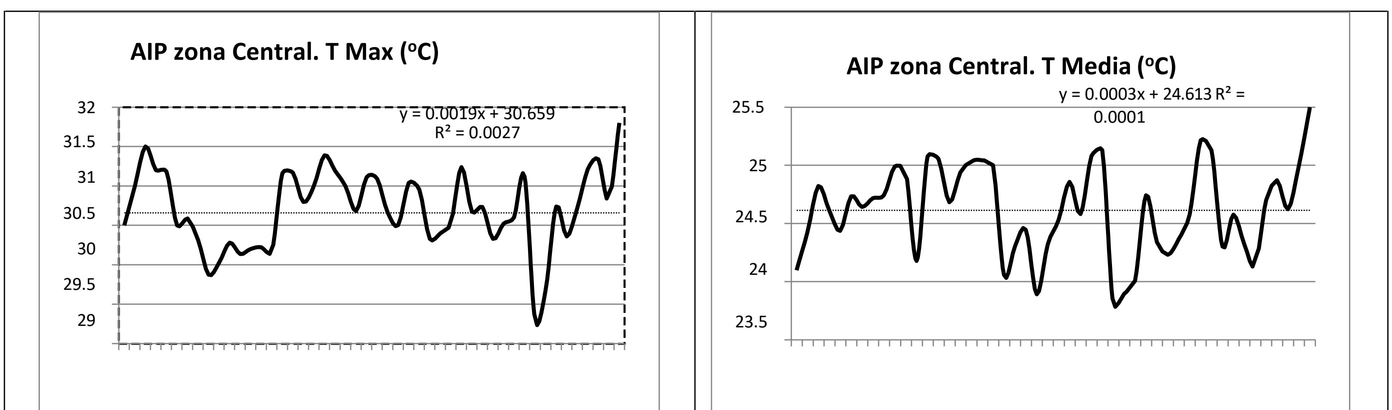
The information reported by the weather stations of Colon, Matanzas and Santo Domingo, and Villa Clara, are those that serve the municipalities that are part of the intervention territories of this project.

Figure 3. Climatic variables Central Zone of the AIP. Colon Weather Station



Source: Colon Weather Station

Figure 4. Climate variables Central Zone of the AIP. Colon and Santo Domingo Weather Station



Source: Colon Weather Station

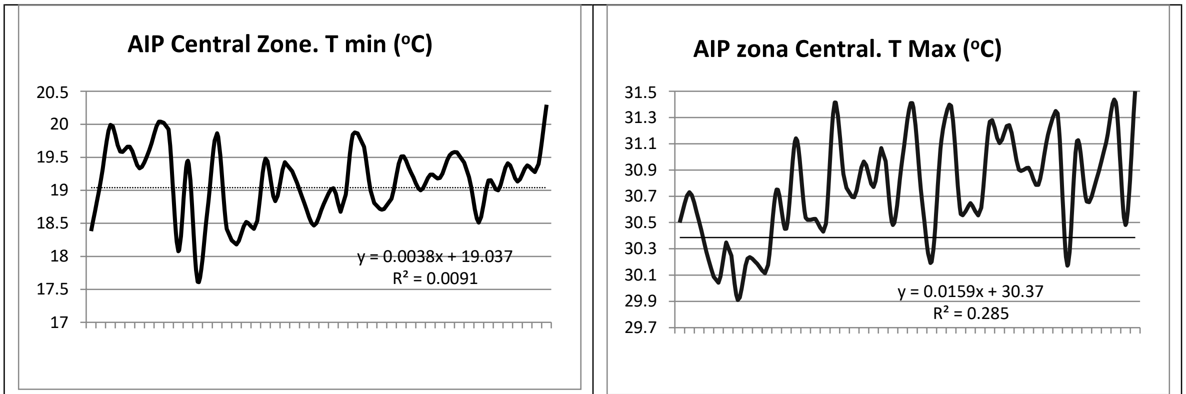
Source: Santo Domingo Weather Station

1970 1973 1976 1979 1982 1985 1988 1991 1994 1997 2000 2003 2006 2009 2012 2015

1970 1973 1976 1979 1982 1985 1988 1991 1994 1997 2000 2003 2006 2009 2012 2015

The trends of the temperature variables are to raise, consistent with national trends. In particular, the trend of the Maximum T reported by the Santo Domingo weather station, where a growth rate of just over 1.6% per year between 1970 and 2016 is observed.

Figure 5. Climatic variables - Central Zone of the AIP. Santo Domingo Weather Station

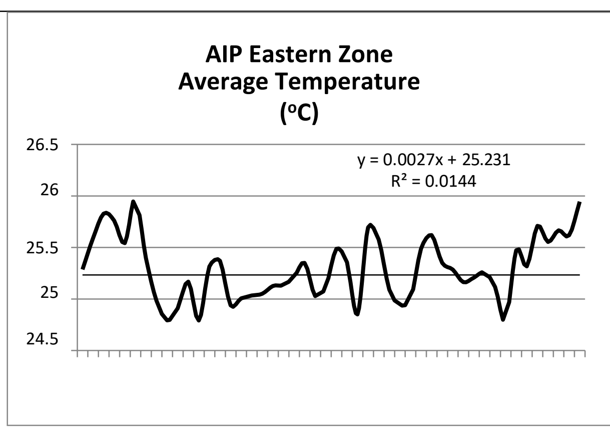


Source: Santo Domingo Weather Station

EASTERN ZONE

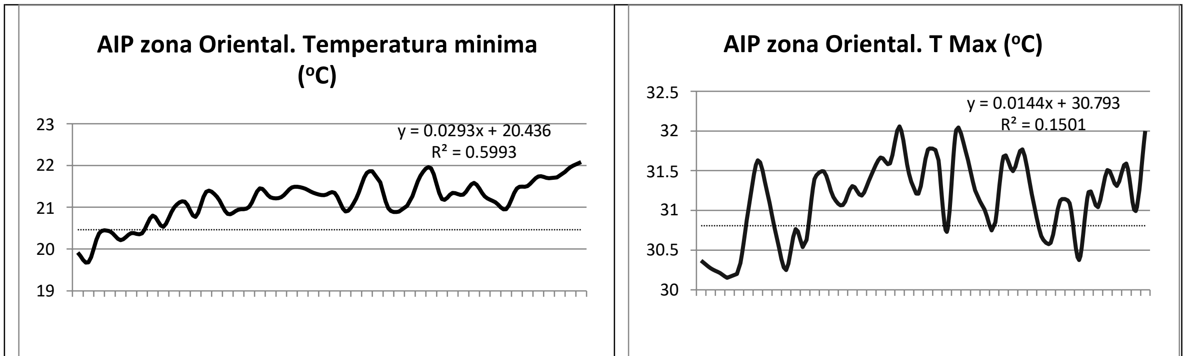
In the case of the Eastern zone, the data reported by Las Tunas weather station was used, since it provides service to the three municipalities involved in the project (Amancio, Colombia and Jobabo).

Figure 6. Climatic variables, mean T, Eastern Zone of the AIP. Las Tunas Weather Station



Source: Las Tunas Weather Station

Figure 7. Climatic variables, minimum T and maximum T, Eastern Zone of the AIP. Las Tunas Weather Station



Source: Las Tunas Weather Station

I.1.2. Precipitation, anomalies in quantity and distribution

In spite of the fact that the average rainfall sheet is 1335 mm for all of Cuba, recurrently there are drought events whose duration can extend even for several years. In the 1990s, the most notable intense drought occurred in the Caribbean Basin, Central America, Mexico and the Southeast of the United States (period from April to July 1998), generated under the influence of the ENSO 1997-1998. The event manifested itself sensibly throughout the country and in particular some municipalities in the eastern region. For its part, in the years after 2000, drought processes of great significance took place in the Caribbean region, highlighting the 2004 event (recorded as the most critical event for Cuba in the last 100 years) and the one of 2009, the most acute for the western region in the last 50 years. In this sense, it is observed that although the series of annual values of precipitation for Cuba of the period 1961-2007 do not show a statistically significant trend since the end of the decade of the 70s, there has been a slight, but continuous increase of positive anomalies, more relevant since the beginning of the 90s.

In general terms, the slight increase in annual values is fundamentally conditioned by the variations that occurred during the dry season. In these rainy months, despite the predominance of negative anomalies, in recent years there has been a slight upward trend, which has been observed since the mid-70s to present, particularly with the increase in the magnitude of positive anomalies in the central region (see Table 1).

Table 1. Abnormalities in the behavior of precipitation (Standardized Precipitation Index) in the periods of Low Rain, Rainy, and Annual 1961-1979 and 1961-2007

	CUBA		WEST		CENTER		EAST	
	1961-79	1961-07	1961-79	1961-07	1961-79	1961-07	1961-79	1961-07
LESS RAINY PERIOD								
MEAN	-0.68	-0.11	-0.58	-0.17	-0.81	0.05	-0.44	-0.15
AVERAGE	-0.67	-0.1	-0.59	-0.27	-0.67	0.03	-0.71	-0.15
D.STAND	2.15	0.96	2.09	0.94	2.07	2.02	2.22	2.03
VARIANCE	2.33	0.92	2.19	0.88	2.14	2.05	2.48	2.07
RAINY SEASON								
MEAN	0.46	0.07	0.21	0.16	0.29	0.07	0.8	-0.06
AVERAGE	0.38	-0.3	0.03	-0.07	0.00	-0.27	0.47	-0.29
D.STAND	2.41	2.3	2.26	2.25	2.26	2.24	2.68	2.24
VARIANCE	2.0	2.69	2.59	2.56	2.58	2.53	7.19	2.53
ANNUAL								
MEAN	-0.08	-0.01	-0.16	0.05	-0.17	0.08	0.19	-0.11
AVERAGE	-0.08	0.07	-0.44	0.1	-0.19	0.01	-0.24	-0.18
D.STAND	2.65	2.07	2.37	2.04	2.59	2.12	2.05	2.17
VARIANCE	2.71	2.14	2.88	2.08	2.52	2.25	4.21	2.36

Source: (Maps Gutiérrez et al., 2012)

In the previous table it can be observed that the negative average values predominate between 1961-1979 during the dry season (November-April), while the tendency in the following decades is towards positive values with a reduction of the range of variation of the magnitudes means and an increase in extreme positive anomalies. Consequently, there is a change in the mean values and in the variance in the decades between the beginning of 1980 and 2007, with respect to the period 1961-1979, which in the case of the Central Zone is -0.81 in the period of 1961 -1979, to 0.05 between 1961-2007. In the Eastern Zone we can also see a tendency to increase the average values of positive anomalies, particularly in the period 1980-2007 (-0.44 to -0.15), also with a reduction in the variation of the mean values.

On the other hand, in the rainy period of the year, the distribution of precipitation anomalies reveals a change in average values during recent decades, but contrary to the trend described for the non-rainy period, in this case there is a tendency to predominance of negative mean anomalies. This behavior implies reduction of the range of variation of the average values, particularly in the Eastern Zone. The most notable fact in this rainy period is the sharp decrease in the average values and variation in this

Eastern Zone (average value of 0.8 in the period 1961-1979, and of 7.19 its variance versus a mean value of -0.06 and variance of 2.53 1961-2007).

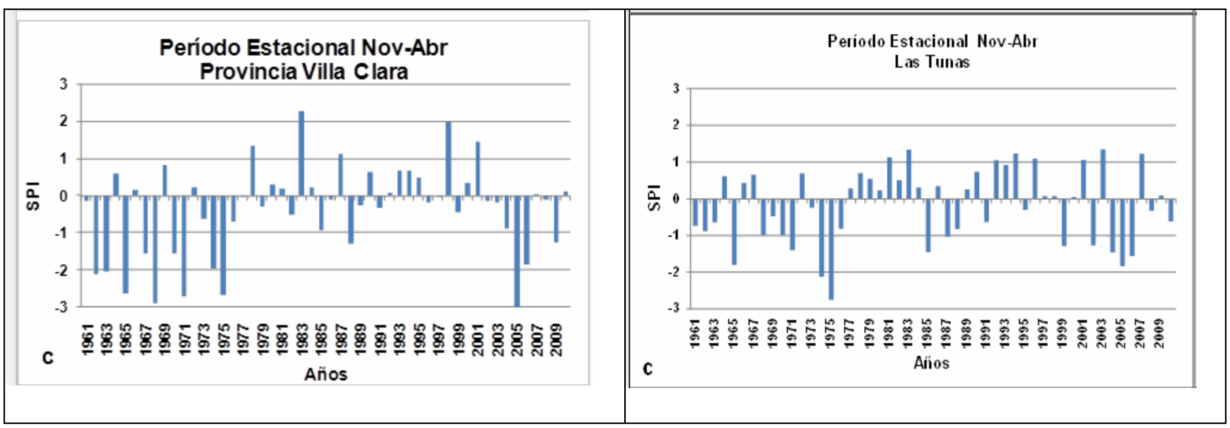
In Figure 8, the graphical representation of the Standardized Precipitation Index (SPI) for the Central and Eastern Zone in the low and rainy period is shown.

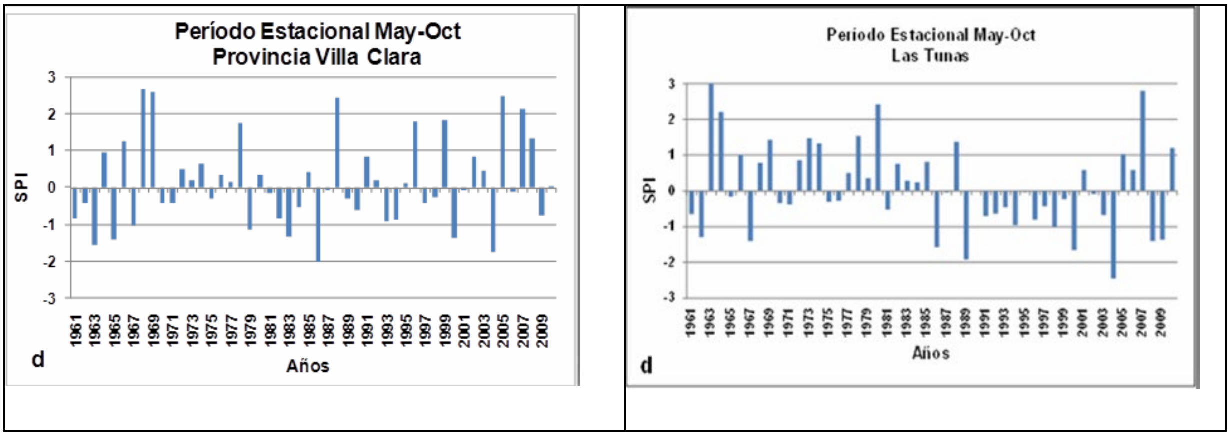
The tendency to increase rainfall in the dry season is related to a decrease in the magnitude of negative anomalies from the mid-70s to the beginning of the 2000s. This fact is associated with a higher frequency of affectation of the ENSO events during this period of the year.

The most important element in the rainy season in Cuba, is related to the decrease in rainfall in the eastern region, which since the decade of the 90 has shown a significant deficit in accumulated precipitation. This variation is one of the most worrying changes observed in Cuba's climate in recent decades.

The observed trends, mainly in the rainy season, are associated with a reduction in the range of variation of the mean values of precipitation. The reduction of rainfall accumulated in the East is largely due to the most frequent occurrence of meteorological drought processes in recent years within the said region.

Figure 8. SPI for the Central and Eastern Zone





Source: (Cutié, V. et al, 2013).

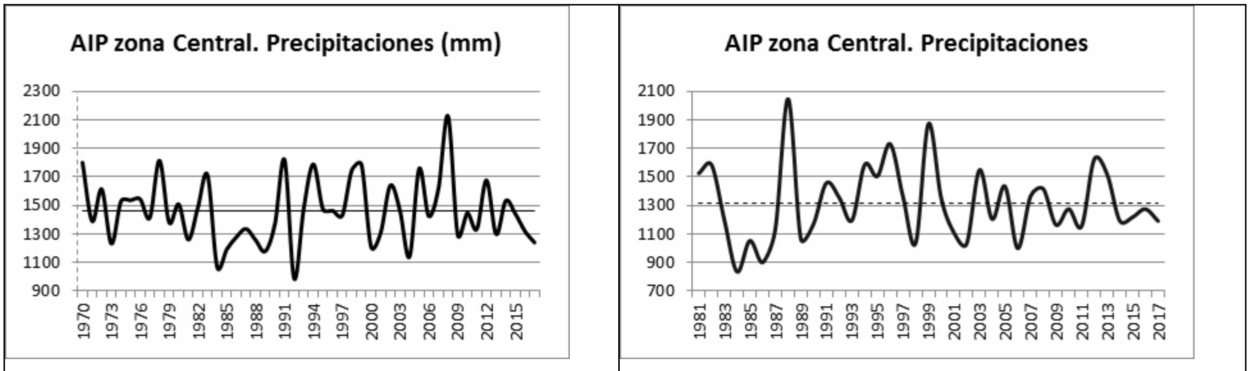
Impacts of the effects of recent drought events

The slight increase of the positive anomalies of the precipitations from the end of the decade of the 70s of the last century, cause that the rains of the little rainy period have increased; However, the most important variation of this element is related to the tendency to decrease these in the eastern region, which since the decade of the 90s of the twentieth century has shown significant deficits in accumulated precipitation.

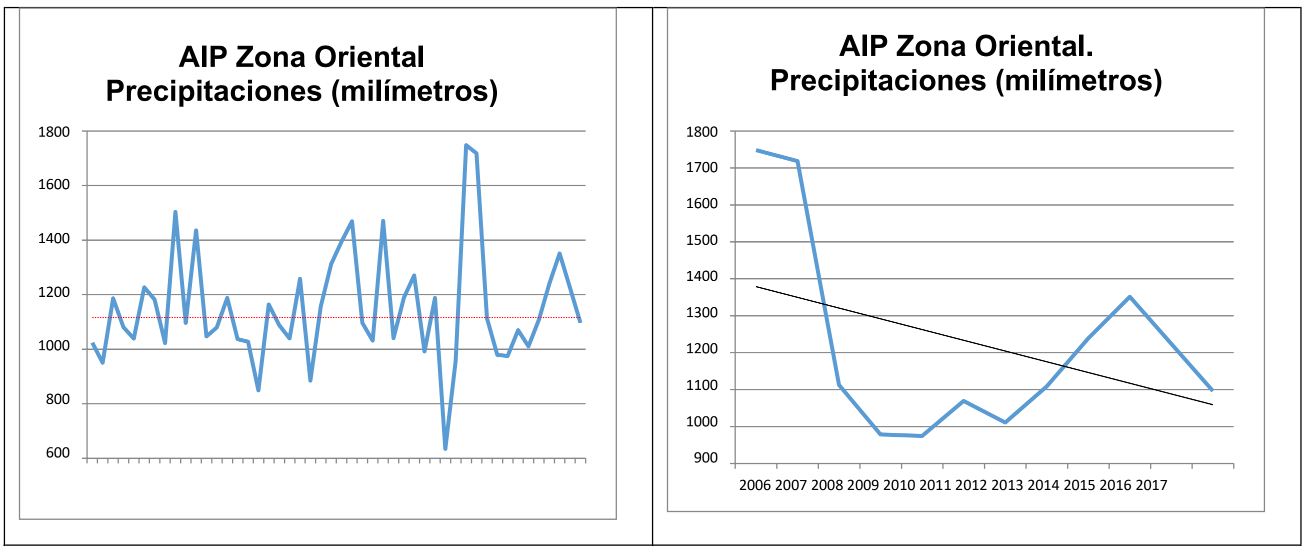
The years following 2000, there have been significant processes of drought in the Caribbean region, highlighting the 2004 event (recorded as the most critical event for Cuba in the last 100 years) and the one of 2009 which was the most acute for the western region in the last 50 years. Regarding the impacts that these events cause, it is important to point out that the short-period drought event occurred from April to July 1998, and that affected large areas of Central America, Mexico, the Southeast of the United States of America and many states of the Caribbean, manifested itself dramatically throughout the country and in particular in some municipalities in the eastern region. The magnitude of the event was such that it reached the category of disaster, generating innumerable damages and discomforts in the population, which even involved temporary emigration. The economic losses only in these areas of the east of the country, reached approximately four hundred million US dollars and several hundred million pesos (Cutié, V. et al, 2013). For its part, the 2004-2005 event generated countless impacts on society and the environment in general. It can be mentioned that at certain times water had to be supplied in trains, tank cars and other means to more than 2 million people throughout the country. The calculated losses exceeded one billion dollars (Cutié, V. et al, 2013).

Finally, from the point of view of the average levels of precipitation, the accumulated records in the stations of Colon, Santo Domingo and Las Tunas, point out that in the last 46 years (from 1970 to 2016), the tendency of the precipitations is towards a slight increase, resulting from the anomalies registered in the non-rainy and rainy periods observed in this period (see Figure 9).

Figure 9. AIP rainfall. Both zones



Source: Colon Weather Station	Source: Santo Domingo Weather Station



Source: Las Tunas Weather Station

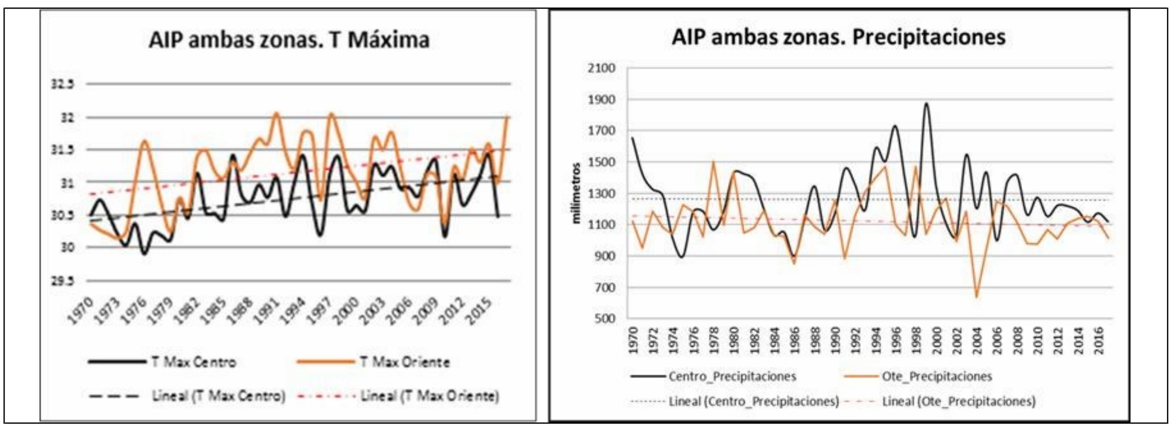
1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016

However, if the tendency of precipitation to decrease in the last 11 years provided by Las Tunas Weather Station is taken into account, the concerns regarding the tendency of intense droughts that threaten this area would be supported.

Another effect of the changes in rainfall patterns is shown in the tendency to increase rainfall in the dry season, related to a decrease in the magnitude of the negative anomalies since the mid-70s until the beginning of the years 2000. However, the differences between the values of the mean and the median, reaffirm the increase of extreme anomalies in the western and central part of the country. This fact is associated with a higher frequency of involvement of ENSO events during this period of the year. An increase in temperature as expected in the national climatic scenarios, whereby mean temperature values in 2050 would be reaching 29 and 30ºC in the AIP of the Central and East respectively; while the average maximum temperature values would be 35 and 36oC respectively.

On the other hand, the national rainfall scenarios estimate drastic reductions for 2050-2100, between 15 and 63% of the current averages. In this sense, according to this scenario, the accumulated rainfall in the AIP would be hovering between 975-481 millimeters in the Central area and 750-370 millimeters in the Eastern area, which would lead to a water crisis situation with repercussions on yields of crops and health of people (see figure 10).

Figure 10. Combined climatic variables, maximum T and rainfall. Both zones



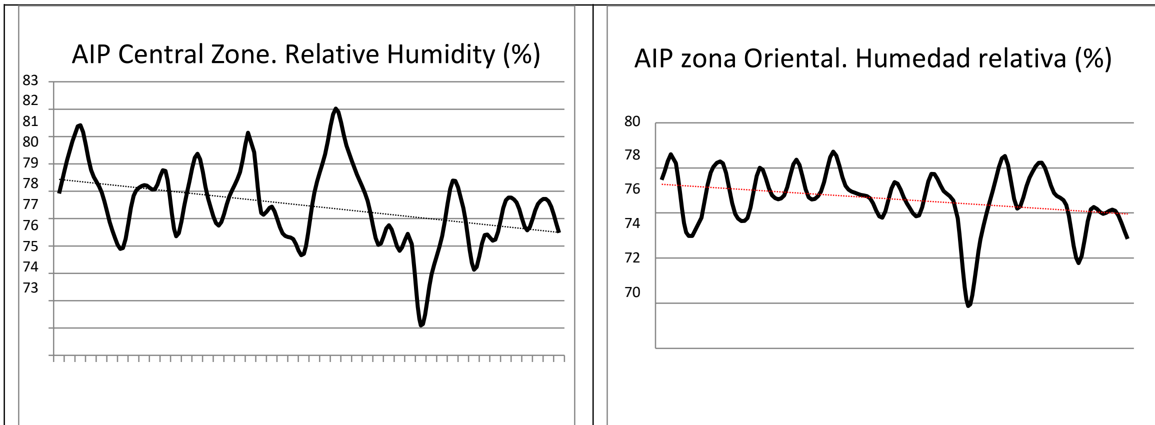
Source: Weather Stations of Santo Domingo (Villa Clara) and Las Tunas

Such a scenario generally affects the agricultural yields of most crops in both areas, with a reduction in the net primary production of pastures and forests, the worsening of the cattle comfort zone, as well as the return of old or / and the appearance of new pests and diseases for crops, livestock and people.

I.1.3. Relative Humidity

The increase in temperature and the reduction of precipitation in the rainy period in the AIP are consistent with the decrease in the relative humidity of the air. This fact seems to indicate the existence of drier conditions than the current ones and that the combined effect of the intense future warming and the reduction of rainfall, mainly during the rainy season, will cause a decline in water resources and a strong tendency to aridity.

Figure 11. Climate variables, Relative Humidity, Central and Eastern AIP.



Fuente: Estación de Santo Domingo	Fuente: Estación de Las Tunas

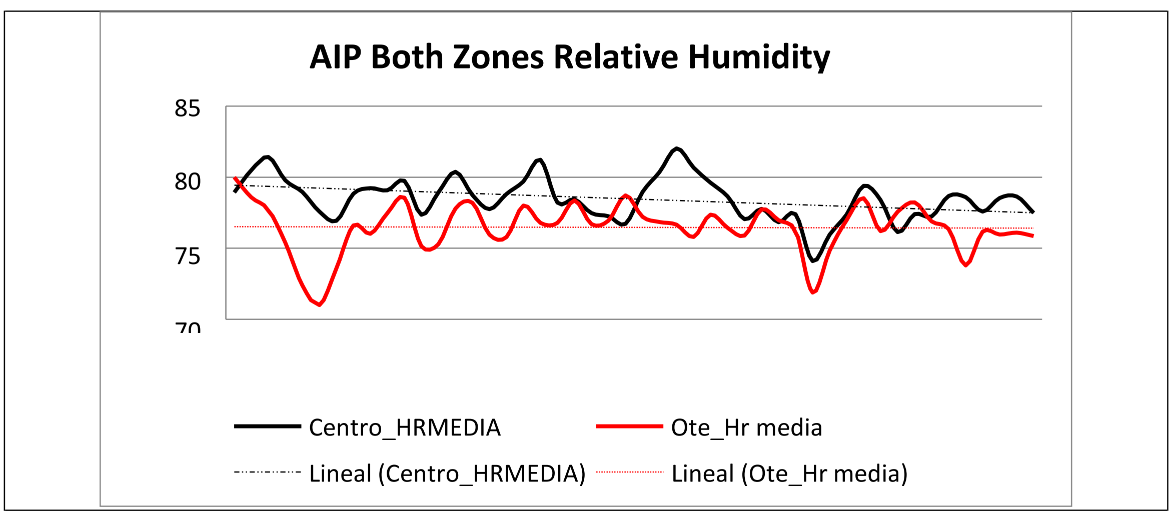
1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014

1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015

The observed trend of relative humidity in the period from 1970 to 2016, is to the reduction in both areas, with a more pronounced propensity in the Eastern zone, which together with the behavior of temperature and rainfall increase the susceptibility of the area to the phenomena of aridity and desertification.

While, for the Central area of the AIP, are the cyclones / hurricanes (heavy rains, strong winds and sea penetration) the most common hydrometeorological events. In the Eastern zone the drought is the climatic phenomenon that occurs most frequently and with a high level of impact hazard.

Figure 12. Combined climatic variables, Relative Humidity. Both zones



1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016

Source: Santo Domingo (Villa Clara) and Las Tunas Weather Stations

I.1.4. Cyclonic Activity (strong winds, hurricanes)

Tropical cyclones and severe local storms are the meteorological phenomena associated with greatest disaster hazards, and are responsible for some of the climatic extremes observed[2]. The frequency of tropical cyclone and hurricanes varies from none to four annually; on average one tropical cyclone per year, and a hurricane every two. The scourge of these events is more frequent towards the western-central region of the country. As of 1996 a new very active period of hurricane activity on Cuba began. Between 2005 and 2017, the country was affected by 11 hurricanes. In recent years the province of Las Tunas has been affected by 4 tropical organisms. (See table 2 and 3).

[2] Severe tropical storms are classified tornadoes, hailstorms, waterspouts and linear winds greater than 90 km / h. The cyclonic season goes from June 1 to November 30, in which the September-October bimester is the most affected and October the most dangerous month, as most of the intense hurricanes have been reported.

Table 2. Impacts caused by tropical cyclones and other extreme events

YEAR/EVENT	Economic losses in Millions of pesos (MP)					
		Of which:				
	TOTAL	Expenses in preventive measures	Replacement cost household	Facilities	Agriculture	Goods and services no longer produced
2005	**3036**	**117.2**	**1074.8**	**213.2**	**893.4**	**658.0**
Dennis (July)	2124.8	188.7	1026.1	201.0	603.4	265.3
Rita (September)	207	25	3.1	8.9	117.7	52.3
Wilma (October)	704.2	73.5	45.6	3.3	172.3	340.4
2006	**95.1**	**15.2**	**24.6**			**40.0**
Ernesto (September)	95.1	15.2	24.6			40.0
2007	**1155.4**	**12.8**	**364.4**	**168.5**	**559.5**	**32.6**
Intense Rainfall and storms						
Tropical Noel (October)	1155.4	12.8	364.4	168.5	559.5	32.6
2008	**9759.3**	**137.7**	**4983.8**	**372.9**	**3605.8**	**525.4**
Fay (August)	37.8	1.6	16.8	4.9	7.1	4
Gustav (September)	2096.7	30.9	1121.5	59.6	868.4	9.8
Ikie (September)	7325.3	95.9	3764.7	304.8	2540.2	501.9
Paloma (November)	299.5	9.3	80.8	3.6	190.1	9.7
2012	**6966.9**	**70.6**	**3546.6**	**295.8**	**2469**	**398**
Sandy (November)	6966.9	70.6	3546.6	295.8	2469	398
2016	**2430.8**	**24.1**	**388.5**	**70.1**	**519.5**	**81.9**
Matthew (October)	2430.8	24.1	388.5	70.1	519.5	81.9
2017	2600	44.0	416.0	75.0	600.0	1248.0
Irma (September) a/	2600	44.0	416.0	75.0	600.0	1248.0

a/ Estimated values. Source: ONEi, 2016

Table 3. Households affected by tropical cyclones (housing)

Year	Event	Damaged homes		
		Total	Total collapse	Percentage
2005		180390	28353	15.7
	Dennis (July)	175615	28082	16.0
	Rita (September)	492	14	2.8
	Wilma (October)	4283	257	6.0
2006		1819	130	7.1
	Ernesto (September)	1819	130	7.1
2007		59826	3473	5.8
	Intense rainfall and storms			
	Tropical Noel (October)	59826	3473	5.8
2008		647111	84737	13.1
	Fay (August)	3305	179	5.4
	Gustav (September)	120509	21941	18.2
	Ike (September)	511259	61202	12.0
	Paloma (November)	12038	1415	11.8
2012		263250	22705	8.6
	Sandy (November)	263250	22705	8.6
2016		46706	8312	17.8
	Matthew (October)	46706	8312	17.8
2016				
	Irma a/	510000	61051	12.0

a/ Estimated values. Source: ONEi, 2016

I.1.5. **Combination of climatic variables and their future impacts on the intervention zones of the Project**

The combined scenarios of rising temperatures, diminution of rainfall, decreased water potential and water quality, complemented by the reduction of agricultural areas due to the retreat of the coast, the migration of coastal ecosystems and the expansion of the marabou, will lead to impacts higher than the estimates, on the total agricultural production and animal husbandry.

For the approach to the combined effects of climatic variables in the AIP areas, statistical models

(Panel Data and Ordinary Least Squares) were used (Hutchinson et al., N.d.), based on two hypothetical assumptions:

- Marabou expansion and climate change are linked

In this sense, the use of the data model Fixed effect panel used as a dependent variable the idle surface as a function of the accumulated precipitation, maximum and minimum temperatures, relative humidity and the standardized precipitation index for the non-rainy period, the results offer empirical evidence that these climatic variables explain an important part of the general behavior of the idle surface in the AIP and reveals that the expansion of the marabou has an important climatic component.

The parameters estimated both individually and as a whole are significant, which indicates that the model used adequately explains the relationship between idle surface (as a proxy of the marabou) and the climatic variables for both areas of the AIP.

There is a degree of positive certainty of the climatic influence in the expansion of the idle surface in the AIP in particular in the Eastern zone. However, the results should be taken with discretion due to the bias introduced by the scarcity / quality of the primary data. Regarding the coefficients, it is possible to identify that, although the marabou has a greater relative capacity for adaptation, recovery and growth, climatic variables such as maximum temperature, relative humidity and SPI for the non-rainy period have negative effects on the expansion of the idle surface.

- The marabou area is less sensitive to climatic variations than the rest of the crops studied in the AIP (cane, various crops, pastures and forest).

The effects of climate change have a greater impact on the yields of crops, pastures and forests than those produced on the marabou. In this sense it is possible to affirm that climate change affects the expansion of the idle surface (at the expense of areas of sugarcane, pastures and other crops that are colonized by the marabou).

Due to the scarcity of data, the Ordinary Least Squares models were used, which have the property of returning the best linear estimators of the parameters, unbiased and efficient, with the intention of demonstrating that the crops are more sensitive to climate change than the marabou, that favors its expansion and colonization of territories.

The correlation coefficients between the idle surface and the different types of crops selected for each area of the AIP are presented in table 4.

Table 4. Correlation coefficients between idle lands and the different types of crops selected

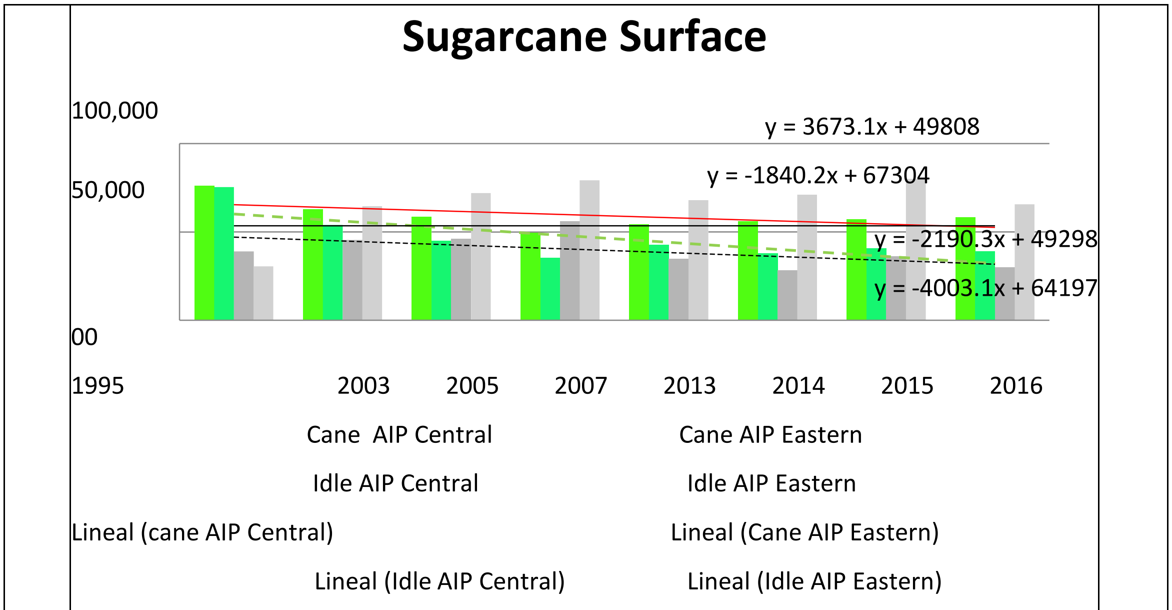
AIP CENTRAL	
Correlation coefficients – Idle vs:	
Sugar cane	-0.153963
Crops	0.595471
Pastures	-0.577423
Forestry	-0.72677
AIP EASTERN	
Correlation coefficients – Idle vs:	
Sugar cane	-0.92627
Crops	-0.2287
Pastures	-0.22543
Forestry	0.36518

Source: Prepared by the authors

The coefficients show weak and negative correlations between sugarcane and idle territories, medium and negative between pastures and idle in the Central AIP; and positive and high negative correlations for pastures and forest respectively. The negative sign should be interpreted as the meaning of the correlation, that is, for example, that in the case of cane there is a weak relationship between areas of this crop and the idle surface, which also go in the opposite direction. The results in the area of the Eastern AIP offer more coherent results than those of the Central: it is the cane that pays most strongly to the increase of the idle surface, and there is a weak but positive correlation of the forest area with the increase of the idle surface. The correlations between crops and pastures are weak, but in the opposite direction, they decrease in favor of the expansion of the idle surface.

Figures 11, 12, 13 and 14 show the differences between the slopes, which display the decreasing tendency of the areas of cane, crops, pastures and forests, more pronounced than what is observed for the idle area, indicating a greater sensitivity with respect to those of marabou, in the face of climate change.

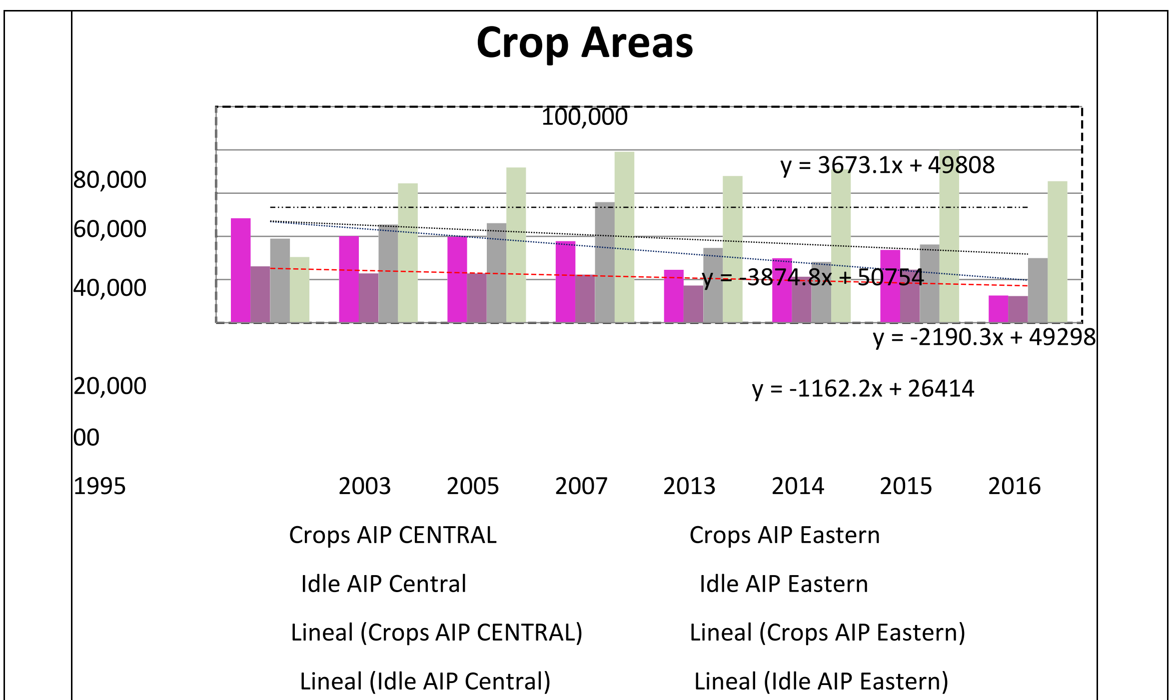
Figure 13. Behavior of the trend of the sugarcane surface (ha)



Source: Prepared by the authors from the Balance of the Earth of the MINAG (ONEi, 2017)

The differences between the slopes of cane crops and idle lands in both zones are observed. In the Central zone both cane and idle slopes decrease at a similar speed.

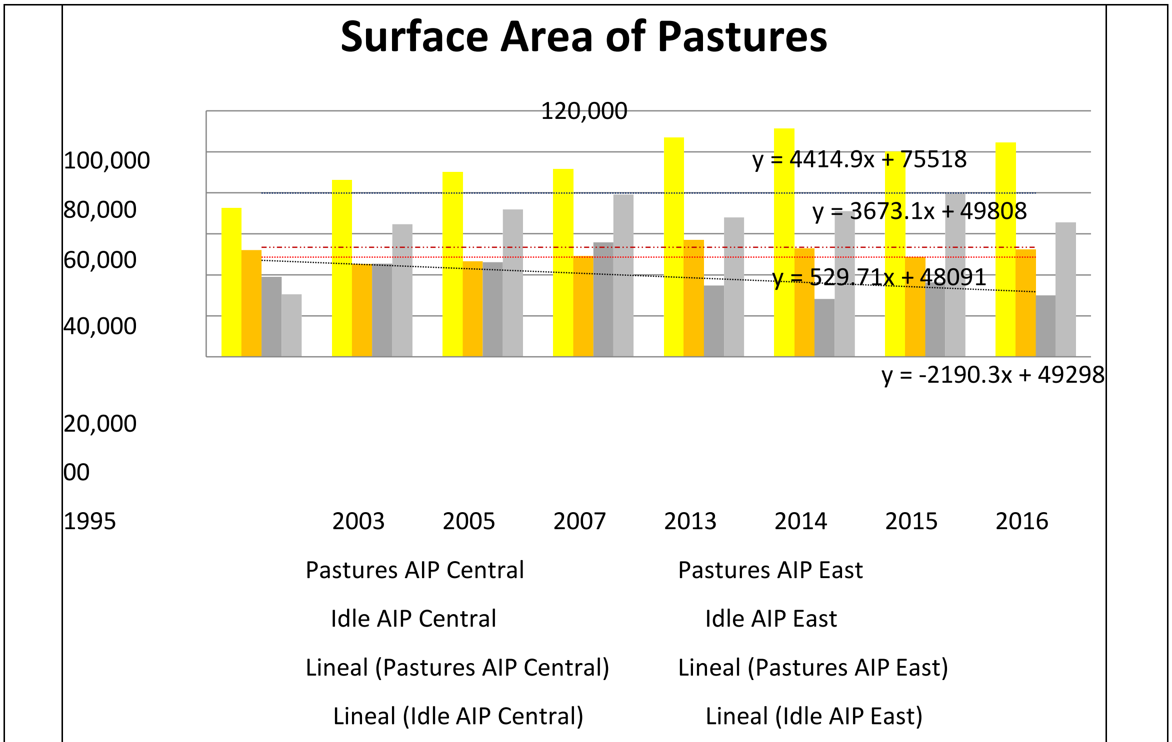
Figure 14. Behavior of the trend of the various arable crops areas (ha)



Source: Prepared by the authors from the Balance of the Earth of the MINAG (ONEi, 2017)

In the Central zone both slopes of several crops and idle decrease, although at a lower rate in the case of the idle surface (the reduction of its surface is slower than that of various crops).

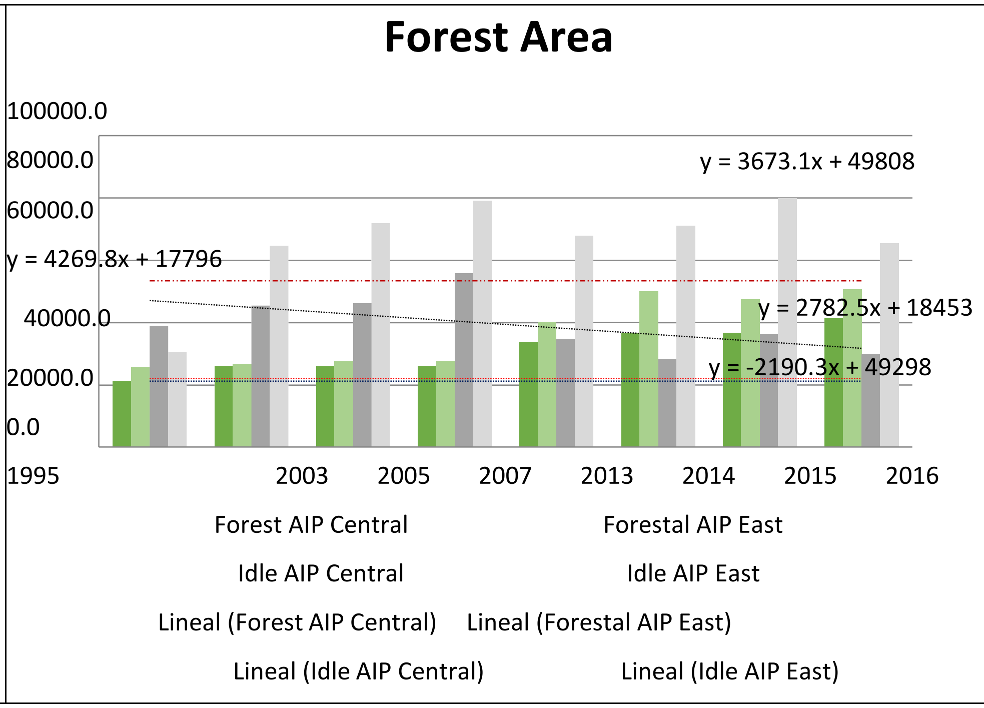
Figure 15. Behavior of the trends of the surface of natural pastures (ha)



Source: Prepared by the authors from the Balance of the Earth of the MINAG (ONEi, 2017)

The slopes of natural pastures and idle lands in both zones show differences. In the Central zone both slopes of pastures and idle land are divergent and in terms of the rates the speed of growth of the pastures is slightly higher than the speed of reduction of the idle surface.

Figure 16. Behavior of the trend of the forest area (ha)



Source: Prepared by the authors from the Balance of the Earth of the MINAG (ONEi, 2017)

In the Central zone the forest surface grows while the idle decreases, however, the idle area decreases at a rate lower than the growth rate of the forest area. In the Eastern zone the idle and forest area grows, although at a slightly higher rate in the case of the idle surface.

Tables 5 and 6 show the elasticities of the climatic variables by types of land surface selected for each area of the AIP, in the Eastern area is observed a greater sensitivity to the climatic variables of the surfaces of crops with respect to the surface idle While in the Central zone the hypothesis of a greater sensitivity of the crops in relation to the idle surface is less solid.

Table 5. Estimated coefficients for the climatic variables in the surface models of each selected crop. Central area of the AIP.

	Hr		SPI no LL		ln precipit		ln TMax		ln TMIN	
	Coef	P>t	Coef	P>t	Coef	P>t	Coef	P>t	Coef	P>t
Cane	-0.01	0.02	0.008	0.037						
Crops			-0.014	0.007	-0.0304	0.262				
Pastures					-0.0796	0.287				
Forest	-0.0015	0.553	-0.0011	0.66	-0.014	0.518	0.196	0.469	-0.222	0.35
Idle	-0.05	0.002	-0.001	0.99	0.482	0.001	-1.978	0.115	1.433	0.173

Source: Prepared by the authors

Table 6. Estimated coefficients for the climatic variables in the surface models of each selected crop. Eastern Area of the AIP.

	Hr		SPI no LL		In precipit		In TMAX		In TMIN	
	Coef…	P>t	Coef	P>t	Coef	P>t	Coef	P>t	Coef	P>t
Cane	-0.027	0.019	-0.006	0.54			-0.723	0.702	0.518	0.67
Crops	-0.0216	0.024	-0.011	0.171			-1.053	0.49	1.17	0.225
Pastures	-0.01	0.004	-0.003	0.242			-0.371	0.53	0.358	0.344
Forest	-0.005	0.066	0.011	0.015	0.027	0.259				
Idle	-0.004	0.439	-0.002	0.438	0.0579	0.272	0.198	0.85		

Source: Prepared by the authors

I.2. IMPACTS OF CLIMATE CHANGE ON THE YIELDS OF RELEVANT AGRICULTURAL ACTIVITIES FOR VULNERABLE HOMES

The potential agricultural and irrigated yields of all the crops will decrease progressively throughout the 21st century, between 10 and 25%; in the cane, between 5 and 10%; and those of the potato up to 50%. Total crop evapotranspiration will generally decrease except for potatoes, but irrigation water needs would rise progressively (40-55% for short-cycle crops and 15-30% for long-cycle and perennial crops). On the other hand, the effect of climate change on weeds would also be applied to grasslands in livestock areas, which in the case of Cuba are predominantly grass, and could benefit exotic invasive species such as marabou.

The studies carried out in the country from combining climate scenarios created by physical - mathematical models of atmospheric concentration of carbon dioxide, and the circulation ocean / atmosphere, with biophysical models of crops provide irrevocable evidence of the existence of considerable negative impacts, derived from climate change, on agricultural crops and agriculture in general.

Table 7. Dryland agricultural yields, in dry matter, for the climatic scenarios used (t / ha)

					Variation vs Reference
Crops	Reference (3)	2030	2050	2100	
Potato	12.34	10.68	9.57	6.44	-48.0%
Bean	2.92	2.84	2.77	2.61	-10.0%
Rice (1)	12.0	11..44	11.16	10.7	-12.0%
Rice (2)	14.49	13.78	13.54	12.9	-12.0%
Cassava (1)	16.56	16.2	15.84	12.87	-16.0%

Cassava (2)	13.45	13.11	12.81	11.16	-17.0%
Corn	12.82	11.77	11.27	10.09	-22.0%
Sugar cane (1)	76.46	74.42	73.1	69.84	-9.0%
Sugar cane (2)	72.11	71.15	70.28	68.17	-6.0%

Source: Rivero, R. et al (2010) Second National Communication to the UNFCCC (Republic of Cuba, 2017)

Caption: (1) Spring sowing; (2) Sowing of cold; (3) Reference

The main cause of the decrease in potential yields is the progressive rise in temperature, which not only leads to a progressive shortening of the duration of the crop cycle but also to a reduction in the intensity of gross photosynthesis and an increase in the intensity of respiratory processes. (Rivero et al., 2011) (Rivero et al., 2010).

In the AIP of the Central zone it is estimated that the total cultivated area is approximately 32 thousand hectares, of which 8.9% are dedicated to the selected crops. In the AIP of this area, the zone dedicated to the cultivation of sweet potatoes, plantain, beans, rice and corn stands out. Regarding potatoes, this crop has stopped being harvested since 2013, due to low yields, as a result of the worsening climatic conditions that the development of this tuber requires.

As for the AIP of the Eastern zone, of the 27 thousand hectares of cultivated area, almost 21% are dedicated to the cultivation of food and grains (5644 ha). Cassava, sweet potato and plantain stand out as the most harvested foods, while corn stands out as the most cultivated cereal.

Table 8. Cultivated surface with selected products

	Cultivated area (ha)	Selected crops (ha)	% in respect to cultivated area
Corralillo	6500	1334	20.5
Quemado	19000	1368	7.2
Santo Domingo	6100	100	1.6
Total Central	31600	2802	8.9
	Cultivated area (ha)	Selected crops (ha)	% in respect to cultivated area
Amancio	5100	1614	31.6
Colombia	12900	1205	9.3
Jobabo	9400	2826	30.1
Total East	27400	5644	20.6

Note: the selected crops are potato, sweet potato, taro, cassava, banana, rice, corn and beans, since they are an important part of the diet of the AIP population. Studies on the impacts of climate change on their yields were carried out for these crops.

I.2.1. *Agricultural Sector*

a) Sugar cane

There is no public information on the harvested area, production and yields, in the AIP. It is estimated that due to the increase of the surface air temperature and the reduction of rainfall (increase in periods of intense droughts), sugarcane yields will be reduced between 6 and 9% with respect to the yields taken as reference (sugarcane harvest). 1990-1991) despite the fact that the cultivation of sugarcane is considered to be the least sensitive to the effects of climate change.

Taking into account that in both Central and Eastern areas of the AIP there are still important sugar cane masses, negative effects derived from the impacts of climate change in the sugar sector are expected in the medium and long term.

Table 8. Historical performance of the yields of the sugar harvests

Sugar harvest	Cultivated Area (Thousand ha)	Sugarcane production (Million tons)	Yield t/ha
1990-1991	1452	79.7	54.9
2009-2010	431	11.6	26.9
2010-2011	506	11.9	23.5
2011-2012	361	14.7	40.7
2012-2013	400	16.1	40.2
2013-2014	405	17.8	43.9
2014-2015	436	19.3	44.3

Source: Cuba Statistical Yearbook, 2015

b) Rice

In the Central zone, in Los Arabos and Corralillo, rice occupies almost 5% of the cultivated area in these municipalities. The highest yields that have been obtained in Cuba have been in the order of 8 t / ha, however, in the AIP of the Central zone they barely exceed 4 t / ha.

On the other hand, in the Eastern zone, the municipality of Amancio stands out as the largest rice producer of the AIP (almost 6% of the cultivated area is dedicated to rice planting). Yields do not exceed 4 t / ha.

c) Corn

Corn reaches its greater relevance in the AIP of the Eastern zone, in particular the areas of intervention of Amancio Rodríguez and Jobabo with 10% of the cultivated areas respectively. However, the yields of the AIP of the Eastern Zone barely exceed 3.7 t / ha.

In the AIP of the Central zone, except Corralillo, which dedicates 5% of the cultivated area to the production of this cereal, the cultivation of corn is not relevant. The yields in this area do not exceed 2.9 t / ha.

d) Beans

Beans such as rice and corn (in the Eastern zone) are a relevant crop in the Cuban diet. The government allocates important financial resources to incorporate more areas and raise the yields of this crop in order to replace imports.

The AIP of the Central zone stands out in the production of this cereal and dedicate some 792 ha to its cultivation, in particular Quemado and Corralillo. In the AIP of the Eastern zone, the cultivation of beans also has an important weight in the cultivated area.

The yields are very discreet in relation to the best results obtained. In the AIP of the center the current yields are in the order of 1.2 t / ha, while in the Eastern area they are somewhat lower (1.1 t / ha).

e) Sweet Potato

The sweet potato, along with cassava and plantain is one of the most important crops in the diet of Cubans and especially of the population of the AIP of the Eastern zone. About 500 ha are devoted to the production of sweet potatoes in the Eastern zone. For its part, in the Central zone, the area dedicated to the cultivation of sweet potatoes is barely 252 ha. The yields that are currently registered in the Eastern zone are between 5-6 t / ha, while those obtained in the Central zone are around 6 t / ha.

f) Cassava / Yucca

In the AIP of the Eastern zone some 1484 ha are dedicated to the cultivation of cassava. The current yields obtained in this area alternate 9 t / ha.

On the other hand, in the AIP of the Central zone, only 323 ha are devoted to this crop, only 22% of the area of what is sown in the Eastern zone. However, the yields in the Central zone are higher: between 9-12 t / ha.

g) Plantain

Plantain is also very important in the diet of the inhabitants of the AIP of the Eastern zone, to which they dedicate 1097 ha. The yields are in the order of 7-10 t / ha.

The areas dedicated to the cultivation of plantain in the AIP of the Central zone, barely exceed 119 ha, with yields approaching 30 t / h (three times higher than those obtained in the Eastern zone).

Table 9. Current yields and scenarios at 2050-2100

		AIP Central			AIP East		
	Best results	Yields (t/ha)			Yields (t/ha)		
		Current	2050	2100	Current	2050	2100
Sugar cane	60.0	54.9	49.0	44.0	54.9	49.0	49.0
Rice	8.0	3.98	3.7	3.5	4.0	3.6	3.4
Corn	7.0	2.9	2.6	2.3	3.7	3.2	2.9
Beans	1.5-2.0	1.17	1.07	1.01	1.1	1.0	0.9
Sweet Potato	17-21	6.1	5.9	5.1	5.3	5.1	4.4
Cassava	20.0	12.1	11.8	10.5	9.4	9.0	7.9
Plantain	14-40.0	30.9	30.1	29.0	11.0	10.6	10.2

Source: elaboration based on information from the Municipal Statistical Yearbook, (Centella Artola et al., 2006), (Somoza et al., 2015).

I.2.2. Livestock Sector

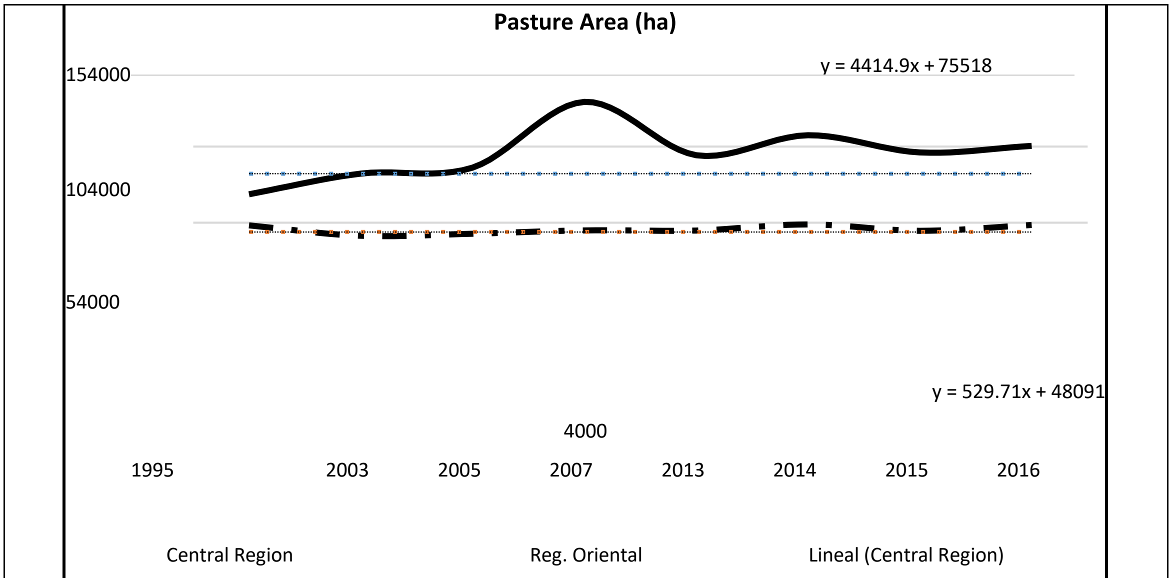
a) Path and projection of pasture growth

In the AIP the dynamics of the surface of natural pastures has had a differentiated behavior, while in the Central zone it has maintained a modest growth rate in the period 1995-2016, in the Eastern zone it has experienced a tendency to stagnation, with slight tendencies to reduction at certain times. (See Figure 17).

The predicted climate change, according to the coupled models of general circulation of the atmosphere and the ocean, will result in an increase in the months with moderate and intense drought processes. The availability of water for crops will be less and less. All of the above will raise the vulnerability of grasslands to fires.

The past and recent behavior, as well as the projected future scenarios of increase in average temperatures and reduction of rainfall, will impact on the reduction of the yields of the natural grasses and therefore of the pasture lands in the AIP, based on the results obtained in the panel model addressed in section I.1.5 used to analyze the interdependence between the behavior of the deterioration of climatic variables and their impact on the growth and expansion of marabou, as well as the explanation of their correlation with the decrease in yields and cane areas, various crops and natural pastures.

Figure 17. Historical performance of the surface dedicated to pastures. Both zones



Source: Prepared by the authors from the Balance of Land of the ONEi, 2017

Behavior and projection of pasture growth with and without Climate Change

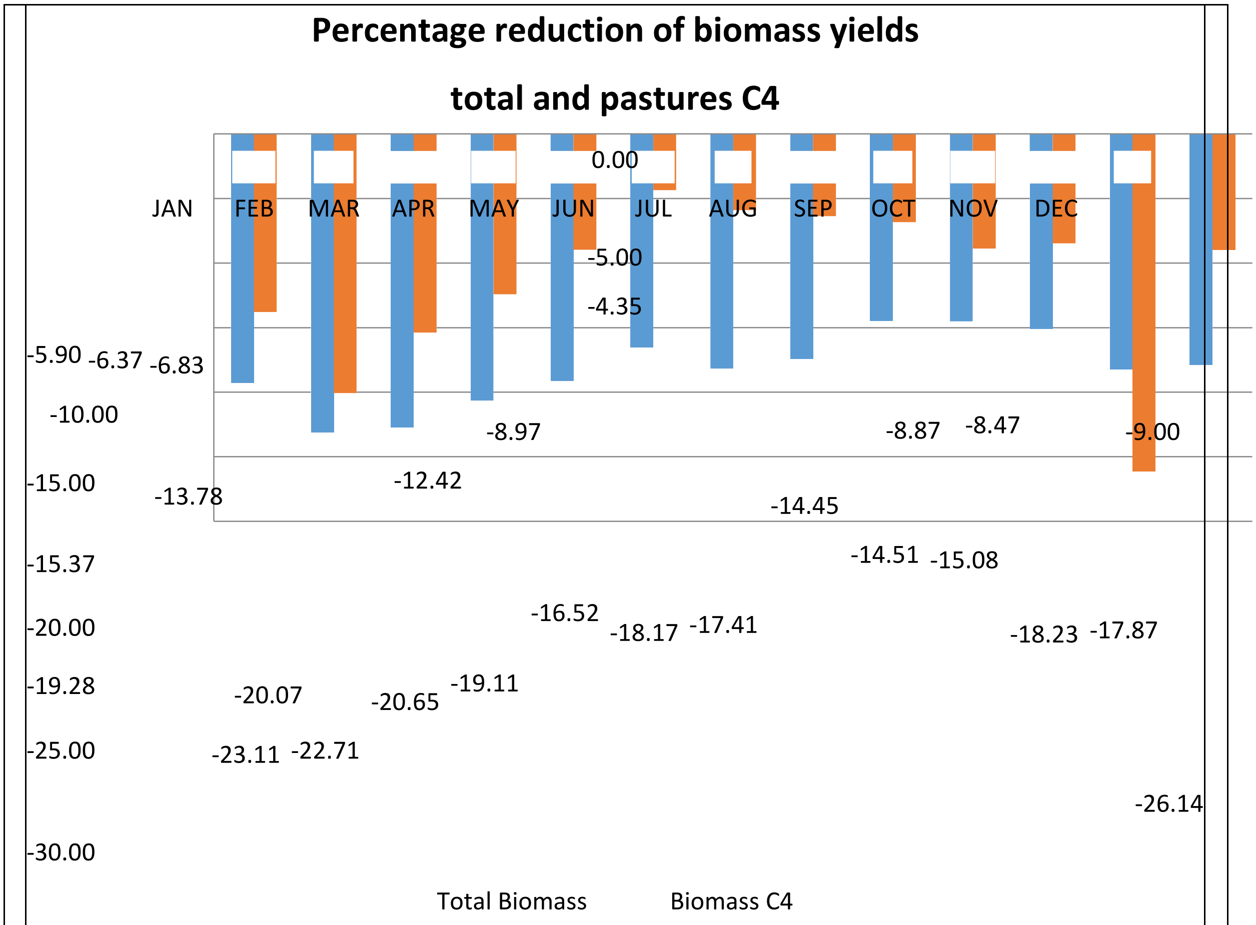
From the analysis of the pasture behavior without livestock exploitation, it can be inferred that the average of the total biomasses of both the pasture vegetation and that of only C4 grasses for each month decreases, without exception (Fonte et al., 2004) and (Rivero and Rivero, 2004) (Rivero and Rivero, 2000). - In the reference scenario or Business As Usual (BAU in its acronym in English), the average change is, for all vegetation, 17.9%, while for grasses is only 9%. (See Table 10, 11 and Figure 18).

Table 10. Impact of Climate Change on the mean values, standard deviation and coefficients of variation (CV) of the total biomass and pastures C4 (grams / m2).

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TOTAL BIOMASS												
Med	-393.6	-597.4	-793.2	-751	-871.6	-831.4	-925.9	-891.6	-723.2	-677	-503.9	-249
D. stand	-222.4	-279.4	-244.1	-250	251.7	-64.7	-89.4	-106.9	-60.1	-56.6	-12.3	-121.9
CV	0.049	0.046	0.0446	0.018	0.096	0.008	0.007	0.004	0.008	0.009	0.033	-0.039
PASTURE BIOMASS C4												
Med	-92.8	-215.8	-261.9	-225	-208.5	-109.4	-151.2	-168.6	-188.6	-226	-136.2	-49.5
D. stand	82.4	90.9	23.5	15.4	-252.4	27.7	44.3	50.8	24.4	34	1.8	19.8
CV	-0.081	-0.118	-0.087	-0.057	-0.13	0.008	0.012	0.012	0.001	-0.001	-0.021	0.066

Source: Calculated from (Rodríguez Vega et al., 2003) (Rivero and Rivero, 2004)

Figure 18. Impact of Climate Change on the reduction of pasture yields



Source: Prepared by the authors

The progressive reduction of the organic matter content of the soil, and therefore the deterioration of its water retention capacity, resistance to erosion and to compaction, is greater as the unitary exploitation load of the pasture increases.

The productive yields of the pastures, expressed as the net primary productivity in dry matter per hectare will be reduced in all the regions. The process of pasture growth will move towards greater lignification and a lower content of proteins and carbohydrates (Rivero, et al., 2010)

Table 11. Percentage reduction of Total Biomass and Pastures C4 (%)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Total Biomass	19.3	23.1	22.7	20.6	19.1	16.5	18.2	17.4	14.4	14.5	15.1	18.2	17.9
C4 Biomass	13.8	20.1	15.4	12.4	9.0	4.3	5.9	6.4	6.8	8.9	8.5	26.1	9.0

Source: Prepared by the authors

As a consequence of the livestock exploitation, there is also a substantial modification of pasture biodiversity indexes, both of the predominance index and the Shannon index. This is a reflection of a greater dominance of pastures C 4 over grasses and shrubs C 3, and reaffirms the importance of pastures, their improvement and efficiency in their management in livestock farming systems in the conditions of AIP, where pastures are practically the only source of animal feed

Table 12. Total living biomass by functional groups (g / m 2). June of the year 16 of the simulation

Functional Group	1969 – 90 No cows	1969 – 90 With 5.0 cows/ ha
Tropical pastures C_4	2258	2225
Non grass C_3	543	31
Shrubs C_3	93	28
Total Biomass	2894	2285

Source: (Rodríguez Vega et al., 2003) and (Rivero and Rivero, 2004)

Table 13. Biological diversity indexes. June of the year 16th of the simulation

	Dominance index	
Functional Group	**1969 – 90 No cows**	**1969 – 90 With 5.0 cows / ha**
Tropical Pastures C_4	0.780	0.974
Non grass C_3	0.188	0.014
Shrubs C_3	0.032	0.012
Shannon Index	0.618	0.138

Source: (Rodríguez Vega et al., 2003) and (Rivero and Rivero, 2004)

b) Bovine bio productive indicators and thermal stress according to incidence of droughts

The behavior of the meteorological and agricultural drought directly affects the bio productive behavior of the cattle, considering that depending on the level of repeatability of droughts in certain areas, some physiological factors are significantly affected (Rodríguez Vega et al., 2003).

Table 14. Behavior of Bovine Bio productive Indicators under four levels of threat of recurrence of droughts in the Eastern Zone

INDICATORS	Degree of threat of recurrence of drought			
	I (11-20 %)	II (21-30 %)	III (31-40 %)	IV (> 40 %)
Birthrate (% de cabezas)	60.4 ± 2.1	52.3 ± 1.9	33.6 ± 3.2	28.8 ± 2.5
First childbirth age (months)	35.0 ± 3.6	40.0 ± 2.4	41.0 ± 4.3	44.2 ± 2.9
General death rate (% heads)	5.8 ± 1.1	7.4 ± 0.9	14.1 ± 1.0	16.5 ± 2.3

Fuente: (Rodríguez Vega et al., 2003)

The degree of threat is expressed in percent of years with drought within the period analyzed and from this result, future scenarios for each season were evaluated taking into account the percentage of years in which drought occurs within each period.

The scenarios of increasing average temperatures and reducing rainfall also have a negative impact on the birth rate of cattle. While in the period 1961-1990 the average birth rate (measured as% of head of cattle), was in the order of 44.0 ± 1.9 and 89.9 ± 2.4 (with a birth level for Santa Cruz del Sur order of 68.8 ± 2.1), in 2050 a decrease is estimated between 25.1 ± 2.5 and 30.6 ± 3.2; in Santa Cruz del Sur 25.1 ± 2.5 births, almost 46% in relation to the number of births in the period taken as reference. In 2100 the predicted reduction in births is even more dramatic, between 15 and 25%.

The effects of climate change also affect the increase in the age of cattle to have the first birth. If in the period 1961-1990 the average of the first birth was between 33 and 40 months, in 2050 it would be around 42 months, and in 2100 in the order of 42-44 months, with negative effects on the economy of livestock activity. On the other hand, the indicators of general mortality are negatively affected, with percentages of mortality in the reference period between 5.6 and 12.6%, to percentages of mortality in 2050 and 2100 that would be between 23.8-27.4% and 32.7- 70.9% respectively.

All the bio productive indicators of the cattle evaluated for the scenarios, underwent considerable changes and the tendencies point to a lower birth rate, increase of the optimal age possible for the first parturition and increase of the general mortality.

c) Conditions of comfort and thermal stress of livestock

It is considered that an average air temperature between 10 ºC and 27 ºC is favorable for the development and productivity of most breeds and species of cattle in the tropical zone. A short-term deviation of the air temperature from the indicated limits does not exert appreciable negative influence on the animal's state of health and productivity.

However, the prolonged descent or rise of the average temperature has a negative influence. The longer and frequent these deviations are, the more comfort for the animals will be impaired. decreasing its productivity. Based on these factors, a classification was made for the comfort state of cattle according to the temperature regime.

Table 15. Qualification of the temperature regime for the comfort of cattle in the tropical zone

Temperature Limits in ºC				***Classification of Temperature regime***	***Grade***	***State of the animals***
Low		***High***				
From	*To*	*From*	*To*			
-	-	16	24	*Ideal*	**5**	The state is optimum and productivity is maximum
10	16	24	27	*Favorable*	**4**	The animals are active, their state is completely satisfactory, productivity remains within normal levels
7	10	27	30	*Non totally favorable*	**3**	Insignificant abatement of animals, particularly at noon, when extreme temperatures manifest themselves
-	-	30	35	*Unfavorable*	**2**	Visible abatement of the animals by the moderation of the movements, search of the shadow, decrease of appetite and productivity.
-	-	35	40	*Very unfavorable*	**1**	Significant animal abatement, poor appetite, accelerated breathing rate and minimal breathing.

Fuente: Fonte A., Roger E. Rivero y Roger R. Rivero (2004)

With the increase of temperatures in an increasingly prolonged period of time in future scenarios, the comfort conditions for cattle will be unfavorable considering that as time passes the number of months in which the maximum and average temperatures average of the air are superior to 27 ºC and 30 ºC respectively. The maximum averages will be higher than 30 ºC in more than 8 months of the year in all regions and the averages will be higher than 27 ºC in more than 7 months in the scenario of 2100.

I.2.3 Impact on Forests

The evaluation of the impact of climate change on forests represents a task as important as that of the rest of terrestrial ecosystems and is still far from having been solved and having universally recognized methodologies for its realization.

Table 16. Characteristics of forests for scenarios based on the general circulation model ECHAM4

Parameter	C. Current	2010	2030	2050	2075	2100
Palo Seco						
Ria[3]	10,22	10,09	9,98	9,87	9,74	9,61
Type	Forest E H.	Forest E H.	Savannah	Savannah	Savannah	Savannah
Life zone	Dry 1B	Dry 1B	Dry 1B	Dry 1B	Dry 1B	Dry 1B
DPBsCO2	404,93	398,57	402,57	401,42	394,97	393,67
DPBcCO2	404,93	445,89	482,35	510,78	536,21	571,86
PPNsCO2	21,324	18,812	20,798	20,545	18,243	17,984
PPNcCO2	21,324	21,045	24,920	26,141	24,766	26,124
Sta. Cruz						
Ria	7,88	7,76	7,65	7,54	7,41	7,29
Type	Savannah	Savannah	Savannah	Savannah	Savannah	Savannah
Life zone	Dry 2	Dry 2	Very dry 1A	Very dry 1A	Very dry 1A	Very dry 1A
DPBsCO_2	323,49	322,42	321,54	320,61	319,53	318,50
DPBcCO_2	323,49	360,70	385,27	407,95	433,79	462,66
PPNsCO_2	9,221	9,049	8,907	8,757	8,582	8,416
PPNcCO_2	9,221	10,124	10,672	11,142	11,651	12,225

Note:
DPBsCO2 - Potential Biomass Density without CO2 fertilization (T / ha) DPBcCO2 - Potential Biomass Density with CO2 fertilization (T / ha) PPNsCO2 - Net Primary Productivity without CO2 fertilization (T / ha) PPNcCO2 - Net Primary Productivity with fertilization by CO2 (T / ha)

Source: Prepared by the authors from (Rivero et al., 2003)

[3] Ria: bioclimatic index of Rábchikov

In the reference scenario there is a progressive increase in the degree of aridity and an evolution towards drier life zones of the forests of the region. This evolution is caused by a sustained increase in temperatures and potential evapotranspiration and a progressive decrease in rainfall.

At the same time that the climate and the zones of life become increasingly dry, the episodes of drought increase considerably, as well as the frequency of years with moderate and severe droughts. Both the evolution of aridity and the frequency of droughts will make forest fires more frequent and intense and will increase the vulnerability of forests to these disasters, which will progressively spread to the Central zone.

Finally, if the effect of CO2 fertilization at the ecosystem scale does not occur, all these processes will be accompanied by a progressive reduction of the biomass potential density and the net primary productivity of the forests throughout the current century. All of the above will imply an increase in the competitiveness of the species corresponding to dry sites to the detriment of those corresponding to wet sites, together with changes in the floristic composition and the biological diversity of the forests.

I.3. IMPACTS OF CLIMATE CHANGE ON SOILS AND WATER RESOURCES

I.3.1. Soils[4]

a) Main types of soils in the two intervention zones of the Project

The main soil types in the two intervention areas of the Project are the Yellowish Ferralitic (25.1%), Brown with carbonate (11.9%) and Fersiallitic Reddish-brown (11.3%) that occupy 239 727 ha, representing 48.4% of the total area of the AIP.

The disaggregated territorial behavior shows that in the Central Zone of the project, the soil types Yellowish Ferralitic (24.0%), Brown with carbonate (22.4%), Humite Carbonate (9.8%) and Ferralitic Quartziferous yellow reddish Lixivium (8.9) predominate. 644 ha, representing more than 68% of the territory, while in the Southern Zone of Las Tunas, the soils of reddish brown Fersiallitic (20.8%), Yellowish Ferralitic (18.1%), Brown without Carbonates (12.6%), Brown with carbonate stand out (10.0%) and Dark Gleyed plastic (11.7%) that occupy 167781 ha, representing more than 70% of the territory (See Table 17 and Figure 19).

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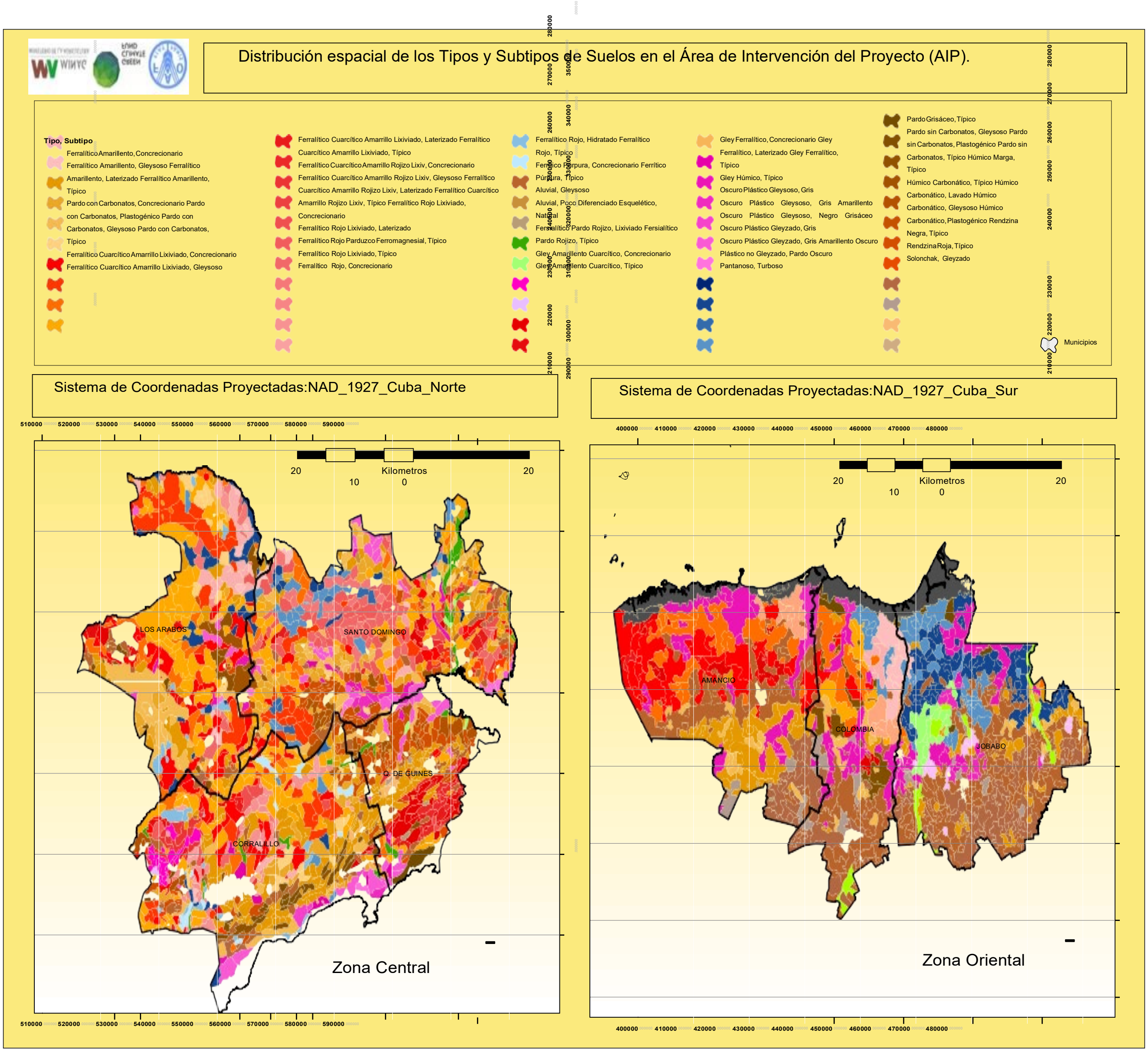
[4] The evaluation of the impact of Climate Change on soils and water resources in the AIP was based on the digital cartographic information and databases provided by the Department of Soils and Fertilizers, the Soil Institute, the National Institute of Hydraulic Resources (INRH)), the Physical Planning Institute (IPF) and the processing of information collected at the territorial level. (GEPROP, 2009) (Department of Soils and Fertilizers, 2017), (Institute of Physical Planning, 2013)
In addition, the databases, cartography and results of the research were used: National assessment of land degradation applying the WOCAT-LADA methodology in the Republic of Cuba (Urquiza Rodríguez et al., 2014) and the Diagnosis and characterization of the state of land degradation in Cuba and its vulnerability to desertification processes (Vantour Causse et al., 2015)

Table 17. Types of Soils in the AIP - Central and Eastern zone.

Type	AIP		Central Zone		Eastern Zone	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Yellowish Ferralitic	124542	26.3	83110	**31.0**	41432	**20.2**
Brown with carbonate	58987	12.5	58987	**22.0**	0	0.0
Humic coal	21035	4.4	21035	7.8	0	0.0
Quartziferous Ferralitic Yellow reddish Lixivium	19461	4.1	19461	7.3	0	0.0
Plastic dark gley	40446	8.6	13667	5.1	26779	13.1
Gley Ferralitic	35396	7.5	12645	4.7	22751	11.1
Fersiallitic Brown Reddish	56151	11.9	8391	3.1	47760	**23.3**
Quartziferous Ferralitic Yellow Lixivium	17108	3.6	11773	4.4	5335	2.6
Ferrallitic Red	12799	2.7	9264	3.5	3535	1.7
Ferrallitic Red Lixivium	6282	1.3	6282	2.3	0	0.0
Alluvial	10217	2.2	3576	1.3	6641	3.2
Red Rendzina	7030	1.5	3376	1.3	3654	1.8
Gley Yellowish Quartziferous	4116	0.9	4116	1.5	0	0.0
Ferrallitic Brownish Red Ferromagnesian	2353	0.5	2353	0.9	0	0.0
Brown without carbonate	31408	6.6	2479	0.9	28929	**14.1**
Ferritic Purple	2003	0.4	2003	0.7	0	0.0
Plastic dark non-gley	3105	0.7	1304	0.5	1801	0.9
Solonchak	2598	0.5	950	0.4	1648	0.8
Black Rendzina	2465	0.5	2465	0.9	0	0.0
Humic Loam	436	0.1	436	0.2	0	0.0
Skeleton	469	0.1	223	0.1	246	0.1
Humic Gley	84	0.0	84	0.0	0	0.0
Marshy	14326	3.0	72	0.0	14254	7.0
Brown Grayish	30	0.0	30	0.0	0	0.0

Source: Extracted from the Soil Map at a scale of 1: 25,000 from the Department of Soils and Fertilizers of MINAG (MINAG, 2017).

Figure 19. Ground distribution of soils by type and sub type. Both regions



b)Vulnerability of soils to Climate Change in the AIP

Vulnerability (see table 18 and figure 21) of the land cover in the AIP was classified and mapped according to the possible scenarios that may occur due to climate change in Cuba. If, in the scenarios of climate change, an increase in the intensity of anomalous rainfall and extreme hydrometeorological events is probable, the most vulnerable because of their properties are the soils with a sandy texture. Associated with the increase in temperatures are the soils with the highest percentage of organic matter, since their mineralization will be more accentuated, being able to evolve to different soils, since their main training factor would be limited.

The prolonged drought may also affect soils that are close to the coastline, or on formations that have halitic rocks, as a result of the water extraction from the aquifers, causing a hydrostatic pressure imbalance and the subsequent penetration of the salt wedge in localities near the coast or the elevation of salts by capillarity in soils whose parent material is sodium chloride.

For this, an environmental matrix was proposed by Leopold (1971), where the magnitude of the process in soils from 1 to 3 was standardized, these being low, medium and high and their subsequent vulnerability classification of values from 3 to 9, Categories: 3 - 4 little vulnerable, 5 - 6 moderately vulnerable, 7 vulnerable, and very vulnerable superiors.

Table 18. Soil vulnerability behavior in the AIP.

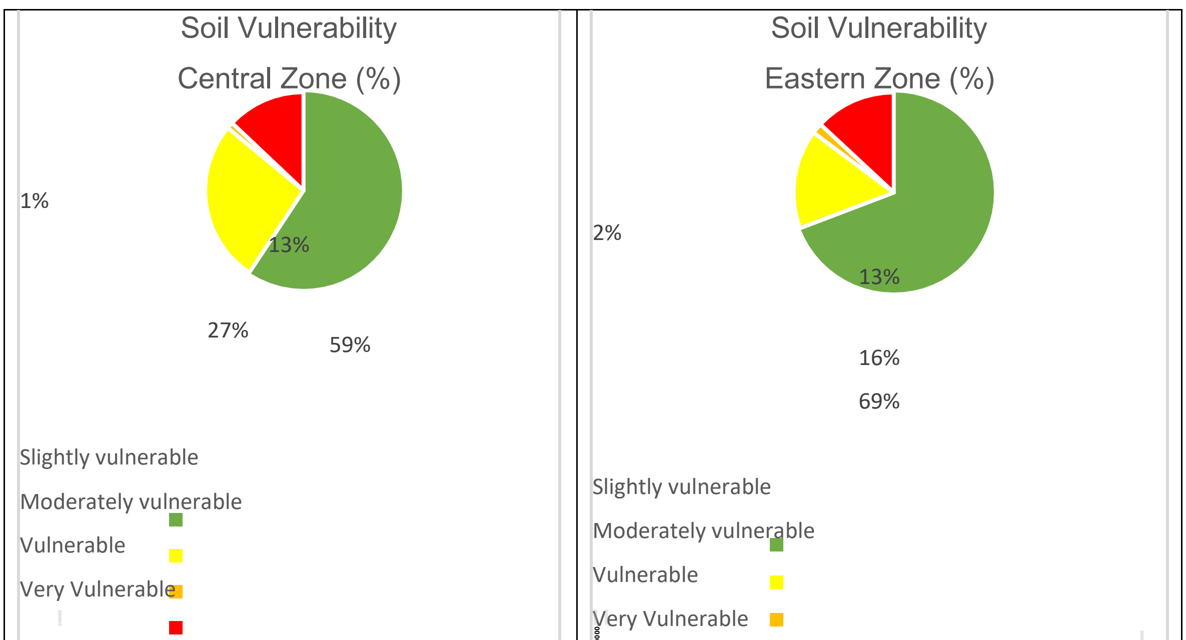
Soils	+ Temp.	+ Intensity of precipitation	Prolonged drought	Total	Vulnerability
Ferralitic yellowish	1	1	1	3	Slightly vulnerable
Brown with carbonates	2	2	1	5	Moderately vulnerable
Humic coal	3	2	3	8	Very vulnerable
Ferralitic Quartziferous Yellow Reddish Lixivium	1	1	1	3	Slightly vulnerable
Dark plastic Gley	3	2	3	8	Very vulnerable
Gley Ferralitic	1	1	2	4	Slightly vulnerable
Fersiallitic Reddish brown	1	2	1	4	Slightly vulnerable
Ferralitic Quartziferous Yellow Lixivium	1	1	1	3	Slightly vulnerable
Ferralilitic Red	1	1	1	3	Slightly vulnerable
Ferrallitic Red Lixivium	1	1	1	3	Slightly vulnerable
Alluvial	1	1	1	3	Slightly vulnerable
Rendzina Red	1	3	1	5	Moderately vulnerable
Gley Yellowish Quartziferous	1	1	3	5	Moderately vulnerable
Ferrallitic Red Brownish Ferromagnesian	1	1	1	3	Slightly vulnerable
Brown without carbonate	2	2	1	5	Moderately vulnerable
Ferritic Purple	1	1	1	3	Slightly vulnerable
Dark plastic non Gley	3	1	3	7	Vulnerable
Solonchak	3	1	3	7	Vulnerable
Rendzina Black	2	3	1	6	Moderately vulnerable
Humic Loam	3	3	1	7	Vulnerable

Skeleton	1	3	1	5	Moderately vulnerable
Gley Humic	3	1	3	7	Vulnerable
Marshy	1	1	1	3	Slightly vulnerable
Brown greyish	2	3	1	6	Moderately vulnerable

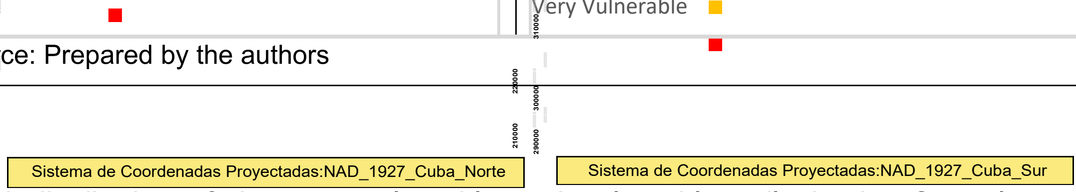
Source: Prepared by the authors

The vulnerability of the soils to the effects of climate change in the AIP and in both zones have a percentage distribution in which the category of low-vulnerable predominates between 59 and 69%, with the predominance in comparative terms in the Central zone of the medium vulnerable category with 27%, while vulnerable and very vulnerable ranges around 15% in both areas of the AIP.
(See figure 20)

Figure 20. Distribution of soil vulnerability. Both areas

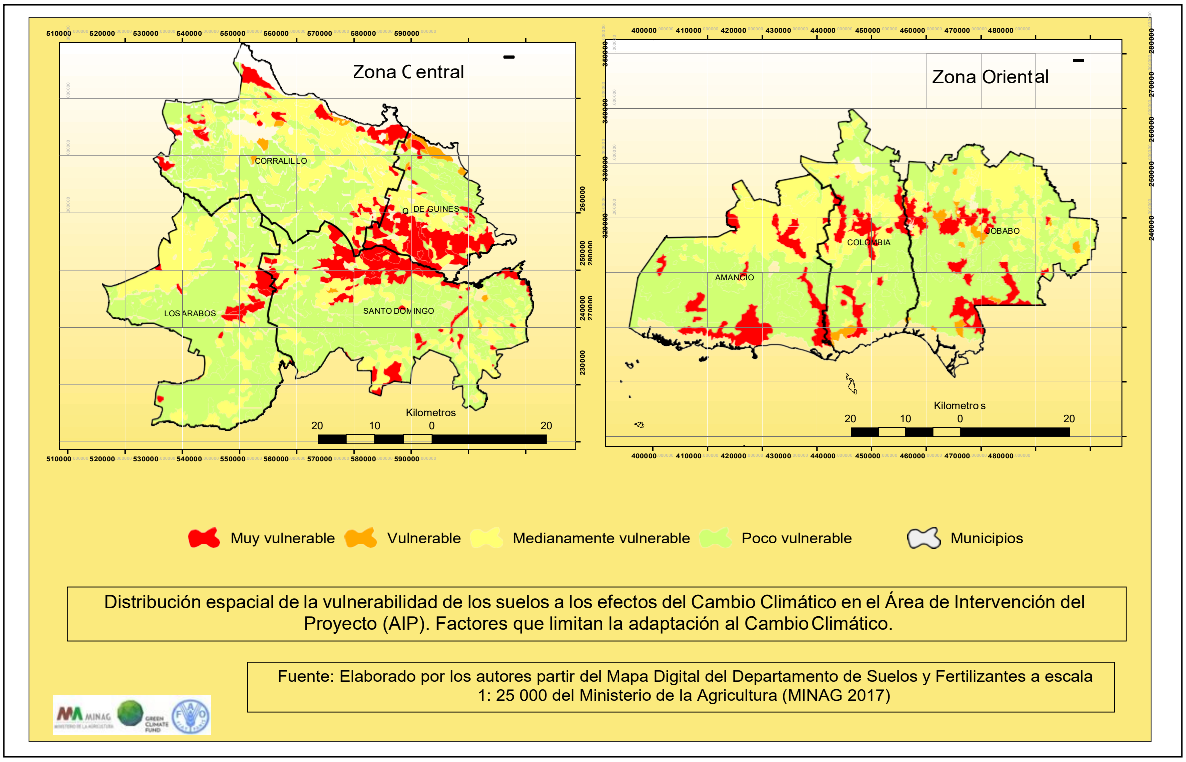


Source: Prepared by the authors



The field distribution of the very vulnerable and vulnerable soils in the Central zone forms a concentration in the southern limit of the municipality of Quemado de Güines and the north of the municipality of Santo Domingo, also presenting a relative linear concentration parallel to the coast that is more evident on the border between the Corralillo and Quemado de Güines municipalities. In the eastern zone the most vulnerable soils have a distribution to the center and south of the territory. (See figure 21).

Figure 21. Field distribution of the types and sub types of soils in the AIP – Both regions



c) Properties of soils and factors that limit adaptation to climate change

Depth

In a deep soil, the plants resist the drought better, since in greater depth, greater capacity for moisture retention, however, in both areas of the AIP, shallow to extremely shallow soils predominate, with the eastern zone experiencing the most unfavorable behavior attending to this property of the soil (See Table 19).

Table 19. Behavior of the soil depth property in the AIP and the Central and Eastern regions (in ha)

	AIP		Central Region		East Region	
Depth Properties	Area (ha)	%	Area (ha)	%	Area (ha)	%
Extremely Shallow (<10 cm)	33545	6.6	3164	1.1	30381	13.3
Very Shallow (11-20 cm)	64328	12.7	43612	15.6	20716	9.1
Shallow (21-40 cm)	238386	46.9	100814	36.0	137571	60.4
Moderately Shallow (41-60 cm)	111696	22.0	105234	37.5	6462	2.8

Deep (61-100 cm)	57862	11.4	27039	9.6	30823	13.5
Very deep (>100 cm)	2166	0.4	398	0.1	1767	0.8
Total	507981	100.0	280260	100.0	227721	100.0

Source: Extracted from the Soil Institute Map at a scale of 1: 250 000, improved by GEPROP (GEPROP, 2009).

Organic Matter

The presence of organic matter in the soil ecosystem influences the reduction of runoff and erosion, increases the moisture retention capacity of soils, particularly those with a sandy texture and is responsible for a high percentage of the Cationic Exchange Capacity. (CIC). Soils with lower humus content and organic matter have a low capacity to retain and infiltrate water and become more susceptible to erosion. In the total and in both areas in the soils of the AIP, the categories of medium to poor content of organic matter predominate in more than 70%, an element that contributes to the susceptibility of the AIP to erosion, degradation and desertification (See Table 20)

Table 20. Behavior of the property content of organic soil matter in the AIP and the Central and Eastern zones (in ha)

Organic Matter Properties	AIP		Central Region		Eastern Region	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
< 2% Poor	124335	24.5	75163	26.8	49172	21.6
De 2.01 a 4% Middle	261286	51.4	143875	51.3	117411	51.6
De 4.01 a 6% Rich	111485	21.9	50346	18.0	61138	26.8
Mayor de 6% Very rich	10876	2.1	10876	3.9	0	0.0
Total	507981	100.0	280260	100.0	227721	100.0

Source: Extracted from the Soil Institute Map at a scale of 1: 250 000, improved by GEPROP (GEPROP, 2009).

Salinity

Soil salinized according to the Institute of Soils (MINAG, 2009) occupy in the AIP 134122 ha, which represent 26.4% of the total territory, of them 57866 ha (11%) classified as little saline and 76257 ha (15%) from medium to very saline. (See Table 21).

Table 21. Behavior of the salinity phenomenon in the AIP and the Central and Eastern zones (in ha)

	AIP		Central Region		Eastern Region	
Salinity categories	Area (ha)	%	Area (ha)	%	Area (ha)	%
Very saline	30062	5.9	0	0	30062	13.2
Saline	37813	7.4	10876	3.9	26937	11.8

Moderately saline	8382	1.7	0	0	8382	3.7
Slightly saline	57866	11.4	23372	8.3	34494	15.1
Subtotal	134122	26.4	34248	12.2	99874	43.8
Non saline	373859	73.6	246012	87.8	127847	56.1
Total	507981	100	280260	100	227721	100

Source: Extracted from the Soil Institute Map at a scale of 1: 250 000, improved by GEPROP (GEPROP, 2009).

The geographical distribution of salinity in the Central zone of the intervention area of the project indicates that it is the municipality of Corralillo that has the most affected area with 12174 ha (35.5% of the total), followed by the municipality of Santo Domingo with 11023 ha (32.2). %) and a lower incidence in terms of area in Los Arabos with 6747 ha and Quemado de Güines 4272 ha. However, the municipalities that present areas with effects of the category of very saline and saline are Corralillo, Quemado de Güines and Los Arabos with 12613 ha representing 36.8% of the total, a phenomenon that is significant in the areas that are concentrated and distributed preferably along the coastal strip in the municipalities of Corralillo and Quemado de Güines, associated with the phenomenon of marine intrusion (See Figure 22).

The geographical distribution of salinity in the area of intervention of the project in the Eastern zone indicates that it is the municipality of Amancio which has the most affected area with 53109 ha (53.2% of the total), followed by the municipality of Jobabo with 33698 ha (32.3 %) and a lower incidence in terms of area in Colombia with 13069 ha (13%). The municipalities with the largest areas affected by the categories of very strongly and strongly are Jobabo with 25316 ha representing 25.3% of the total, and the municipality Amancio with 20384 ha (20.4%), which are distributed along the coastal strip, associated with the phenomenon of marine intrusion. (Figure 22).

In summary, the phenomenon of salinity affects with greater severity and by superficial extension to the Eastern zone of the AIP.

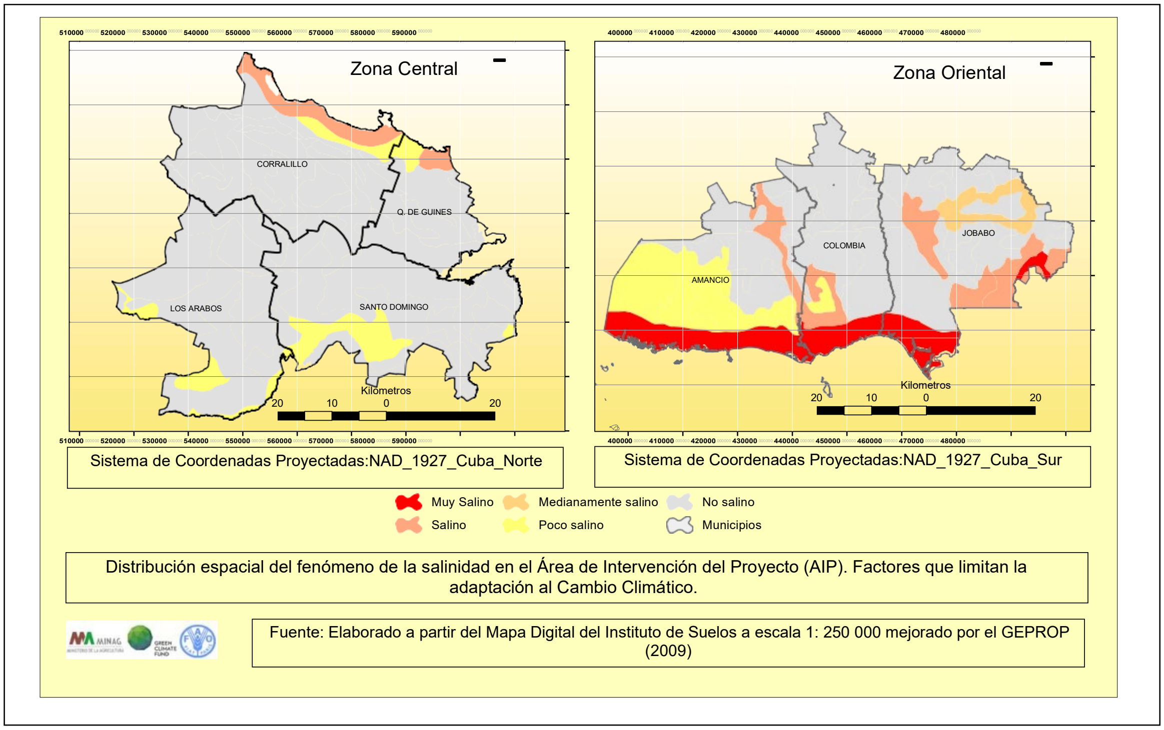


Figure 22. Field distribution of salinity in the AIP. Both zones

Erosion

Soils eroded according to the Institute of Soils (MINAG, 2009) occupy in the AIP 245530 ha representing 48.3% of the total territory, of them 102992 ha (20%) classified as little eroded and 142538 ha (28%) between medium and very eroded. (See Table 22)

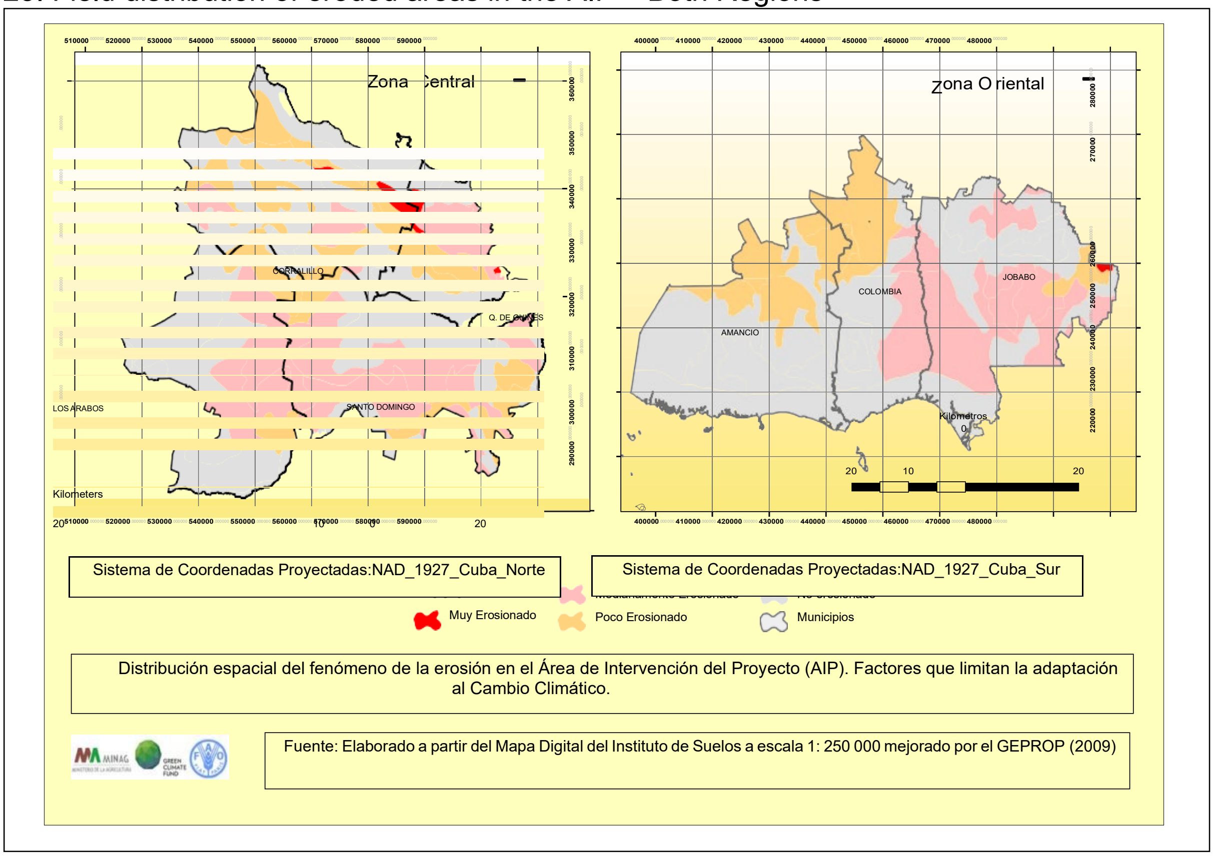
Table 22. Behavior of the phenomenon of erosion in the AIP and the Central and Eastern zones (ha)

Type	AIP		Central		Eastern	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Very Eroded (Total loss of A and + 50% of B)	3590	0.7	3271	1.2	319	0.1
Moderately Eroded (Loss of up to 50% of A)	138948	27.4	84747	30.2	54201	23.8
Slightly Eroded	102992	20.3	59478	21.2	43514	19.1
Subtotal	245530	48.3	147496	52.6	98034	43
Non eroded	262451	51.7	132764	47.4	129687	57

Source: Extracted from the Soil Institute Map at a scale of 1: 250,000, improved by GEPROP (GEPROP, 2009).

The erosion occupies in the Central zone an extension of 147496 ha that constitutes 60% of the territory affected by the erosion in the total of the AIP, of them 88018 ha (59.7%) considered from medium to very eroded, res and 1022 ha (0.5%) from moderately to very strongly eroded. The geographical distribution of erosion in the area indicates that it is the municipality of Santo Domingo that has the most affected area with 55803 ha (37.8% of the total), followed by the municipalities of Corralillo and Los Arabos with 71617 ha, both represent 48.5% of the total, and a lower incidence in terms of area in Quemado de Güines. The municipalities that present areas with effects of the highly eroded category are Quemado de Güines and Corralillo with 3271 ha (Figure 23).

Figure 23. Field distribution of eroded areas in the AIP – Both Regions



In the Eastern zone, erosion is less significant and extends to 98034 ha representing almost 40% of the total of the AIP, of which 54201 ha (23.8%) considered to be fairly eroded (with loss of up to 50% of the horizon) and 43514 ha (19.1%) are little eroded. The geographical distribution of the erosion in the area of intervention of the project is concentrated from the middle part to the north of the municipalities of Amancio and Colombia, and in the case of Jobabo in the Center-South part, it is the municipality of Jobabo that possesses more affected area with 45730 ha (47% of the total), followed by the municipality Colombia with 29607 ha (30.2%), both representing 76.8% of the total. The Jobabo municipality has the largest areas affected by the categories from medium to very eroded with 42191 ha, representing 77% of the total of the Eastern zone (Figure 23).

d) Other edaphic factors that limit the adaptation that may be mentioned in relation to climate change.

Agroproductive categories

In the AIP, the soils with medium to little productive agricultural production categories occupy 267857 ha (53.9%) and the productive ones with very productive 215821 ha (43.4%), however, the predominance of the medium to little productive categories in the Eastern Zone with 161441 ha (60.3%), where the category of Little productive exceeds 113875 ha. (See Table 23).

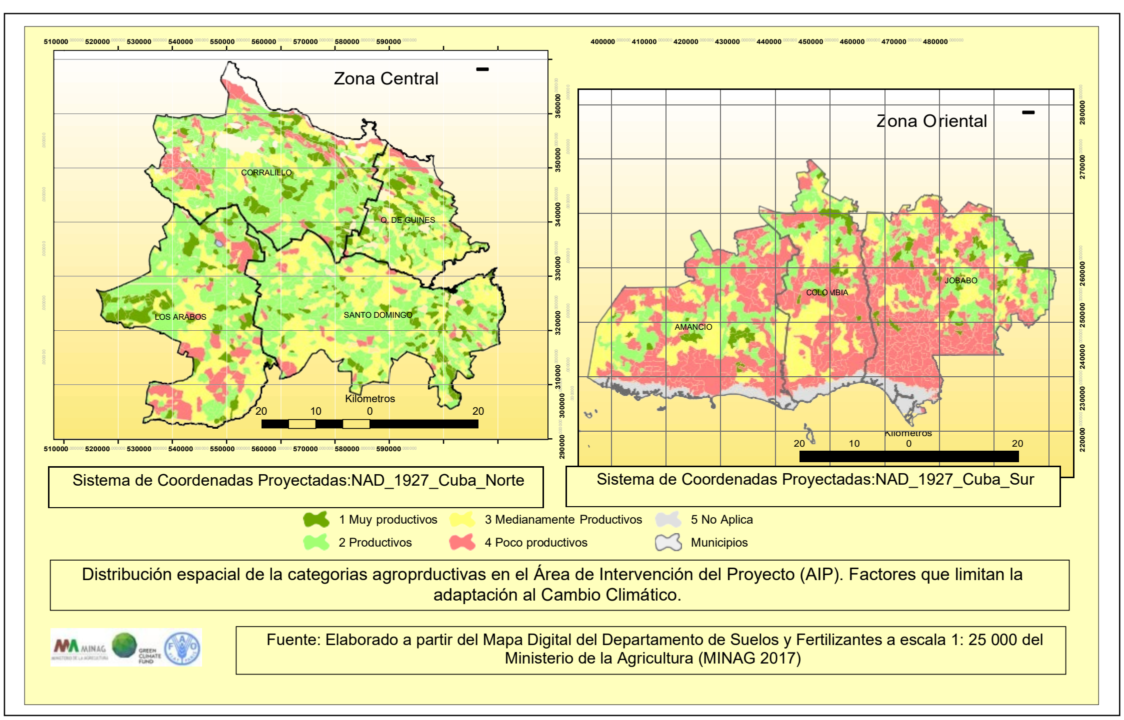
Table 23. Agroproductive categories in the AIP and the Central and Eastern zones

Agroproductive categories	AIP		Central Region		Eastern Region	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
I: Very productive > 70%	45091	9.1	35541	13.3	9550	4.2
II: Productive 50-70%	170730	34.3	125720	46.9	45009	19.6
III: Moderately productive 30-50%	125599	25.3	78033	29.1	47567	20.8
IV: Slightly productive < 30 %	142256	28.6	28383	10.6	113875	49.7
V: Not applicable	13362	2.7	150	0.1	13212	5.8
Total	497040.	100	267828	100	229213	100

Source: Prepared by the authors from Map 1: 25,000 of the Department of Soils and Fertilizers of the Ministry of Agriculture (MINAG, 2017).

The greatest agroproductive potential of the Central zone is concentrated in the municipalities of Santo Domingo, Corralillo and Los Arabos, the first two with more than 101376 ha (62.8%) in the productive to very productive categories and with Los Arabos (41258 ha) they come to have the greatest productive heritage with more than 88% of their productive soils. (See Figure 24).

Figure 24. Field distribution of agroproductive categories of soils in the AIP- Both regions



In contrast, the Eastern zone has a low agroproductive potential that is grouped in the municipalities of Jobabo and Amancio in 119723 ha, which represent more than 70% of the low productive categories.

I.3.2. Uses and changes in land use

a) Historical trajectory of uses and changes in land use. Direct and indirect causes

The evaluation of the historical trajectory of uses and changes in land use and its direct and indirect causes in the AIP was made based on the detection and field identification of changes in coverage and use using the digital bases of the Institute of Physical Planning (Institute of Physical Planning, 2013) grouped into five classes that are considered relevant to the project's objectives: Cane, Miscellaneous Crops, Pastures, Forestry and Idle Lands. The quantification and the data on the detection of changes are the result of the measurement with the geometrical calculation tool of the GIS extracted using the System of Plane Coordinates of Cuba Norte for the Central zone and the System of Plane Coordinates of Cuba Sur for the Eastern zone. .

The information obtained is consolidated in an input / output table in Excel that allows to identify and quantify the decreases in the coverage and determine at the expense of whom (the horizontal reading in the rows of the table in the detection section quantifies the decrease in the coverage / use at the expense of other coverage), and in the vertical reading it makes it easier to determine and account for the hedges that grow and determine at the expense of whom.

The changes and trends in the behavior of land cover and land use in the AIP detected a significant decrease in the areas of natural grasses (88508 ha) and cane (54626 ha) and a moderate growth in the period analyzed from 2007 to 2013 (by conversion to other uses) of various crops (21364 ha) and notable forest cover (30797 ha) and idle land (78257 ha). The idle land in the AIP amount to 144418 ha resulted from the sum of the area that remains stable (66161 ha) and the increase of 78257 ha by conversion at the expense of other uses.

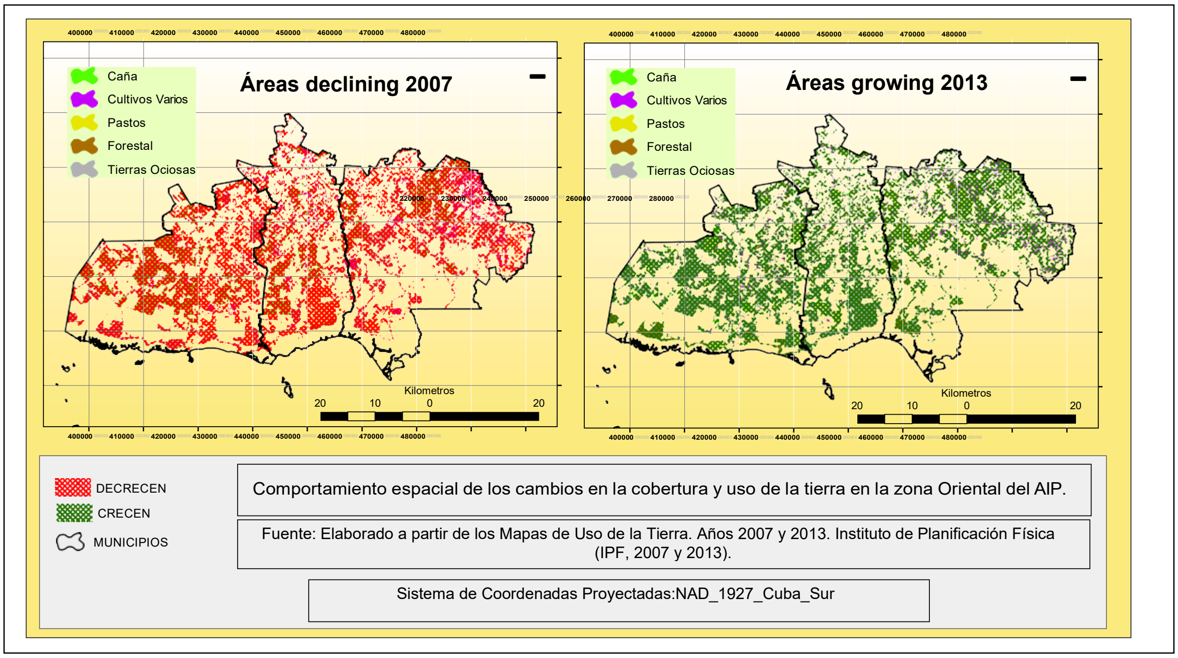
The decrease in the area of natural pastures occurred at the expense of conversion to: idle land in 45202 ha and forestry in 18974 ha, representing 72.5%. In the case of cane, its decrease occurs at the expense of conversion of its area to: idle lands 23998 ha and natural pastures 20730 ha (82%).

The changes and trends in the behavior of the coverage and use of the land detected in the Central area of the AIP show pasture areas with a notable decrease of 63335 ha, at the expense of their conversion into cane (12486 ha), forestry (16478 ha), various crops (4548 ha) and idle land (29823 ha). In the case of cane, a decrease of 23483 ha at the expense of conversion to 11888 hectares of pasture and 6126 hectares of idle land. The increase of the idle land areas, which in more than 90% are occupied by the invasive exotic species known as "marabou", corresponds to the loss of biodiversity and is the result of inadequate land management practices (traditional and conventional).) that the vulnerability of the agrosystems to the changes and variation in the behavior of the climatic variables, successive periods of severe droughts and elevation of the temperature as a direct cause of the change were not adapted and worsened.

Climate that experimented the study area, in particular in the areas occupied by cane and pastures that decreased by conversion to idle lands in 6126 ha and 29823 ha respectively. A slight increase in the area of various crops is observed in the Central zone of intervention at the expense of the conversion of previously occupied areas by cane and natural pastures in about 8367 ha. The pasture coverage that has the largest area that remains stable (69899 ha) plays a buffer role in the balance and trend of changes in coverage and land use in the Central zone.

In the Eastern zone (South of Las Tunas) the changes and trends in the behavior of the coverage and use of the detected land indicate cane areas with a notable decrease of 31,143 ha, at the expense of their conversion into pastures (8842 ha), various crops (3373 ha) and idle land (17872 ha). The increase in the areas of idle lands (Marabou) in the Eastern region has been more significant in relation to its extension and persistence, and although it responds to the same causes described above for the Central zone, it should be noted that in this area of intervention the phenomenon of drought has been more extensive and severe, affecting in particular in the areas occupied by cane and pastures that decreased by conversion to idle lands in 17872 ha and 15379 ha respectively. A notable increase in the area of various crops is observed in the intervention zone at the expense of the conversion of areas covered by pastures in some 5922 ha, cane in 3373 ha and idle land in 3448 ha. The coverage of idle land that has the largest area that remains stable (53285 ha) plays a buffering role in the balance and trend of changes in coverage and land use in the Eastern zone (See Table 24 and Figure 25) .

Figure 25. Field behavior of changes in coverage and land use in the area Oriental del AIP



The decrease in the use and coverage of sugarcane, as well as the growth of idle land evidence the worsening of the effects and impacts on agricultural yields derived from climate change (discussed in sections I.1.5 and I.2) over current traditional systems of land management, in particular on cane, various crops and pastures. The forest and idle land cover, on the other hand, experience a clear growth trend, although there is evidence that the forests will experience impacts on their growth, varietal composition and biodiversity, which will give way to the invasion, growth and territorial dominance of the exotic invasive species known as marabú.

Table 24. Quantification of detection of change in coverage and land use in both intervention zones, Central Zone and Eastern Zone (in ha).

BOTH INTERVENTION AREAS (AIP)										
Coverage / Use	2007	2013	Remains stable		Downturn at the expense of:					
				Downturn at the expense of:	Sugar Cane	Various crops	Pastures	Forest	Idle Surface	Total
Sugar Cane	106480.2	68838.6	51854.4		0.0	6727.6	20730.0	3170.5	23997.8	54625.9
% of growth	22.6	14.6	19.2		0.0	**31.5**	**38.8**	10.3	**30.7**	**27.2**
% of downturn					0.0	12.3	**37.9**	5.8	**43.9**	100.0
% of correlation both areas										
Various Crops	39145.7	50482.5	29118.3		896.6	0.0	5540.0	947.5	2643.2	10027.4
% of growth	8.3	10.7	10.8		5.3	0.0	10.4	3.1	3.4	5.0
% of downturn					8.9	0.0	**55.2**	9.4	**26.4**	100.0
% of correlation both areas										
Pastures	182035.5	147002.2	93527.3		13863.6	10469.4	0.0	18973.5	45201.8	88508.4
% of growth	38.6	31.2	34.6		**81.6**	**49.0**	0.0	**61.6**	**57.8**	**44.1**
% of downturn					15.7	11.8	0.0	**21.4**	**51.1**	100.0
% of correlation both areas										
Forest	42206.6	60568.0	29770.6		196.3	511.9	5313.7	0.0	6414.1	12436.0
% of growth	9.0	12.9	11.0		1.2	2.4	9.9	0.0	8.2	6.2
% of downturn					1.6	4.1	**42.7**	0.0	**51.6**	100.0
% of correlation both areas										
Idle Surface	101441.3	144417.9	66161.0		2027.7	3655.4	21891.2	7705.9	0.0	35280.1
% of growth	21.5	30.6	24.5		**11.9**	17.1	**40.9**	**25.0**	0.0	17.6
% of downturn										
% of correlation both areas					5.7	10.4	**62.0**	**21.8**	0.0	100.0
Total	471309.4	471309.2	270431.6		16984.2	21364.3	53474.9	30797.4	78256.9	200877.7

Source: Prepared by the authors as a result of the geoprocessing and quantification of the surface of the digital field bases of the Institute of Physical Planning (Institute of Physical Planning, 2013).

Table 24. Quantification of detection of change in coverage and land use in both intervention zones, Central Zone and Eastern Zone (in ha). (Continuation...)

CENTRAL AREA										
Coverage / Use	2007	2013	Remains Stable		Downturn at the expense of:					
					Sugar Cane	Various crops	Pastures	Forest	Idle Surface	Total
Sugar Cane	54283.0	44959.8	30800.2	Downturn at the expense of:	0.0	3354.6	11888.3	2114.5	6125.5	23482.9
% of growth					0.0	40.1	**41.9**	9.8	15.0	20.7
% of downturn					0.0	14.3	50.6	9.0	26.1	100.0
% of correlation both areas	51.0	65.3	59.4		0.0	49.9	57.3	**66.7**	25.5	43.0
Various Crops	25524.2	31738.3	23371.3		525.6	0.0	1001.8	109.0	516.5	2152.9
% of growth					3.7	0.0				
% of downturn						0.0				
% of correlation both areas	65.2	62.9	**80.3**			0.0				21.5
Pastures	133233.3	98274.2	69898.8		12486.1	4547.8	0.0	16477.7	29822.8	63334.5
% of growth					88.2	54.4	0.0	**76.4**	**73.1**	55.9
% of downturn					19.7	7.2	0.0	26.0	47.1	100.0
% of correlation both areas			**74.7**		**90.1**	43.4	0.0	**86.8**	66.0	71.6
Forest	17562.6	29862.7	8286.1		149.5	256.9	4551.5	0.0	4318.6	9276.5
% of growth							16.0	0.0	10.6	8.2
% of downturn					1.6	2.8	49.1	0.0	46.6	100.0
% of correlation both areas			27.8				**85.7**	0.0	67.3	74.6
Idle Surface	27891.4	53659.4	12876.0		998.4	207.7	10933.9	2875.4	0.0	15015.4
% of growth							**38.5**		0.0	
% of downturn									0.0	
% of correlation both areas	27.5	37.2	19.5				49.9	37.3	0.0	
Total	258494.4	258494.4	145232.4		14159.7	8367.0	28375.4	21576.6	40783.4	113262.1

Source: Prepared by the authors as a result of the geoprocessing and quantification of the surface of the digital field bases of the Institute of Physical Planning (Institute of Physical Planning, 2013).

Table 24 Consolidated: Quantification of the detection of change in coverage and land use in both intervention zones, Central Zone and Eastern Zone (in ha). (Continuation…)

ZONA ORIENTAL										
Coverage/Use	2007	2013	Remains Stable	Growth at the expense of:	Downturn at the expense of:					
					Sugar Cane	Various Crops	Pastures	Forest	Idle Surface	Total
Sugar Cane	52197.3	23878.8	21054.3		0.0	3373.0	8841.8	1056.0	17872.3	31143.0
% of growth					0.0	26.0	35.2			
% of downturn					0.0					
% of correlation both areas	49.0	34.7	40.6		0.0	50.1				**57.0**
Various Crops	13621.5	18744.3	5747.0		371.0	0.0	4538.3	838.5	2126.8	7874.5
% of growth						0.0				
% of downturn						0.0	57.6			
% of correlation both areas		37.1	19.7			0.0				**78.5**
Pastures	48802.3	48728.0	23628.5		1377.5	5921.6	-	2495.8	15379.0	25173.9
% of growth						45.6				
% of downturn										
% of correlation both areas		33.1	25.3		9.9	56.6			34.0	
Forest	24644.0	30705.3	21484.5		46.8	255.0	762.3	0.0	2095.5	3159.5
% of growth								0.0		
% of downturn								0.0		
% of correlation both areas		50.7	**72.2**				14.3	0.0	32.7	
Idle Surface	73550.0	90758.5	53285.0		1029.3	3447.8	10957.3	4830.5	-	20264.8
% of growth							43.7			
% of downturn										
% of correlation both areas	72.5	62.8	**80.5**				50.1	**62.7**		57.4
Total	212815.0	212814.8	125199.3		2824.5	12997.4	25099.5	9220.8	37473.5	87615.6

Source: Prepared by the authors as a result of the geoprocessing and quantification of the surface of the digital field bases of the Institute of Physical Planning (Institute of Physical Planning, 2013).

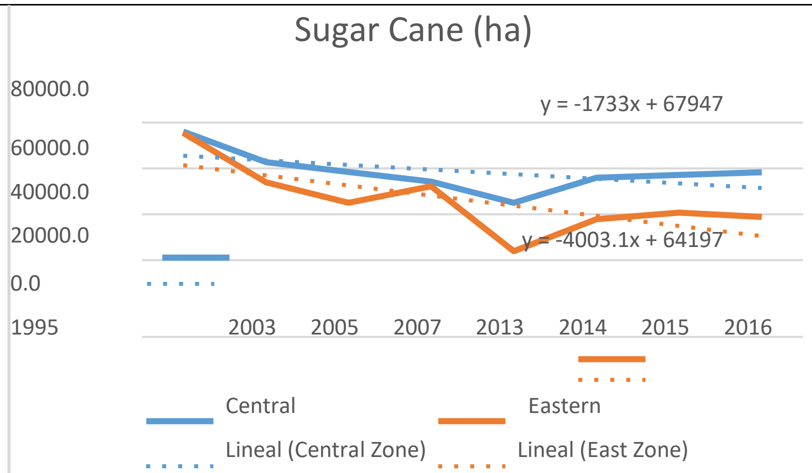
b) **Projection of uses and changes in land use according to future climate scenarios (with and without the intervention of the Project)**

The projection of uses and changes of land use in the AIP according to future climate scenarios without the intervention of the project is estimated to correspond to the trends and trajectories experienced by the relevant uses and coverage studied (cane, crops, natural pastures). , forestry and idle lands) exposed in the previous section (I.3.2 a) and with the predicted impacts of Climate Change on the yields of the main crops and livelihoods of vulnerable households addressed in section I.2, taking into account There is a close interrelation between the impacts and effects of climate change, changes in coverage and use of land and water resources, which in the case of Cuba and the AIP is highly dependent on the behavior of rainfall and of the moderate territorial capacity and edaphic and climatic limitations (addressed in sections 1.1 and 1.3.1) that have both areas of the AIP.

It can be considered that the increase in the areas of idle lands occupied mainly by "marabou", is evidence that in the AIP and with greater incidence the Eastern zone is observed a loop or spiral of environmental degradation and vulnerability aggravated by the impact and effect of Climate Change that favor the expansion of marabou, in particular by the occurrence of extensive and persistent periods of severe and intense droughts that in the coastal zones concur and overlap with the threat of marine saline intrusion and requires a new paradigm of land management that contributes to increasing the resilience of the rural landscape, reversing the processes of vulnerability and increasing the adaptation capacity of the communities.

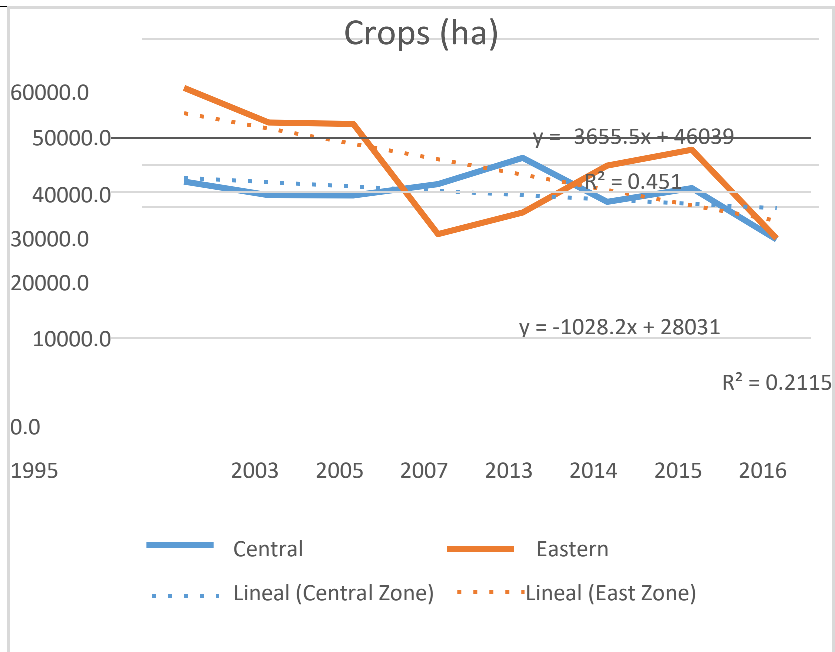
The trend lines of the time trajectory of the relevant uses and land cover selected in the AIP that are observed in figures 26, 27, 28, 29 and 30 show that without a project and with the worsening of the effects and impacts on agricultural yields and trends in changes in land cover and use, derived from Climate Change (discussed in sections I.1.5 and I.2) on current traditional land management systems, cane areas and several crops in both areas are threatened with a drastic reduction and even disappear in the foreseen future scenarios. The areas of natural pastures, forestry and idle land, on the other hand, experience growth trend lines, in the case of pastures moderately, and in the case of forest and idle land, a notable growth trend, although there is evidence that pastures and forests will experience impacts on their growth, varietal composition and biodiversity, which will give way to the invasion, growth and territorial dominance of the invasive exotic species known as marabou, which constitutes 90% of the idle lands.

Figure 26. Temporal dynamics of the cultivated area of sugar cane in the AIP



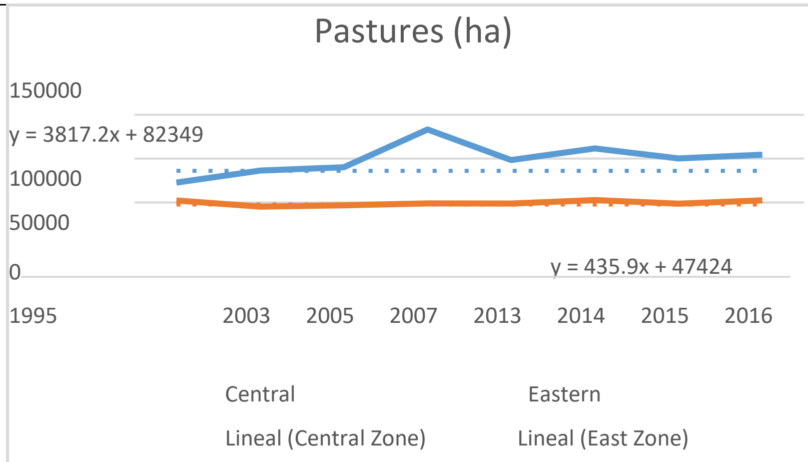
Source: Prepared by the authors based on inputs from ONEi, 2017

Figure 27. Temporal dynamics of the surface of various crops in the AIP



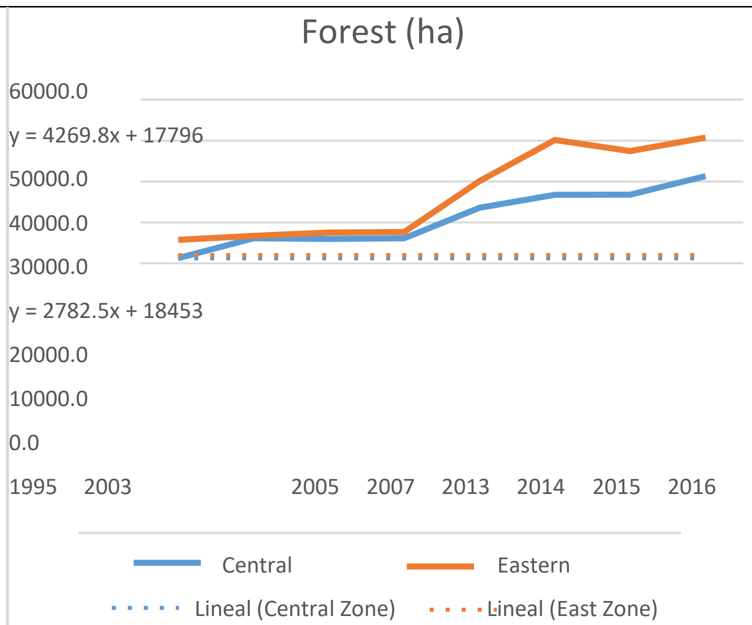
Source: Prepared by the authors based on inputs from ONEi, 2017

Figure 28. Temporal dynamics of the surface of natural pastures



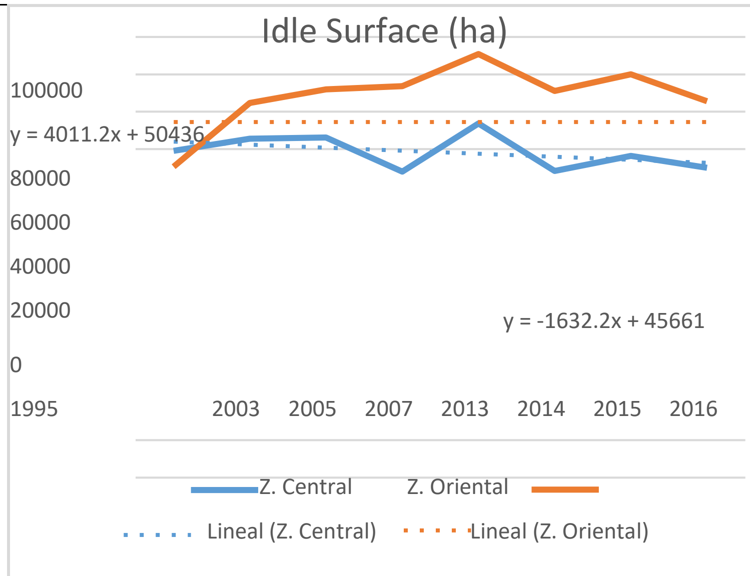
Source: Prepared by the authors based on inputs from ONEi, 2017

Figure 29. Temporal dynamics of the forest area in the AIP



Source: Prepared by the authors based on inputs from ONEi, 2017

Figure 30. Temporal dynamics of the surface of idle lands in the AIP



Source: Prepared by the authors based on inputs from ONEi, 2017

In our consideration, both areas of the AIP are trapped in the spiral and loop of environmental degradation and vulnerability, in a process that will lead, under the effects and growing impacts of Climate Change, to a human desertification of the rural landscape, which requires us to start acting immediately under the prism of a new paradigm of land management.

c) **Characterization and area (ha) of zones with soils prone to desertification, degradation and salinization as a consequence of Climate Change in the intervention areas of the Project**

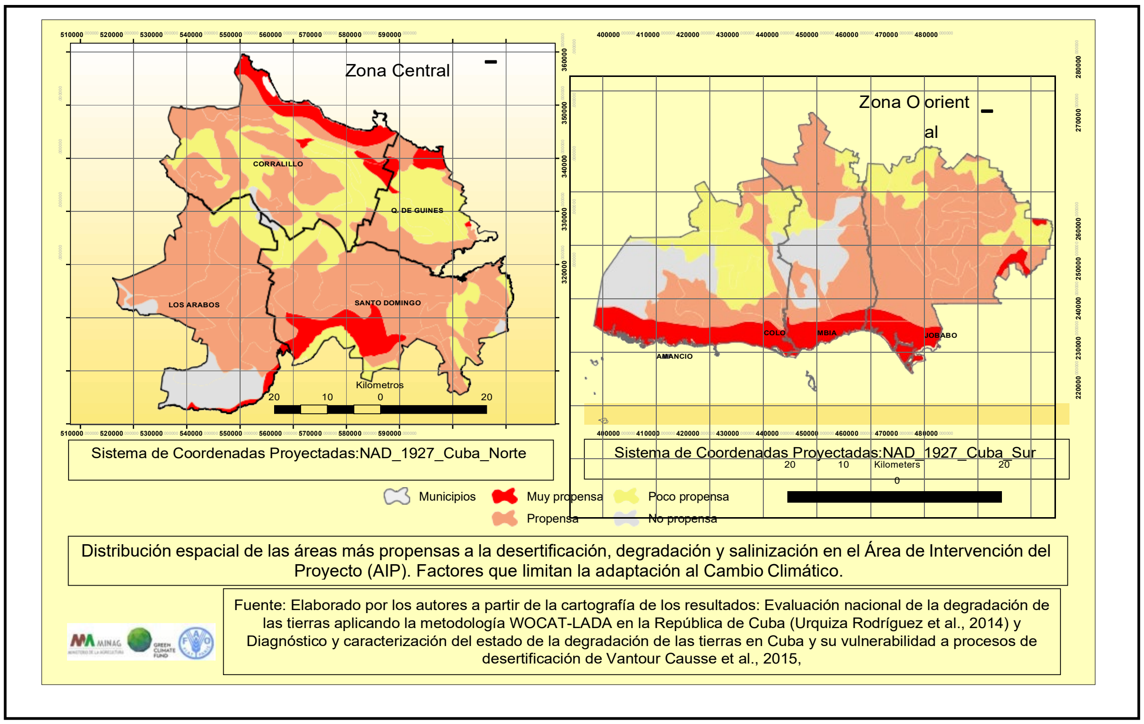
Based on the background and the cartography of the research results: National assessment of land degradation applying the WOCAT-LADA methodology in the Republic of Cuba (Urquiza Rodríguez et al., 2014) and the Diagnosis and characterization of the state of land degradation in Cuba and its vulnerability to desertification processes (Vantour Causse et al., 2015), it was identified that, in the AIP more than 60% of the soils are in a state of moderately degraded to degraded, being the processes of acidification, erosion, compaction, poor drainage, salinity and low natural fertility, the most representative of degradation. As a result of these processes, 67.2% of the surface of the AIP classifies in the categories of areas of medium to very prone to desertification, degradation and salinization, standing out by this indicator the Central zone with 69.3%. (See Table 25 and Figure 31). The basic variables used were: Climate, Soil, Vegetation and Human Pressure, this group of variables were those that more accurately typified the areas in processes and / or exposed to desertification, degradation and salinization, which made possible its categorization in the AIP in four levels: not prone, little prone, moderately prone and very prone.

Table 25. Surface in process and / or prone to processes of desertification, degradation, and salinization in the AIP and in the Central and Eastern zone.

	AIP		Central Zone		Eastern Zone	
Categories	Area (ha)	%	Area (ha)	%	Area (ha)	%
Very prone	57235	11.3	26854	9.6	30381	13.3
Moderately prone	283729	55.9	167215	59.7	116513	51.2
Little prone	117571	23.1	69335	24.7	48236	21.2
Not prone	49446	9.7	16856	6.0	32591	14.3
Total	507981	100.0	280260	100	227721	100

Source: Prepared by the authors based on the results and the cartography of Urquiza et al. (2014) and Vantour et al. (2015).

Figure 31. Field distribution of the areas most prone to desertification, degradation and salinization in the AIP



d) **Synthetic summary and area (ha) of current uses and zones most prone to desertification, degradation and salinization**

The field zoning of the current uses in the areas in process and / or prone to the phenomena of desertification, degradation and salinization in the AIP shows that the Central zone has greater cultivated area (cane and various crops) and natural pastures in the category of highly exposed, while in the Eastern zone, the most exposed land use covers are those occupied by forestry and idle lands. A similar behavior occurs in relation to the current uses exposed to the category of moderately prone with the exception of the forest cover that happens to have a higher level of participation in the Central zone and continues to dominate the coverage of idle lands in the Eastern zone (See Table 26 and Figure 32).

There is therefore a significant difference between the Central and Eastern zones in relation to the use of the present land and its field distribution in the most prone areas and exposed to desertification, degradation and salinization, particularly in relation to the surfaces that occupy the uses and coverage of natural pastures and idle lands (see Figure 33), a relevant aspect that must be taken into account in the implementation of the agroforestry modules promoted by the project.

Table 26. Distribution and quantification of the relevant uses in the AIP and in the areas in process and / or prone to processes of desertification, degradation and salinization in the Central and Eastern zone

	AIP		Central Zone		Eastern Zone	
Categories	Area (ha)	%[1]	Area (ha)	%[2]	Area (ha)	%[2]
Very prone	**57235**	**11.3**[1]	**26854**	**9.6**[1]	**30381**	**13.3**[1]
Sugar cane	3237	5.7	3231	99.8	6	0.2
Various crops	3117	5.4	2701	86.7	417	13.4
Natural Pastures	11414	19.9	9198	80.6	2216	19.4
Forest	20332	35.5	3118	15.2	16826	84.8
Idle lands	14505	25.5	5874	**40.5**	8631	**59.5**
Moderately prone	**283729**	**55.9**[1]	**167215**	**59.7**[1]	**116513**	**51.2**[1]
Sugar cane	36525	12.9	26932	73.7	9593	26.3
Various crops	31146	11.0	19559	62.8	11588	37.2
Natural Pastures	90552	31.9	63906	70.6	26647	29.4
Forest	23844	8.4	16123	67.6	7721	32.4
Idle lands	81101	28.6	28340	34.9	52760	65.1
Little prone	**117571**	**23.1**[1]	**69335**	**24.7**[1]	**48236**	**21.2**[1]

Sugar cane	22389	19.0	14131	63.1	8258	36.6
Various crops	14604	12.4	9195	63.0	5410	37.0
Natural Pastures	36407	31.0	20950	57.5	15456	42.5
Forest	7704	6.6	5635	73.1	2069	26.9
Idle lands	26340	22.4	13556	51.5	12867	48.5
Not prone	**49447**	**9.7**[1]	**16856**	**6**[1]	**32591**	**14.3**[1]
Sugar cane	6771	13.7	753	11.1	6018	**88.9**
Various crops	1612	3.3	306	19.0	1305	**81.0**
Natural Pastures	8628	17.4	4220	48.9	4409	**51.1**
Forest	7728	15.6	4803	62.1	2925	**37.9**
Idle lands	22472	45.4	5889	26.2	16583	**73.8**
Total	507981	100[1]	280260	100	227721	100

1 Refers to the percent in relation to the Total in the vertical (for rows that are in bold).
2 Refers to the percent in relation to the total surface by relevant uses by category in the horizontal.

Source: Prepared by the authors based on the geoprocessing of the digital field database of Use and Coverage of the Earth of the IPF, 2013.

Figure 32. Field distribution of land use in areas most prone to desertification, degradation and salinization in the AIP and both zones

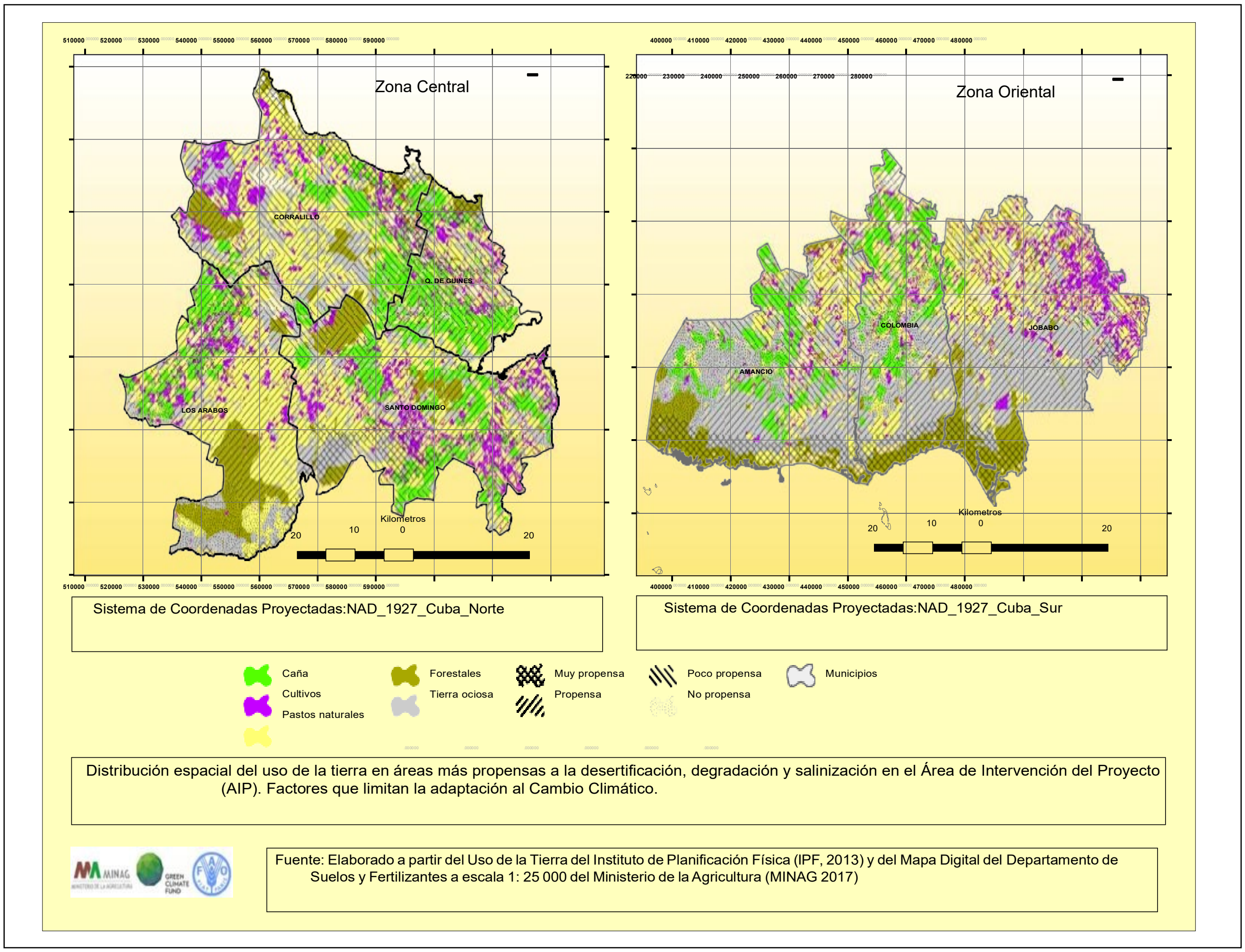
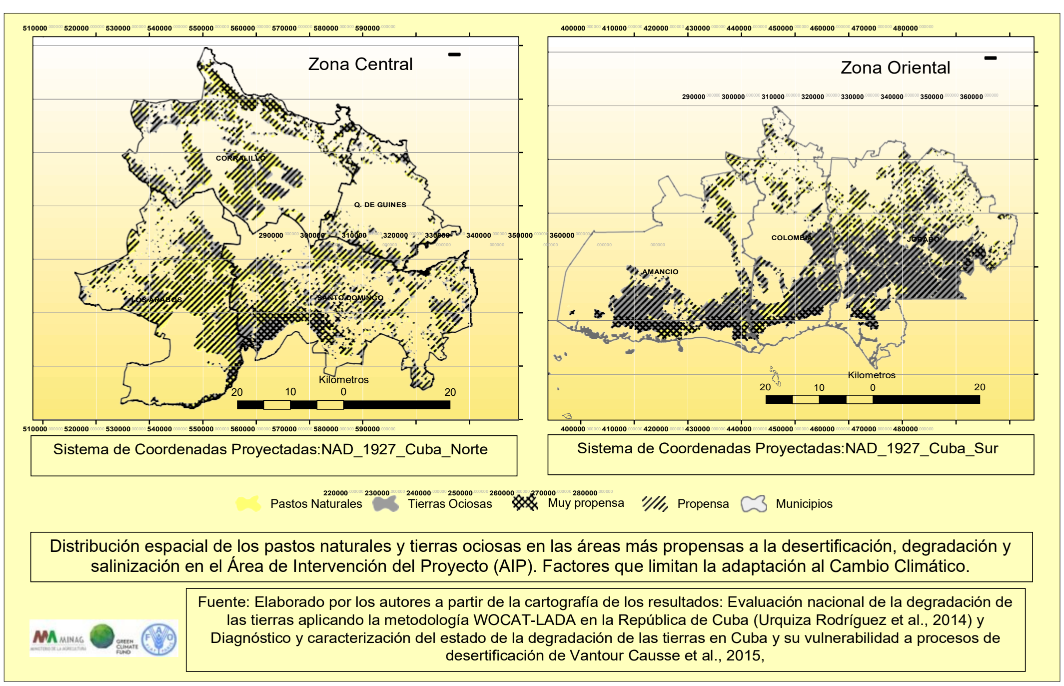


Figure 33. Field distribution of natural pastures and idle lands in highly prone areas to desertification, degradation and salinization in the AIP and both zones.



I.3.3. Situation of water resources and water availability.

a.) Annual water balance

Potential water resources[5] of the project's intervention area (AIP) are evaluated, for more than a decade and it is estimated to amount to a total of 835 million m³ per year. Of these, 490 million are underground distributed in 9 hydrogeological units and the remaining 345 are superficial, distributed in 21 hydrographic basins. However, the results of the rain study for the preparation of the current Isolate Map of Cuba 1961 - 2000 (INRH, 2005), indicate that these potential resources are probably lower (See Table 27).

The changes in the behavior patterns of rainfall and its reduction, the increase in evaporation, together with the increase in saline intrusion as a consequence of the rise in the mean sea level, will affect the availability and quality of the water resources of the AIP .

Table 27. Hydrographic basins located in the AIP. Both zones

Project Intervention Areas (AIP)	Number of basins	Area (km^2)	Potential volume of water resources W_o (hm^3)		
			Current	2050	2100
Surface basins					
Central	8	2466	**66**	55	28
Eastern	13	1700	279	232	136
Sub-total	21	4166	345	287	164
Underground basins					
Central	6	390	**90**	75	38
Eastern	3	1238	400	333	196
Sub-total	9	1628	490	408	234
Total	30	9589	835	695	398

Source: Prepared by the authors based on information from the INRH, 2017

[5] Term that refers to the total volume of water that enters by means of surface runoff and the infiltration of rainwater that falls directly into the territory, as well as the quantities of water that flow from neighboring territories and / or aquifers. At the country level, the INRH, for an average precipitation behavior of 1 335mm, identifies a total of 38 100 million cubic meters as potential water resources, of which 24,000 million are available, around 63%.

As can be seen in the water balance of the AIP, the potential volume of water in 2050 (Scenario A2 of the IPCC) is reduced to 695 million m³ (17%) and in 2100 to 398 million m³, reducing by 52% with relation to the current registered average volume. In 2100, the Central Area of the AIP will have the greatest impact on the reduction of the potential water volume (66 hm3), followed by the reduction in the eastern area of the AIP with 332 hm3, respectively (it is the sum of the subtotal of the surface watersheds of the Eastern zone, 136 hm3 and the 196 hm3 of the underground basins), which indicates that in this reference scenario the shortage of water in the AIP will be a critical element. The situation of the water balance in the AIP and in the Central and Eastern zones (table 27) is consistent with the results of the country's baseline studies (table 28) and with the projected 2050 and 2100 scenarios at national and regional disaggregation in Cuba (table 29).

Table 28. Annual water balance of the country. Baseline 1961-1990

Variables	Cuba	Central Region	Eastern Region
Pa	1326	1279	1414
Ph	992	979	880
E	1712	1728	1679
ETP	1032	1024	1073
Q	294	255	341
W_o	32463	10754	12488

Source: (Planos Gutiérrez et al., 2012)

Table 29. Cuba's annual water balance according to: Model ECHAM4, Scenario SRES[6] A2

	Cuba		Central Region		Eastern Region	
	2050	2100	2050	2100	2050	2100
Pa	1303	1093	1262	1061	1385	1009
Ph	1009	866	977	835	845	744
E	1884	2189	1905	2212	1864	2170
ETP	1054	963	1049	954	1101	1042
Q	248	130	213	107	284	167
W_o	27446	14332	8934	4508	10395	6117

Source: (Planos Gutiérrez et al., 2012)

Note: Pa and Ph are, respectively, the sheets of annual precipitation and the wet period (mm), calculated by the isohyet method (data from the National Basic Network); ETP, real evapotranspiration sheet (mm), obtained by the Turc Formula (Sokolov and Chapman, 1981); E, potential evaporation sheet (mm), Turc formula; Q, runoff sheet (mm) obtained by equation of water balance and; Wo, Potential volume of water resources (hm3).

[6] Storyline and scenarios family on Special Report from Emission Scenarios (SRES) at IPCC

The national water balance shows that the potential volume of water is almost halved between 2050 and 2100 according to the climate scenarios used in the projection (A2 of the IPCC), about 13.1 thousand hm3, 40% in relation to the average volume recorded between 1961 and 1990. The Central region of Cuba reports the greatest impact on the reduction of potential water volume (4426 hm3), followed by the reduction in the Eastern region with 4278 hm3, which indicates that in the scenario of reference the water deficit will be critical, particularly for human and agricultural use.

b.) Elevation of sea level

The sea level rise is an impact of Climate Change that will affect five of the seven municipalities that make up the AIP for the expected scenarios of sea level rise of 27 cm in 2050 and 85 cm in 2100. (See Table 30). This threat will affect 20070 ha of land surface in the AIP that represent 4% of the total, of which 13239 ha in the Eastern Zone (66%), in the affected areas natural forests predominate and the plant formations of mangrove and grassland of swamp (natural forest area) and is not significant for the agricultural areas of cane, various crops and idle land.

Table 30. Elevation of the mean sea level in the AIP and use of agricultural land that will be affected. Both areas.

Sea level elevation	AIP		Central Zone		Eastern Zone	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Both Scenarios (2050 y 2100)	20070	100.0	6831	34.0	13239	66.0
Sugar cane	12	0.1	12	100.0	0	0.0
Various crops	44	0.2	44	100.0	0	0.0
Natural pastures	269	1.3	138	51.3	131	48.7
Forest	11406	56.8	1366	12.0	10040	88.0
Idle lands	342	1.7	120	35.1	222	64.9
subtotal arable land	12073	60.2	1680	13.9	10393	86.1
% of AIP which will be affected	4.0		3.3		5.8	

Source: Prepared by the authors based on data from the Macro project (IPF, 2017) and the digital field database on Land Use and Coverage (IPF, 2013).

In addition to the impact on the earth's surface and current uses and coverage, sea level rise will enhance the phenomenon of marine intrusion in coastal aquifers (groundwater), which is one of the greatest impacts due to the high vulnerability of same in the AIP due to their condition of open karstic aquifers. The results of several studies carried out in coastal aquifers in the Central and Eastern zone confirm that there is already contamination and warn that the intrusion of the salt wedge will be greater if the amount of rainfall is lower and as a consequence the reduction in the availability of groundwater would be significant and the affectation could lead to the final salinization of the AIP reserves (Suárez Pecoso, 2015), (Jiménez Reyes, 2011), (Valcarce and Rodríguez, 2011), (Cuevas Valdés, 2016), (Monteagudo Zamora, 2008) and (Iturralde-Vinent and Serrano Méndez, 2015).

c.) Saline intrusion and its effect on the water table

Saline intrusion is a process that is currently present in the AIP that will increase its viability derived from the rise in sea level expected in future scenarios of climate change. With the intensification of the drought experienced by both areas of the AIP, and in particular the Eastern zone, the levels of salinity in soils and waters will increase notably; increasing the areas prone to desertification, degradation and salinization and the reduction of food production for the population, among other negative incidences (CITMA, 2013).

Undesirable consequences of the Saline Intrusion is the disabling of areas of aquifers due to high salinity, with limiting factors in soils such as salinity, poor drainage, erosion, compaction and desertification, which cause a decrease in living conditions in populations that live within these areas due to crop losses, low food sustainability, risk of food insecurity and food imports.

All this causes an emigration of the population to areas of better living conditions, concentration in urban areas and the need to look for new areas of agricultural exploitation. The saline intrusion in the AIP of the Central zone, would affect the aquifers VC-4, VC-3 and VC-5 and in the Eastern zone it will impact the southern coastal zone of the aquifers Sevilla, Colombia and Birama, which constitute the main source of water supply to the rural population of those territories.

In 2015 the IPF carried out an investigation that showed that 48% of the wells used for the water supply of Las Tunas are affected by salinization, which represents damages for the economy and the health of 105,000 people. After the severe drought suffered by the region in recent years it is estimated that these figures may have increased. In Las Tunas, for example, the Birama basin is in the process of being salinized in the south, although there are also impacts on those in Colombia and Seville.

Leomiguel Rodríguez Quesada, of the Provincial Delegation of Hydraulic Resources, comments that "of the present results in the 163 underground sources for human consumption, significant alterations are observed by nitrification that are above the maximum admissible limit, evidencing contamination".

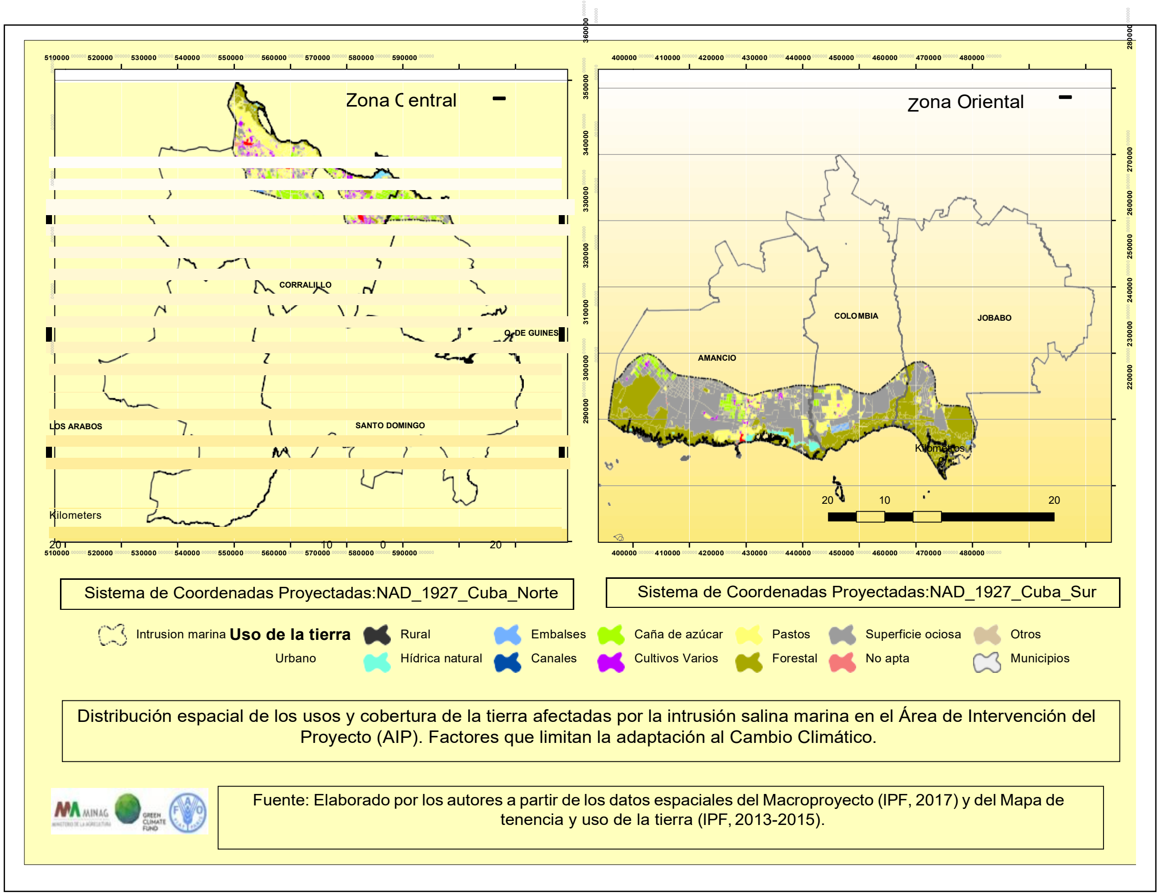
South of Camagüey to Punta Birama, there is an aquifer in Miocene limestone rocks of great thickness and high-water content, affected by marine intrusion with SST> 1 g / l as a result of the natural penetration of seawater and overexploitation (Iturralde-Vinent and Serrano Méndez, 2015).
The area affected by marine intrusion in the AIP is 86,741 ha, impacting the coastal zone of five municipalities and 12 Popular Councils, 7 in the Central zone and 5 in the Eastern zone (see table 31 and Figure 34). In subsection g of this baseline study of adaptation and vulnerability, a detailed summary is developed and presented with a field zoning that identifies the areas most affected by saline intrusion and drought in the AIP at the level of the Popular Council. show the most vulnerable areas where both phenomena overlap (See Table 34 and Figure 36).

Table 31. Marine intrusion in the AIP and affected use coverages[7]. Both regions

Affected coverage	AIP both regions	Central Zone		Eastern Zone	
		Area (ha)	% AIP	Area (ha)	% AIP
Area of intrusion	86741	28457	32.8	58284	67.2
Urban	487	352	0.4	135	0.2
Rural	231	149	0.2	82	0.1
Natural water	1228	481	0.6	747	0.9
Reservoirs	872	376	0.4	496	0.6
Channels	29	27	0.0	2	0.0
Sugar cane	6888	5105	5.9	1783	2.1
Various crops	3767	3294	3.8	473	0.5
Forest	26313	3768	4.3	22545	26.0
Pastures	16097	10392	12.0	5705	6.6
Idle surface	29744	3610	4.2	26134	30.1
Not fit	206	110	0.1	96	0.1
Other	879	793	0.9	86	0.1
% of AIP Total	17.1	13.7		25.6	
Source: Prepared by the authors based on data from the Macro project (IPF, 2017) and the digital spatial database on Land Use and Coverage (IPF, 2013).					

[7] The area of marine intrusion and coverage excludes the area of the adjacent keys

Figure 34. Field distribution of uses and land cover affected by marine saline intrusion in the Project Intervention Area (AIP)



d.) **Provision of fresh water to the rural population (well, tanker, natural water source, others)**

The water supply to the population from different sources in the AIP shows a better situation in the Central zone where more than 50% of the population is covered by the aqueduct system and is supplied through its network, while in the area Eastern this form of supply only reaches 25.7% of the total population. In relation to the total population supplied by pipes permanently the two zones have a similar behavior, and the difference lies in the total population that needs to be supplied by pipes during the drought, showing the eastern area a greater dependence on this form of supply (See Table 32), with more than 40% of the population highly vulnerable to this threat

It represents 66.4% of the total AIP, which corresponds and corroborates with the behavior of the phenomenon of intense drought, which although present in both areas, always its effects by intensity, territorial and temporal extent are more severe and complex in the Eastern zone (Centella Artola et al., 2006).

Table 32. Water availability according to sources of supply in the AIP. Both zones

Variable	AIP	Central Zone	Eastern Zone
km^2	5054	2818	2236
Total Population	242438	120929	121509
Total Population supplied with water by network	100081	68846	31235
% of total population	41.3	56.9	25.7
Total population supplied with water by pipes	7754	3907	3847
% of total population	3.2	3.2	3.2
Total population supplied with water by pipes	46440	19911	26529
% of total population	19.2	16.5	21.8
Total people supplied by wells within the territory	51856	21917	29939
% of total population	21.4	18.1	24.6
Total Population supplied by individual wells	30883	13974	16909
% of total population	12.7	11.6	13.9
Population with high vulnerability to drought	74930	25210	49720
% of total population	30.9	20.8	40.9
Households with high vulnerability to drought	30062	12594	17468

Source: Prepared by the authors

e.) Water level of reservoirs relevant to the rural population in the intervention areas of the Project

The AIP has a capacity of water reservoir of 173.2 million m³, distributed in 8 reservoirs (154.24 hm3) and 17 micro-dams (18.97 hm3), destined preferably to meet the demand of the agricultural sector, in particular to the various crops that sustain and they constitute means of life for the rural population.

In the AIP, the "Palma Sola" reservoir (with a capacity of 80 million m³) located in Corralillo stands out in the Central zone. The Eastern zone has a water reservoir capacity of 79.89 million m³, distributed in 6 reservoirs and 12 micro-dams. The reservoirs include "Las Mercedes" (with a capacity of 25.20 million m³) located in Colombia and "Cayojo" (13.65 Hm³) in the Jobabo municipality. (See Table 33)

Table 33. Number of dams and micro-dams located in the AIP. Both zones

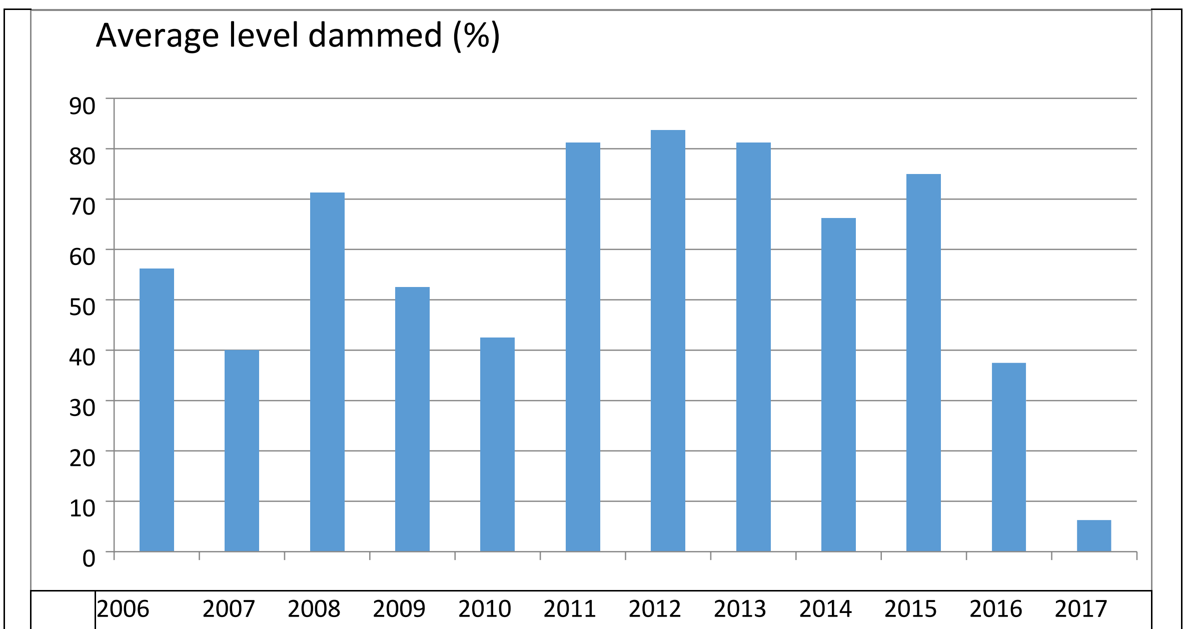
Project Intervention Area	Number	Use	Vol NAN

(AIP)			(hm^3)
Dams			
Central	2	Agriculture	90.6
Eastern	6	Agriculture	63.64
Sub-total	8		154.24
Micro-Dams			
Central	5	Agriculture	4.403
Eastern	12	Agriculture	14.565
Sub-total	17		18.968
Total	25		173.208

Source: Prepared by the authors from INRH, 2017

In the AIP, reservoir filling levels and their availability and access are affected by the recurrent periods of moderate and severe drought and the tendency to decrease rainfall due to the progressive effects of climate change. The temporary trajectory of the fill levels in the reservoirs of the Central area of the AIP, taking as reference the data supplied by the hydraulic utilization company for the Palma Sola dam, is illustrated in figure 35. It is highlighted that in the month of May 2017 came to dry completely.

Figure 35. Behavior of the average level of water stored in the Palma Sola Dam of the Central area of the AIP (in %)



Source: Prepared by the authors from the data of the Company of Hydraulic Utilization of the INRH (2017)

A study carried out by the INRH in the eastern area of the AIP for a period of 34 years showed that only in 8 of the 34 years, the average volumes have behaved close to the nominal volumes, the other years have been below 50% of filling, evidencing that the precipitation parameters for which these dams have been designed have had changes in their behavior.

These elements show the hyperrational behavior of the reservoirs in correspondence with the decrease of the precipitations and the affectation by intense droughts that the AIP has experienced, that in its historical behavior have extended by periods superior to the 12 months in the Central zone and to the 24 months in the Eastern zone (Centella Artola et al., 2006)

f.) **Superposition of areas with greater affectation due to drought and saline intrusion**

Table 34 shows a summary of the territory of the AIP in both areas, affected by intense droughts and saline intrusion. Only CPs are included where the effects of drought overlap with significant levels of intrusion with the exception of CP Mártires de Pino Tres, where vulnerability to drought is low, but is the most affected by the phenomenon of marine saline intrusion.

Table 34. Surfaces affected by intense drought and saline intrusion in the AIP. Both zones

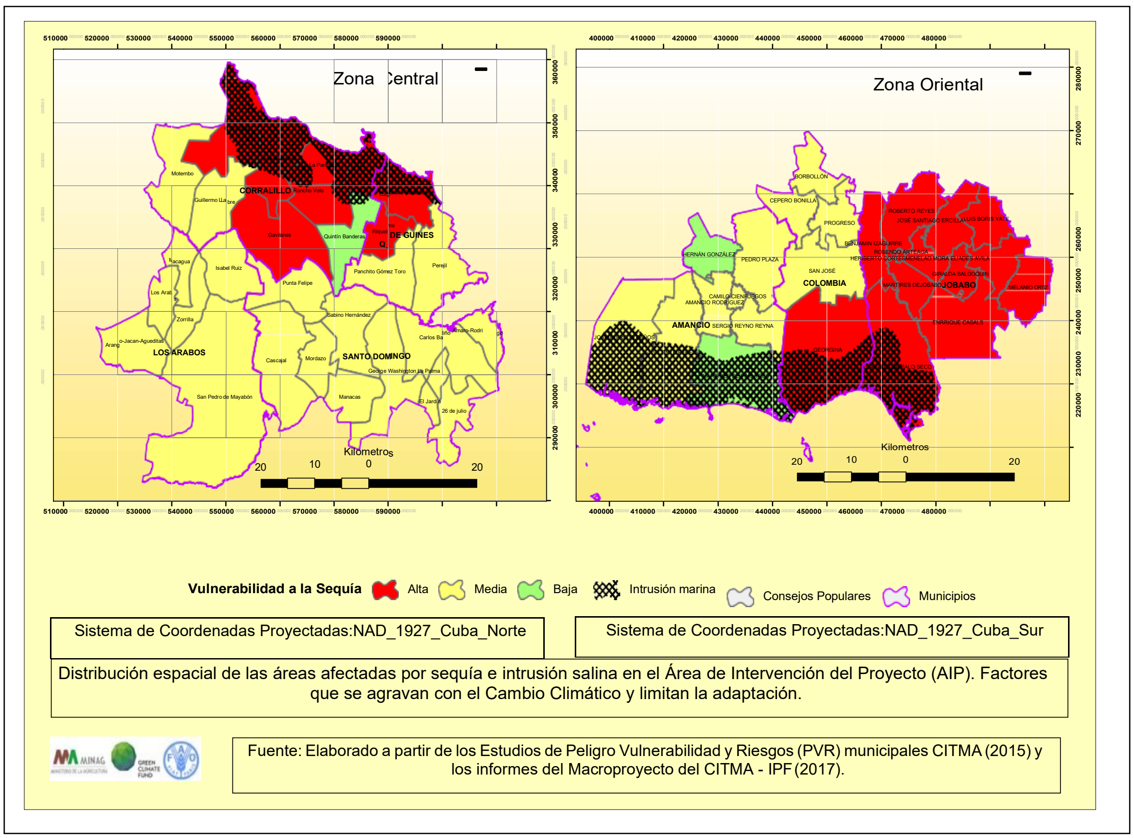
	AIP		CENTRAL REGION		EASTERN REGION	
Popular Councils	(km2)	%	Drought	Saline Intrusion	Drought	Saline Intrusion
Corralillo	129.8	7.8	129.8	78.3		
Sierra Morena	104.8	6.3	104.8	69.8		
Rancho Veloz	109.8	6.6	109.8	54.3		
La Panchita	59.4	3.6	59.4	37.3		
Gavilanes	151.8	9.1	151.8	5.5		
Riquelme	45.9	2.7	45.9	1.2		
Lutgardita Carahata	79.4	4.7	79.4	41.8		
Subtotal central	680.9	40.7	681	288.2		
Batalla de Palo Seco	207.6	12.4			207.6	119.7
Georgina	253.3	15.1			253	122.9
José Alfredo Baños	195.3	11.7			195.3	108.8
Mártires de Pino Tres	175	10.5				133.3
Vicente Pérez	160.6	9.6			160.6	91.8
Subtotal Eastern	991.8	59.3			621.2	443.2
Total	1672.7		681	288.2	621.2	443.2

% drought			40.7		37.1	
% saline intrusion				17.2		26.5
% drought intrusion both regions			77.8			43.7

Source: Prepared by the authors

The effects of the drought are notable in both areas of intervention of the project, although the area affected in the CPs of the Center constitutes almost 41% of the total area of intervention, standing out in this the 7 coastal CP Corralillo and Quemado de Güines. On the other hand, in the Eastern zone, the saline intrusion processes affect a larger area, and negatively impact the availability of water for the supply of the population and the productive characteristics of the soils. 26% of the total area of intervention of both zones corresponds to the AIP of the Eastern zone (see Table 34 and Figure 36).

Figure 36. Field distribution of the areas affected by drought and saline intrusion in the AIP



SECTION II - STUDY OF VULNERABILITY OF HOUSEHOLDS, AND THEIR LIVELIHOODS

In this section we present a synthesis of the results of the PVR studies in the AIP for the main phenomena that affect these areas, namely: intense rains; penetration of the sea by increase of the mean level: strong winds; and intense droughts.

II.1. METHODOLOGY USED IN THE STUDIES OF HAZARDS, VULNERABILITY AND RISK

The increase in the frequency and the destructive force of extreme hydrometeorological events, and their main manifestations (penetrations of the sea, intense rains and strong winds and the possibilities of disasters), condition the need to improve the political, social, economic and environmental approach of risk management and management and the need for its study at the country level. In this sense, the Vice President of the National Defense Council assigned the CITMA (Directive No. 1 d, 2005) to carry out studies on Danger, Vulnerability and Risk (PVR), as well as the environmental impact of disaster situations to ensure the Preparation, organization and planning of the country for disaster situations. The CITMA delegated to the Environment Agency (AMA), the responsibility to implement compliance with this directive, which establishes general guidelines for organizing the necessary information, the fundamental procedures that order research and guarantee a level of measurement and homogeneous analysis at national level. Although the PVR studies are carried out based on information and existing studies, the results are given at the provincial level with output at the municipal and popular council levels. In the case of heavy rains, it starts from the hydrographic basin, in the penetration of the sea at municipal level and in strong winds at the level of popular council.

The PVR studies comprise four phases:

1. Identification of hazardous scenarios
2. Calculation of the hazard
3. Vulnerability calculation
4. Estimation of risks

II.1.1. First phase: Identification of the hazard scenarios of the event to be studied

The first phase of PVR studies consists in the identification of territorial spaces where natural or induced conditions exist that make them susceptible to the occurrence of dangerous phenomena, independently of their probability and intensity.

II.1.2. Second phase: Calculation of the hazard

Disaster risk is understood as "a probable extraordinary or extreme event, of natural or technological origin, particularly harmful, which may occur at a specific time and place and which, with a given magnitude, intensity, frequency and duration, may adversely affect human life, the economy or the activities of society to the point of causing a disaster"[8]

[8] Risk Assessment Group. Environment Agency. CITMA, June 2008

To perform the hazard calculation, the following questions must be answered (in probabilistic terms): Where, when and how will the extraordinary or extreme event occur? To answer the question of "where" the event will occur, it is necessary to characterize the place that is likely to be affected, that is, characterize the environment where the environmental conditions are created, or facilitate the occurrence of the harmful event, the maps obtained in this case is the maps of susceptibility of the environment to danger, or maps of danger scenario.

When the question of "when" is answered with the frequency of occurrence of the event or its recurrence period, how many events of a certain intensity can be repeated over a period of time, calculated from the statistics of historical data, for the case of the hydrometeorological dangers, this information is compiled by the Institute of Meteorology of the CITMA and by the National Institute of Hydraulic Resources.

And finally, to the question of "how" respond the values of intensity or severity that could be expected from the occurrence of the event, for each period of recurrence or frequency and in each place of the highlighted ones in the hazard scenario maps.

II.1.3. Third Phase: Vulnerability Assessment

In this methodology is defined as "vulnerability" to disasters, to the predisposition to suffer losses or damage, of biotic or abiotic elements exposed to the impact of a danger of a certain severity. It is directly related to the qualities and properties of the element or elements in question in relation to the danger or the dangers that could affect it. The calculation of this indicator requires the compilation of information about the goods and the population exposed to the danger. In this case, it is necessary to use maps and socioeconomic information on the population, housing, critical facilities and vital lines, exposed to potential danger.

The main sources of information are the municipal housing, physical planning, health, education, municipal government, CITMA delegation, civil defense, among others. You should also consult the studies carried out previously in the region. All the information must be georeferenced, for its future cartographic expression.

The vulnerability (V) will be expressed from the mathematical point of view as a bounded number between zero (0) and one (1). This implies that for an event of a certain intensity V take the value 0 when the predisposition to suffer the damage is null and 1 when the predisposition to suffer total damage is the highest.

The existing level of vulnerability of the exposed elements will condition the magnitude of the losses when a dangerous agent hits a given "intensity", which can cause a disaster situation in a certain area. Both vulnerability variables and judgments of values are determined in workshops by expert criteria. The following types of vulnerability are considered in this study: physical, social, ecological and economic.

To analyze and evaluate physical vulnerability, three types have been differentiated: structural, non-structural and functional.

Structural Vulnerability

The resistive capacity to the destructive forces of the different dangers in the buildings of the housing fund will be analyzed, for this the construction typology, the technical condition and the height of these constructions will be analyzed, as well as location parameters such as soil type, elevation, among others, depending on the hazard.

Non-Structural Vulnerability

The effects that may affect the vital lines of the territory, such as roads, gasification systems, communications, energy system, high voltage towers and electrical networks (including underground, in case of flood) as well as the state of the drainage system and sewage networks will be evaluated.
The structural and non-structural vulnerabilities will express the exposure factors, that is, they will allow to assess the degree of exposure of the studied territory to the influence of the hazards.

Functional Vulnerability

In this analysis we will study the influence of structural and non-structural vulnerability on the stability or paralysis of production and services, before each type of event of a certain category, the analysis of this vulnerability will allow us to see the status of the response factors , from the availability of emergency generators, the preparation of the health system for disasters, the ability to offer shelter to evacuees and certification of facilities, access to isolated areas, the reserve of basic supplies (water , food, fuel, medicines) and others.

Social Vulnerability

It will assess the degree to which social factors can increase vulnerability. The total population exposed, population density or impact on the population (APOB), perception of the risk and degree of preparation, presence of solid waste in the streets and the preparation of the management bodies will be evaluated.

Ecological Vulnerability

Consideration should be given to the exposure of areas of potential danger of: Fragile ecosystems or ecologically sensitive zones; and Protected areas. The ecologically sensitive zones are selected according to the Guide for the preparation of National Biodiversity Studies and adapted for Cuba by Rodríguez and Priego, UNEP, 1998.

Economic Vulnerability

The economic factors will be evaluated taking into account the industrial zones in risk areas, the amount of cultivated areas and animals in these danger zones. The respective Disaster Reduction Plan should indicate the level of execution of the vulnerability reduction budget, the cost of the response and the concrete measures. Vulnerability is expressed as the sum of all vulnerabilities, that is, calculated independently.

$$V = V_e + V_{ne} + V_F + V_s + V_{ec} + V_{ecn} \quad (1)$$

Where:

V_e: Structural vulnerability

V_{ne}: Nonstructural vulnerability

V_F: Functional vulnerability

V_s: Social vulnerability

V_{ec}: Ecological vulnerability

V_{ecn}: Economic vulnerability

The cartographic output will be based on a GIS project, with classification attributes, total number of people exposed, total number of housing exposed, typologies, state of the housing and all the information related to each element that are part of the different vulnerabilities. Classification will be divided into high red, medium yellow and low green. This classification is based on the following intervals:

Table 35. Methodology of PVR studies. Vulnerability classification

CLASIFICATION	VULNERABILITY TYPE
Less than or equal to 0.33	Low vulnerability
Greater than or equal to 0.34 and less than or equal to 0.67	Moderate vulnerability
Greater than or equal to 0.67 and less than or equal to 1	High vulnerability

11.1.4. Fourth Phase: Risk Assessment

Disaster Risk are the expected losses, caused by one or several particular hazards that simultaneously or concatenate affect one or more vulnerable elements at a given time, place and conditions. It constitutes the fundamental element for the determination of the recommendations directed to the prevention of the disasters, in addition to those of preparation and confrontation. The risk can be represented by a simple mathematical equation: Disaster risk = Hazard x Total Vulnerability.

The total risk will also consider the economic valuation of the losses and will be expressed according to the following formula:

$$R = C\sum_{i=1} V_i * P_i \qquad (2)$$

Where:

C: Value of the exposed goods, expressed in "current" pesos

V_i: Vulnerability of goods exposed to a hazard of high intensity.

P_i: High intensity hazard.

n: Number of intensities intervals analyzed.

The Total Risk is evaluated from the product of the danger (P) of a potentially damaging event due to the vulnerability (V) and the cost of the exposed goods (Equation 2). In case the cost of the different exposed goods is not available, the specific Risk can be calculated, multiplying the danger times vulnerability.

$$R = \sum_{i=1} V_i * P_i \qquad (3)$$

For calculations and risk mapping, the following georeferenced table of the areas affected by the event studied in the popular council is used.

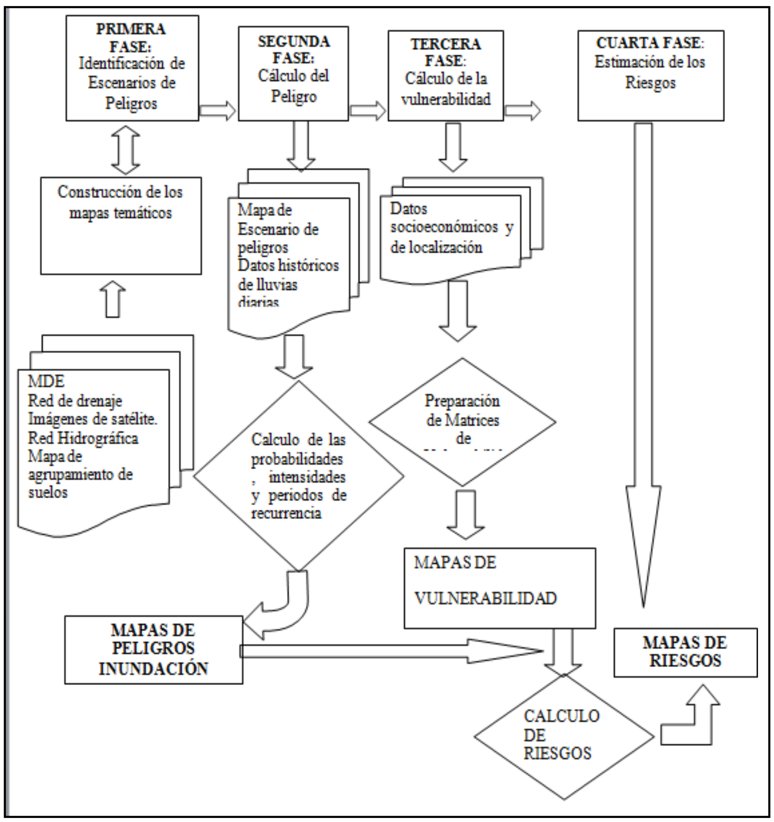
Table 36. Risk calculation table in the area where the phenomenon occurs

Hazard intensity	Vulnerability Vi	Probability Pi	Risk Ri	Flood area risk $R_i = \sum_{i=1}^{n} V_i * P_i$
High	V1	P1	V1P1	0 - 0,33 With Risk 0.34 - 0,66 Medium Risk
Medium	V2	P2	V2P2	0.67 - 1 High Risk V1P1+V2P2+V3P3
Low	V3	P3	V3P3	

Source: Risk Assessment Group. Environment Agency; Ministry of Science Technology and the Environment: "Methodological guidelines for carrying out the studies of danger, vulnerability and risks of flood disasters due to the penetration of the sea, flooding due to heavy rains and damage caused by high winds"; June 2008

Figure 37 synthesizes the stages of the methodology used in PVR studies in the country.

Figure 37. Adopted methodology for PVR studies. Flowchart



Source: Risk Assessment Group. Environment Agency; Ministry of Science Technology and the Environment: "Methodological guidelines for carrying out the studies of danger, vulnerability and risks of flood disasters due to the penetration of the sea, flooding due to heavy rains and damage caused by high winds"; June 2008

II.2. VULNERABILITY STUDIES

The objective of the Project is to improve the adaptation of households and communities to the effects of CC through the rehabilitation of productive landscapes, namely livelihoods, including housing and types of crops. The agroforestry modules will help, with the combination of trees and crops more complex and stable, to diminish the impact of strong winds, intense rainfall, the elevation of the mean sea level and consequently the penetration of the wedge, and the severe effects of drought, on crops such as sugarcane, plantain, yucca and other similar crops, livestock, aquifers and wells for the supply of water to the population, crops, animals and agroindustry.

For this purpose and for the purpose of quantifying the surfaces of crops, households and vulnerable population in the AIP, a quantity of relevant data and information has been used, contained in reports, statistical yearbooks, results of simulations and other scientific investigations and in particular the Hazard Vulnerability and Risk (PVR) reports prepared by the municipalities and provinces involved with the Project's Intervention Areas.

II.2.1. Impacts due to heavy rains

Floods due to heavy rains are directly related to the passage of cyclones of different categories and the entry of cold fronts, which is why the areas facing the greatest dangers are located on the northern coast of the Central zone, particularly in the municipalities of Corralillo and Quemado de Guines. While in the Eastern zone, the danger of floods due to intense rainfall is related to the passage of these events, although in this case it is also linked to the occurrence of tropical waves, the so-called "Sures". It should be noted that in the area of implementation of the project in the Eastern zone, in the last 10 years only 4 tropical cyclones have impacted.

a) Hazard Calculation and vulnerability and risk assessment for the Central Zone

Hazard

In the danger of flooding due to heavy rains, for a return period of 5 years, rainfall of the order of 300 mm can occur in 24 hours with nuclei of greater significance in the AIP of the Central zone.

The danger of flooding due to heavy rains in the AIP of the Central Zone has its genesis in:

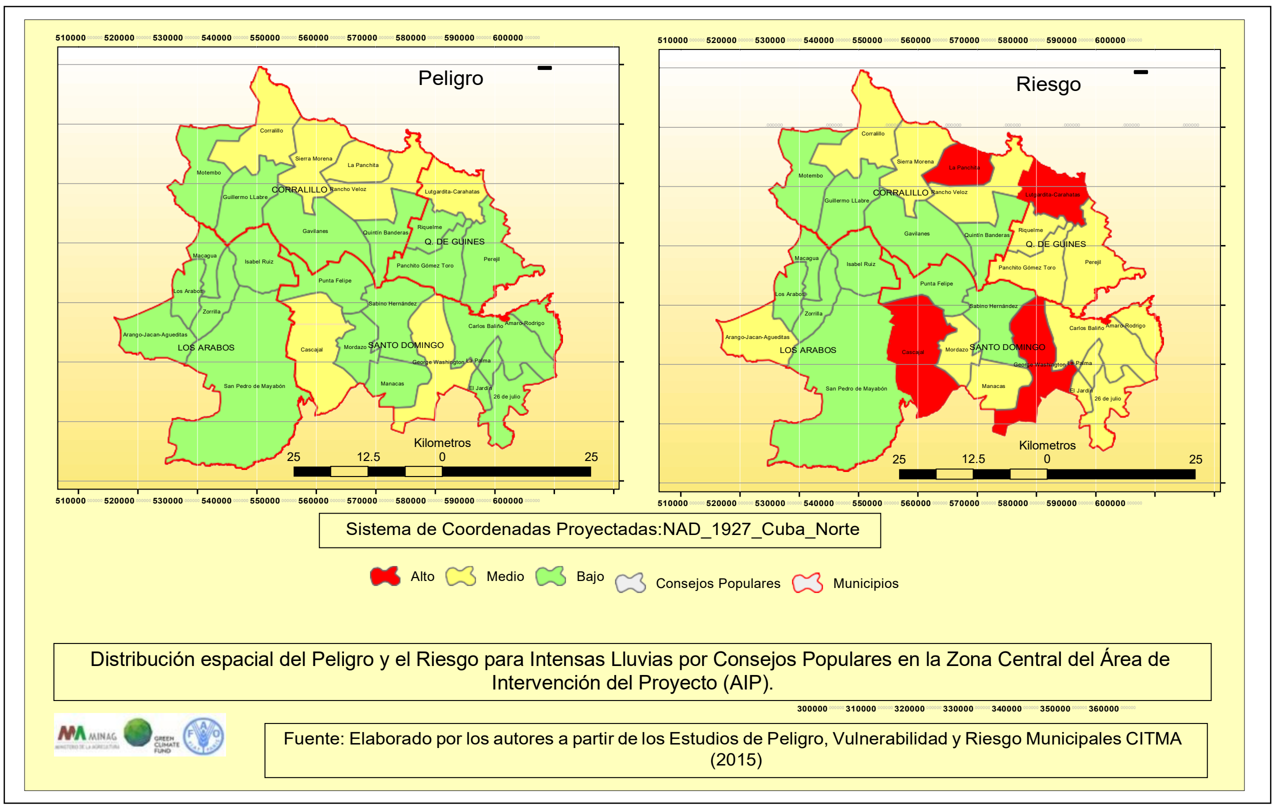
- The flat relief, the existence of rivers of importance as the Sierra Morena in Corralillo, Majá and Jicotea, in Quemado, and the areas of the middle and lower courses of the Sagua la Grande river, in Santo Domingo, and of canals that cross the plain coastal, as well as interruption of the drainage network due to lack of sewerage in urban population settlements increases the natural susceptibility to flooding.
- On the other hand, the existence of areas with poor drainage and natural impermeability of soils and slow runoff that tend to puddling in flat areas, low vegetation cover, along with geo-transformations such as roads and rail lines as in the case of Santo Domingo and the route

Santo Domingo-Corralillo, settlements on water courses and hydrotechnical works in poor condition that impede the flow of water through the hydrographic network, reinforces the natural susceptibility to flooding in several Central areas.

- The highest incidences of flooding due to heavy rains have occurred in the CP of Corralillo, Motembo, Sierra Morena, Lugardita Carahatas, Perejil, Cascajal, Manacas, El Jardín, George Washington and La Palma.

In Figure 38, the evaluation of danger to floods due to heavy rains is presented. In Los Arabos, all CPs have a LOW danger rating. On the other hand, in Corralillo and Quemado de Güines the MODERATE danger predominates and finally in Santo Domingo a mixture of LOW and MODERATE danger can be observed.

Figure 38. Distribution of danger areas and risk of flooding due to intense rainfall. Central Region



Vulnerability

In the AIP of the Central zone, total low vulnerability predominates. However, CPs are identified with the most important levels of vulnerability, namely: in Corralillo, the CPs La Panchita, Quintín Banderas, Sierra Morena, Rancho Veloz; in Quemado, Lutgardita Carahatas, El Perejil and Panchito Gómez Toro; and Santo Domingo, George Washington, July 26, La Palma, El Jardín and Carlos

Baliño, for the Structural and Social vulnerability, for the technical condition of the exposed dwellings and density of the population existing in areas vulnerable to flooding due to heavy rains and , economic vulnerability mainly due to the exposure of crops to the incidence of floods due to heavy rains (See Table 33, Figure 39).

Figure 39. Field distribution of flood vulnerability due to intense rainfall and strong winds from the AIP of the Central Zone

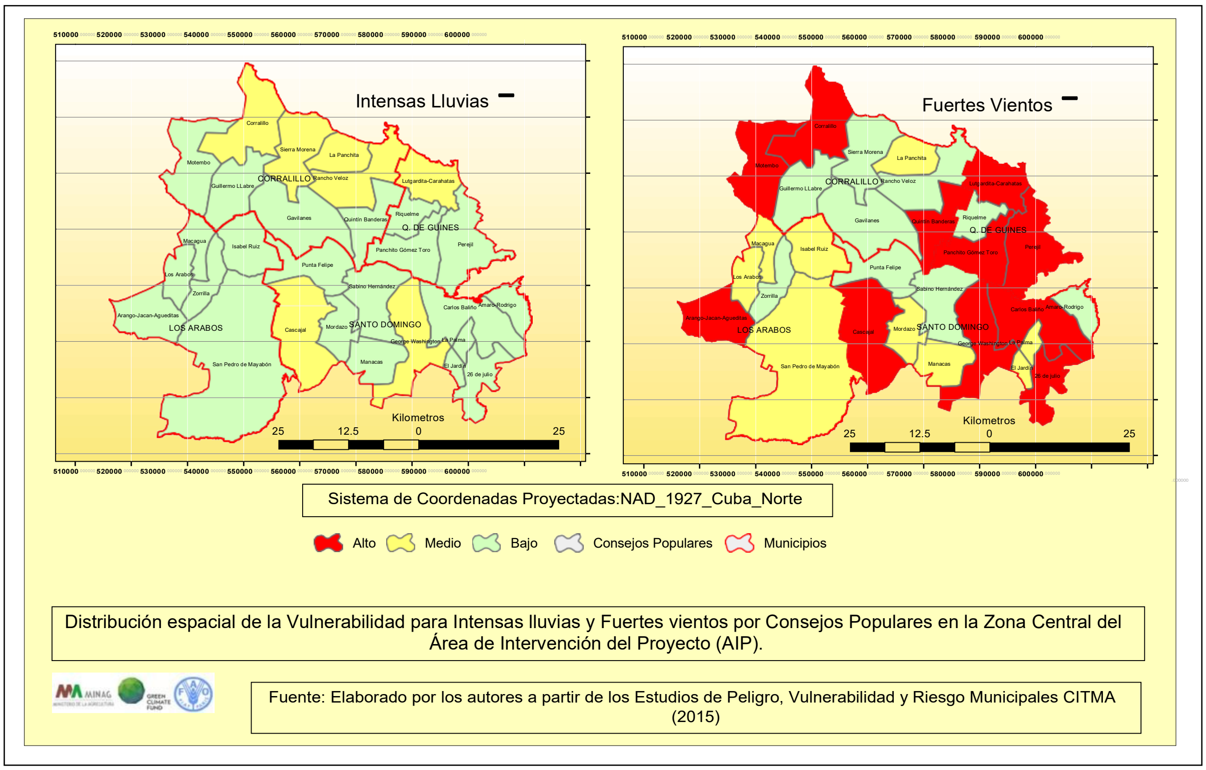


Table 37. Vulnerability due to heavy rains in the AIP of the Central zone (CP more vulnerable)

Popular Council	Municipality	Total Area (ha)	Total Households	Exposed Population	Vulnerability Classification
Corralillo	Corralillo	129.8	4587	6313	MODERATE
Sierra Morena	Corralillo	104.8	1293	3626	MODERATE
Rancho Veloz	Corralillo	109.8	2164	6106	MODERATE
La Panchita	Corralillo	59.4	1019	2225	MODERATE
Cascajal	Santo Domingo	157.6	2425	8184	MODERATE
Lutgardita-Carahatas	Quemado de Güines	79.4	1558	2453	MODERATE
George Washington	Santo Domingo	125.4	1061	3726	MODERATE

Source: Prepared by the authors based on the Hazard, Vulnerability and Risk (PVR) Municipal Reports.

Risk

The risk of floods due to intense rainfall increases towards the areas close to the coasts, as with the upwelling of the sea that can occur in hydrometeorological events (cyclones, intense rains and cold fronts, for example) there is a hyperaccumulation effect of the water that runs down the channels of the area. Such are the CPs of La Panchita and Lutgardita-Carahatas, in the municipalities of Corralillo and Quemado, and Cascajal and George Washington, near the channel of the Sagua la Grande river (see Figure 40 where the field distribution of the flood hazard is presented). Finally, in the AIP of the Central zone a MODERATE risk level predominates to floods due to heavy rainfall.

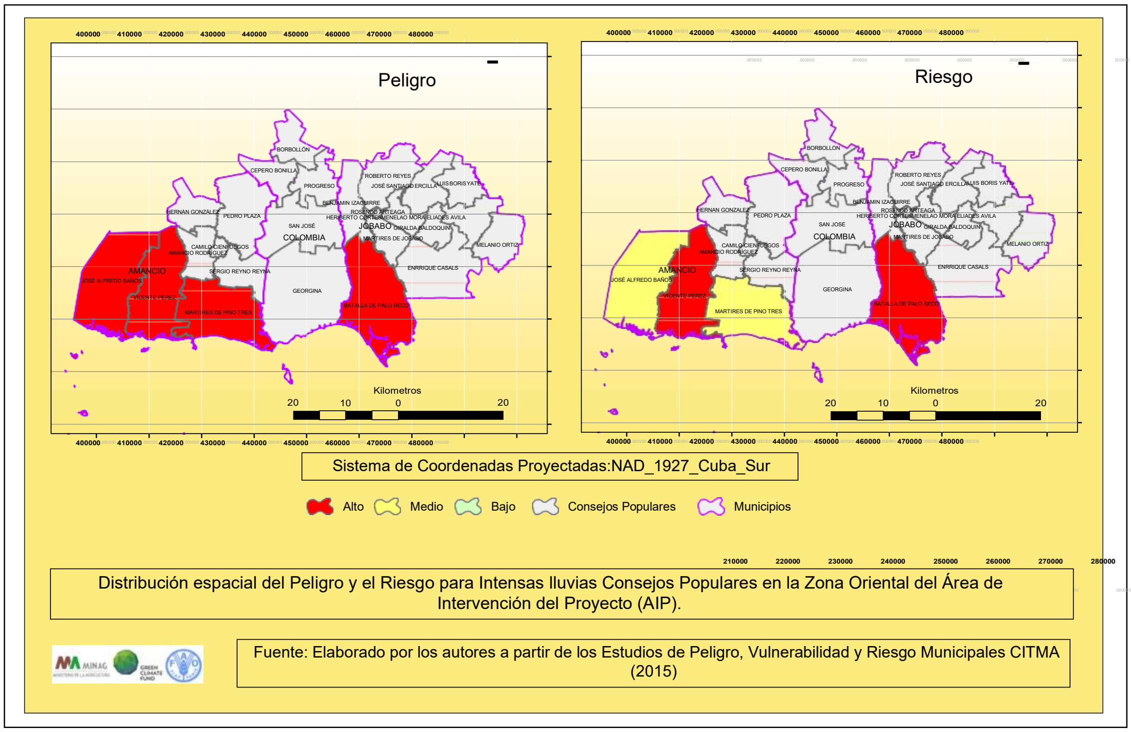
b) Hazard calculation and vulnerability and risk assessment in the Eastern Zone (South of Las Tunas)

Hazard

Figure 40 presents the assessment of Hazard and Risk to floods due to heavy rainfall. In the AIP of the Eastern zone, the predominant danger type is HIGH, particularly in the municipalities of Amancio Rodríguez and Jobabo.

Figure 40. Field distribution of the Danger and Risk to floods due to intense rainfall and strong winds in the AIP, Eastern Zone

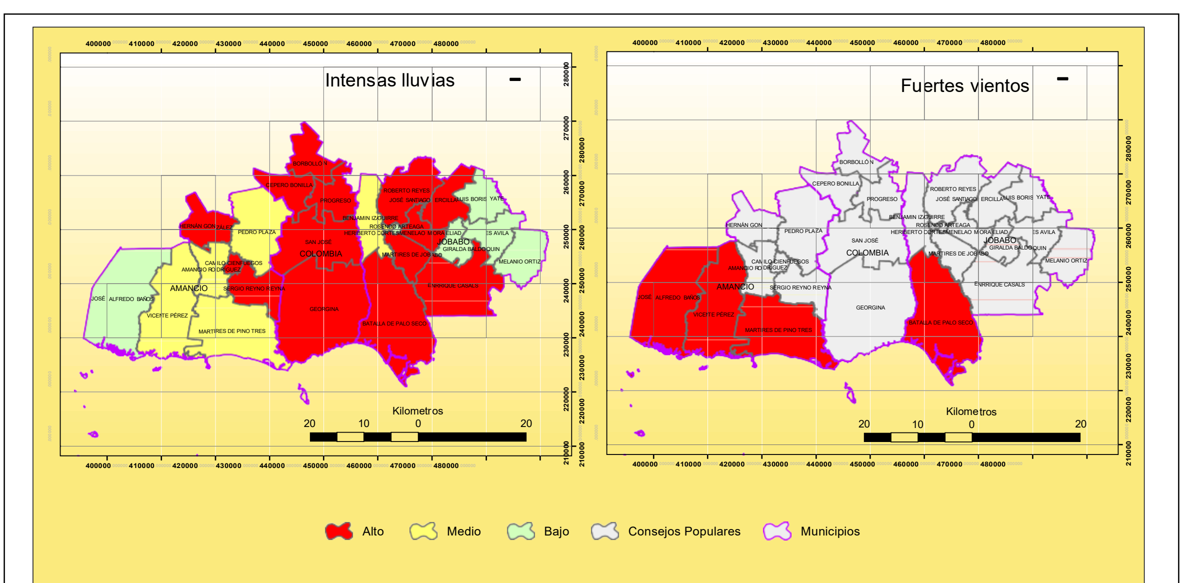
Riesgo



Vulnerability

Figure 41 shows the field distribution of vulnerability to intense rainfall in the CPs belonging to the municipalities of Amancio, Colombia and Jobabo. In the AIP of the Eastern zone the total HIGH-HIGH vulnerability predominates. In the AIP, there are 14 CPs out of 20, which present a level of vulnerability to floods due to heavy rainfall classified as ALTO. The rating is given, mainly, by the structural vulnerability (quantity and condition of the houses exposed to this threat), social (exposed population), and economic due to the exposure of crops to the incidence of floods due to heavy rains (see Table 39). and Figure 41).

Figure 41. Field distribution of flood vulnerability due to intense rainfall and strong winds in the AIP. Eastern zone



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Risk

Figure 40 shows the field distribution of the risk of heavy rainfall in the AIP of the Eastern Zone, by CPs. With a risk level qualified as HIGH are the CPs of Amancio Rodríguez, Vicente Pérez, Camilo Cienfuegos and Hernán González, belonging to the municipalities of Amancio, Georgina, San José, Borbollón, Cepero Bonilla and El Progreso, belonging to the municipality of Colombia; and by Jobabo, the CPs of Batalla de Palo Seco, Enrique Casals, Mártires de Jobabo, Menelao Mora and Benjamín Izaguirre.

The CPs qualified as MEDIUM risk in the face of intense rainfall are those belonging to the Amancio municipality: José Alfredo Baños, Mártires de Pino Tres, and Pedro Plaza; and those located in Jobabo: Roberto Reyes and José Santiago Ercilla (see Figure 40).

Table 38. Vulnerability due to heavy rains in the AIP of the Eastern Zone

Popular Council	Total Area (ha)	Households	Population	Vulnerability
Camilo Cienfuegos	1047	2202	5506	HIGH
Sergio Reynó Reyna	6564	5156	12761	HIGH
Vicente Pérez	16661	495	1630	MODERATE
Hernán González	6113	700	1948	HIGH
Mártires de pino tres	17016	1449	4254	MODERATE
Amancio Rodríguez	5576	2848	9818	MODERATE
Pedro plaza	12405	1027	3165	MODERATE
Cepero Bonilla	5342	2574	8952	HIGH
San José	13790	578	3508	HIGH
Georgina	25230	2574	1830	HIGH
Borbollón	5644	2027	10551	HIGH

Progreso	5988	1045	7893	HIGH
Heriberto Cortes	476	2068	7197	MODERATE
Batalla de palo seco	21769	373	1278	HIGH
Benjamín Izaguirre	6714	527	1212	MODERATE
Roberto Reyes	10836	847	2404	HIGH
Mártires de Jobabo	5984	1007	2675	HIGH
Menelao Mora	4743	1604	4751	HIGH
Enrrique Casals	16298	347	1465	HIGH
José Santiago Ercilla	7292	730	2321	HIGH
Total	195491	30178	95119	H-M

Source: Prepared by the authors based on the Hazard, Vulnerability and Risk (PVR) Municipal Reports.

II.2.3. Impacts due to strong winds

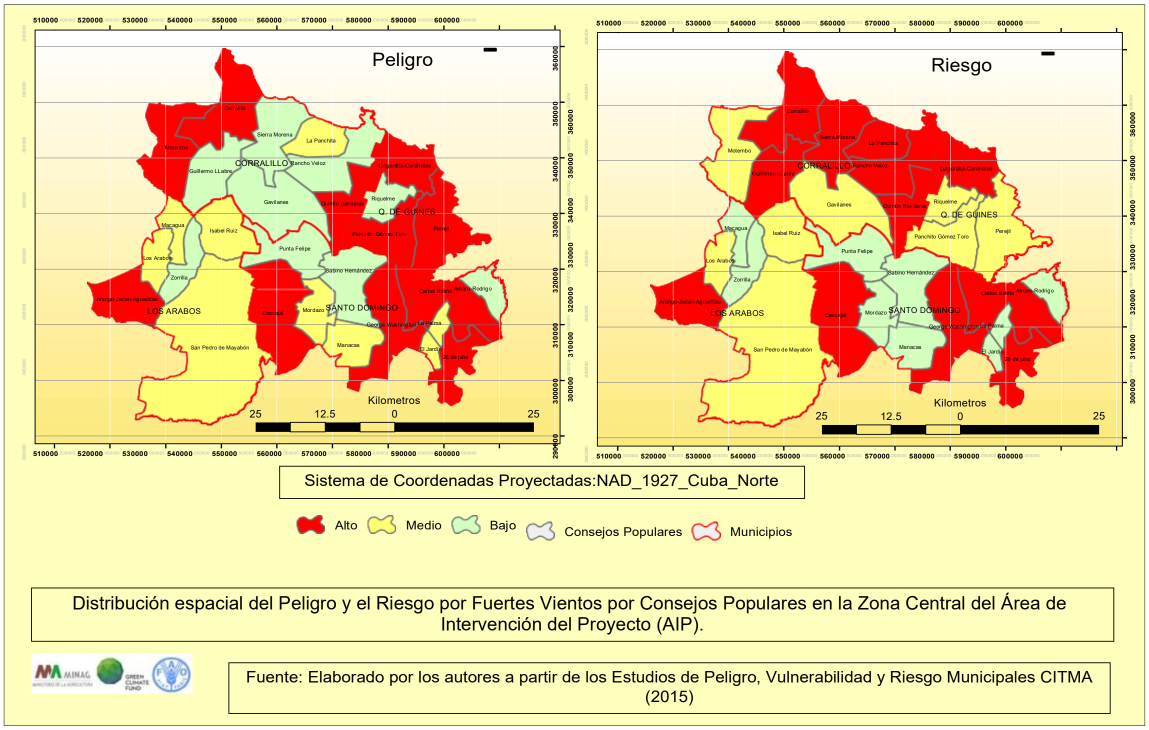
The objective of the Project is to improve the adaptation of households and communities to the effects of CC through the rehabilitation of productive landscapes, namely livelihoods, including housing and types of crops. The agroforestry modules will help, with the combination of trees and crops more complex and stable, to reduce the impact of strong winds on crops such as sugar cane, bananas, cassava and other similar crops.

The physical-geographic position of the AIPs of the Central and Eastern zone of Cuba, in the Caribbean Region, determines that there is the probability of occurrence of extreme hydrometeorological events generating strong winds, the tropical cyclones being the most dangerous, which every 5 years can affect the territory with a probability of 20%, and intensity of winds in the order of 115 km / h (equivalent to tropical storm), while the occurrence of these category I events with (CT-1) can strike every 10 years, category III (CT-III) every 25 years and category V (CT-V) every 100 years, there are probabilities of 10%, 2% and 1% respectively, mainly in the period from June to November (cyclonic season). Other events that generate strong winds that can also affect both areas, although with greater intensity to the Center area are: the passage of frontal systems (cold fronts) characteristic of the winter or dry period of the year and Severe Local Storms (TLS), which tend to activate in the summer.

a) Hazard Calculation, Vulnerability and Risk Assessment for the Central Region

In Figure 42, the field distribution of the CPs according to the hazard estimate due to strong winds in the AIP in the Central zone is presented. The CP with HIGH danger classification, are located mostly in the coastal area of Corralillo and Quemado de Guines, although there are also others to the south-central area corresponding to Los Arabos (Arango-Jacan-Aguedita) and Santo Domingo as El Perejil, Panchito Gómez Toro, Quintín Bandera, George Washington and July 26 (see Figure 42).

Figure 42. Field distribution of the Hazard and Risk due to strong winds in the AIP. Central region



Vulnerability

Figure 39 shows the popular councils with greater vulnerability to strong winds and their field distribution. The three CPs encompass some 269 ha, 3033 households and almost 11 thousand inhabitants. The HIGH vulnerability predominates.

Risk

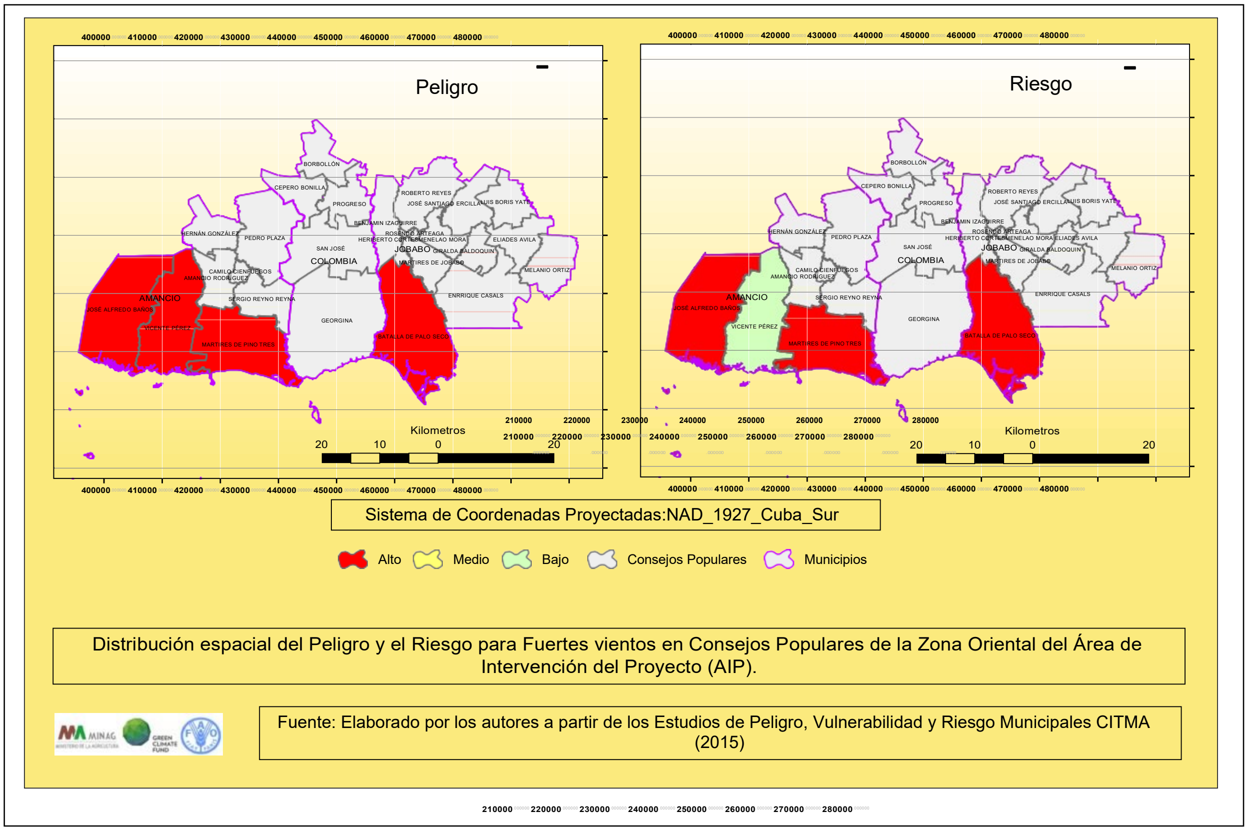
Taking into account the situation of danger and vulnerability (threat and exposure), from the area of intervention of the project in this Central zone, the CPs with High Risk, are the coastal CPs of the municipalities of Corralillo and Quemado de Güines plus Arango-Jacan-Agueditas , from Los Arabos and Cascajal, Carlos Baliño, Washington and July 26, belonging to Santo Domingo (see Figure 42).

b) Hazard Calculation, Vulnerability and Risk Assessment for the Eastern Region (South of Las Tunas)

Hazard

Figure 43 presents the field distribution of the hazard by strong winds in the AIP in the Eastern zone, by Popular Councils. All CPs located near the coastal zone of Amancio, Colombia and Jobabo are classified as HIGH Hazard, with Jobabo standing out due to the fact that except the CP Mártires of July 26, the rest are at HIGH level of danger.

Figure 43. Field distribution of hazard and risk due to strong winds in the AIP. Eastern Region



Vulnerability

In Figure 41, the field distribution of vulnerability to strong winds in the AIP of the Eastern Zone, by popular councils, is presented. There are 20 CPs with HIGH vulnerability.

Table 39. Vulnerability to impacts due to strong winds in the AIP, Eastern Zone

Popular Council	Total Area (ha)	Households	Population	Vulnerability
José Alfredo Baños	19897.3	461	1803	HIGH
Vicente Pérez	16660.8	495	1630	HIGH
Hernán González	6113.1	700	1948	HIGH
Mártires de Pino Tres	17015.6	1449	4254	HIGH
Pedro plaza	12405.4	1027	3165	HIGH

Cepero Bonilla	5342.6	2574	8952	HIGH
Georgina	25230.4	2574	1830	HIGH
Borbollón	5644.3	2027	10551	HIGH
Heriberto Cortes	476.5	2068	7197	HIGH
Batalla de Palo Seco	21769.4	373	1278	HIGH
Benjamín Izaguirre	6713.9	527	1212	HIGH
Roberto Reyes	10836.2	847	2404	HIGH
Menelao Mora	4743.5	1604	4751	HIGH
Enrrique Casals	16297.7	347	1465	HIGH
Giralda Baldaquín	4953.2	591	2169	HIGH
Luis Boris yate	6013.2	1268	4093	HIGH
Eliades Ávila	6754.3	1770	5523	HIGH
Melanio Ortiz	8031.6	1541	5292	HIGH
Rosendo Arteaga	507.8	2221	7510	HIGH
José Santiago Ercilla	7291.6	730	2321	HIGH
Total	202698	25194	79348	HIGH

Source: Prepared by the authors based on the Hazard, Vulnerability and Risk (PVR) Municipal Reports.

There are about 25 194 households in these HIGH Vulnerability CPs, which represents almost two thirds of the total homes of these Popular Councils, and just over 79300 inhabitants (see Table 39).

Risk

In Figure 43, the field distribution of the risk of impact from strong winds by CP of the AIP of the Eastern zone is presented. The level of risk in the three municipalities that make up the AIP is MODERATE-HIGH. Of these high-risk CPs, three are located in the coastal zone and six are located in the interior of the AIP. In the municipality of Jobabo most of the CPs are concentrated with HIGH risk level, in correspondence with the greater exposure to the danger of impact by strong winds of cultivated areas (46% of the AIP with high vulnerability) of sugar cane mainly, and of households in regular and poor condition (almost 64% of households with HIGH vulnerability).

II.2.3. Impact due to penetrations from the sea

The elevation of 27 centimeters of the mean sea level for the country for the year 2050 and 85 for 2100; are consistent with the ranges of values estimated by the Intergovernmental Panel on Climate Change (IPCC), for the entire planet and by national scenarios in the Second National Communication to the United Nations Framework Convention on Climate Change. This will imply the slow reduction of the surface for the AIP territories in both zones, and the gradual salinization of the underground aquifers by the advance of the "saline wedge" of seawater. As a significant aspect, it is ensured that the relative elevation of the sea level has increased rapidly during the last five years, according to the measurements of the tides in 5 points of the archipelago and between those reported by the station of La Isabela, North of Villa Clara.

These scenarios of the rise of the mean sea level would imply a loss of 2.3% and 5.5% of the total surface of mainland; including other surfaces in cays and islets of the archipelago (areas more sensitive and vulnerable to ascent), not yet estimated. The most affected areas are those occupied by swamps with mangrove formations, grasslands, and low coastal territories.

In the Reference 2050 scenario, it is estimated that an average sea level rise of 27 cm would cause severe damage to a surface that would be in the order of 49 180 ha, while in 2100 in this same scenario, the surface affected by the increase in the mean sea level by about 0.85 meters would be in the order of the additional 21 750 ha. Between 2050 and 2100, settlements such as La Panchita (Corralillo) and Carahata (Quemado de Guines), will lose up to 15 and 90% of their land surface, respectively.

On the other hand, the area of marine intrusion belonging to the AIP of the Eastern zone is around 33 600 ha, and it is estimated according to the climatic scenarios simulated for Cuba, an additional increase of 3221 ha, by year 2050 and 1728 ha more by 2100. In the AIP of this Eastern zone, the settlement Guayabal (municipality of Amancio Rodríguez), according to the 2050-2100 scenarios, will lose 16-18% of its land surface.

In addition to the affectation to the terrestrial surface and current uses and coverage, the rise in sea level will enhance the phenomenon of marine intrusion in coastal aquifers (groundwater), which is one of the greatest impacts due to the high vulnerability of them in the AIP due to their condition of open karstic aquifers. As discussed in section I 3.3 subsection b, several studies warn that the intrusion of the salt wedge will be greater if the amount of rainfall is lower and as a consequence the reduction in the availability of groundwater would be significant and the affectation could lead to the final salinization of the AIP reserves (Suárez Pecoso, 2015)) and (Jiménez Reyes, 2011).

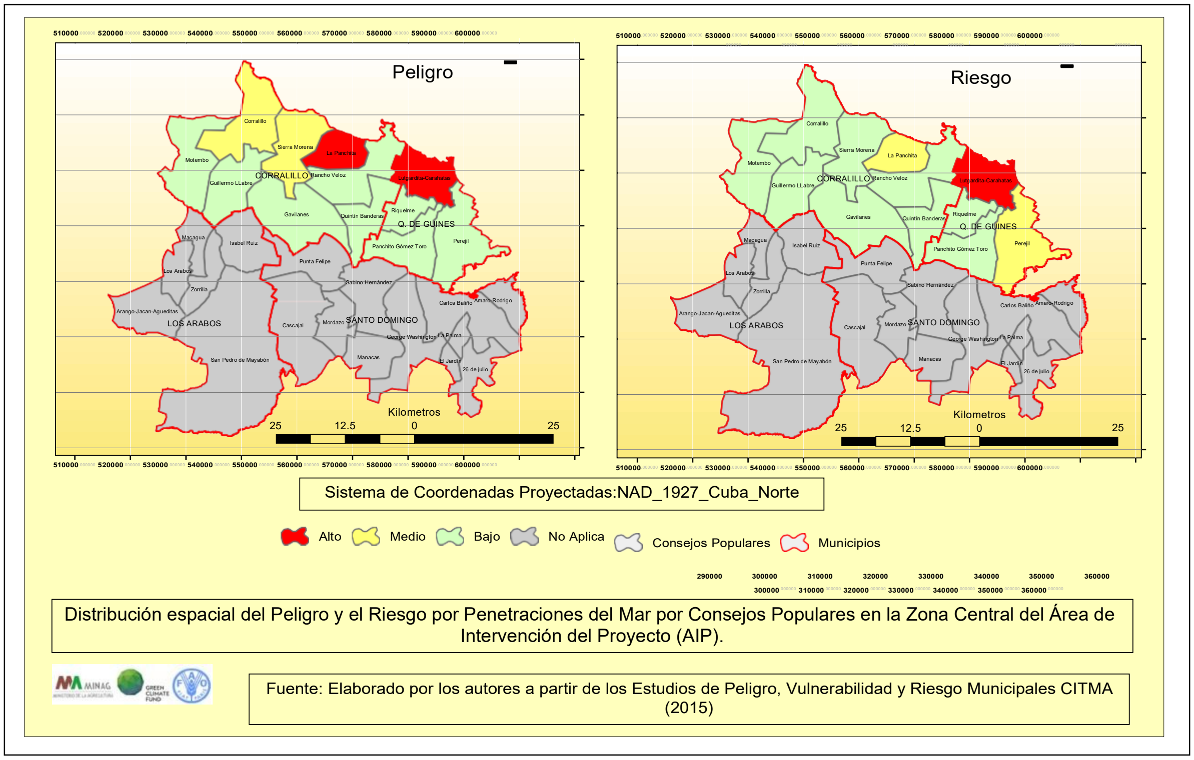
The elevation of the sea level will cause in the AIP of both zones, the increase of salinization of cultivated lands and aquifers.

a) Hazard Calculation, Vulnerability and Risk Assessment for the Central Region

The calculation of hazards by penetration of the sea takes into account the values of sea elevation and the probability of occurrence of cyclones of different categories. In this case, for a probability of occurrence of a category I cyclone. Figure 44 shows the field distribution of the flood hazard due to sea penetrations in the AIP of the Central zone. The CP Corralillo and Sierra Morena (Medium or Moderate Hazard), La Panchita and Lutgardita-Carahata (HIGH Hazard) are identified with MODERATE-HIGH hazard level.

Riesgo

Figure 44. Field Distribution of the Hazard and Risk from Penetrations of the Sea in the AIP. Central zone



Vulnerability

Table 40 and Figure 45 show the results of the vulnerability calculation by sea penetrations and their field distribution in the AIP of the Central zone. The highest levels of vulnerability are identified in the five coastal CPs.

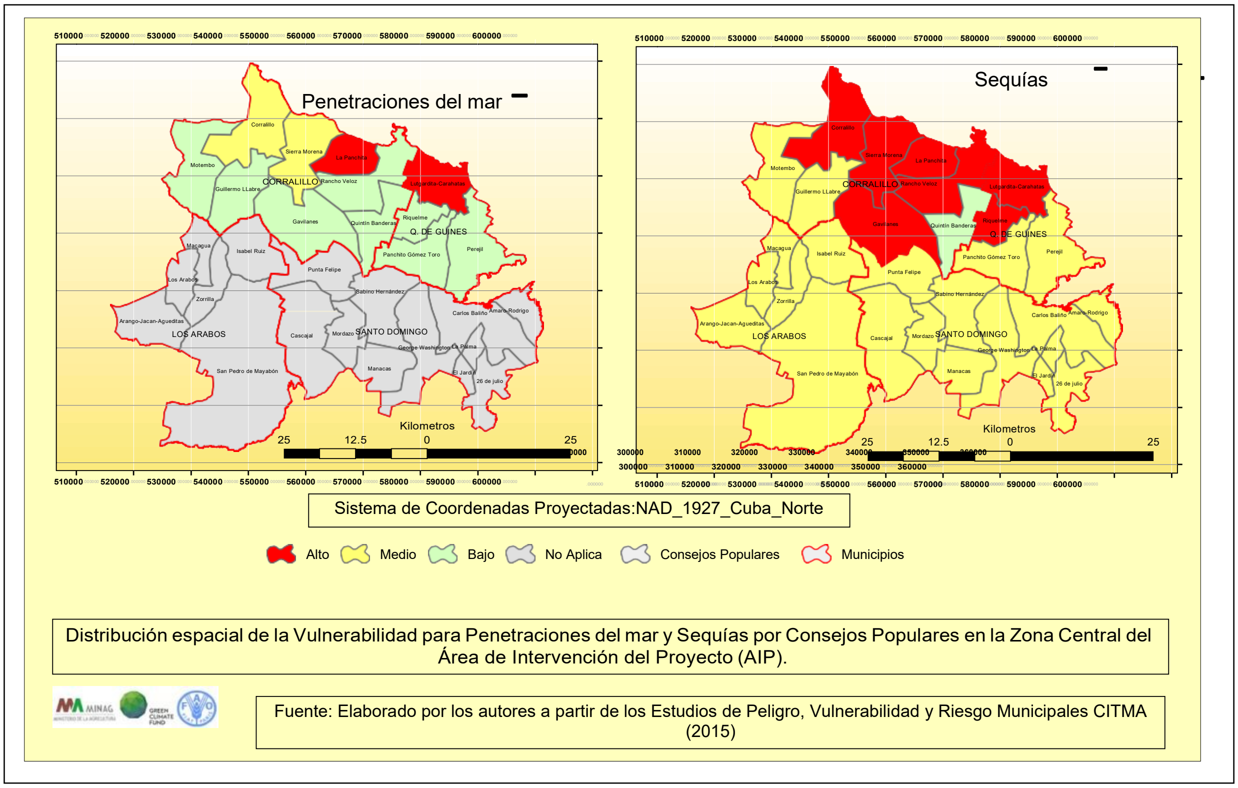
Table 40. Vulnerability to floods due to sea penetration in the AIP, Central zone

CP	Municipality	Total Area (ha)	Total households	Total Population
Corralillo	Corralillo	129.8	4587	6313
Sierra Morena	Corralillo	104.8	1293	3626
Rancho Veloz	Corralillo	109.8	2164	6106
La Panchita	Corralillo	59.4	1019	2225
Lutgardita-Carahatas	Quemado de Güines	79.4	1558	2453
	Total	483	10621	20723

Source: Prepared by the authors based on the Hazard, Vulnerability and Risk (PVR) Municipal Reports.

In these CPs of HIGH-MODERATE VULNERABILITY, some 10621 households and 20.7 thousand people are located, and a cultivated area, especially of plantain and rice, of 483 ha. The main aquifers that supply both the population and the crops are also there.

Figure 45. Field distribution of the vulnerability to sea penetrations and drought at the AIP Central Region



Risk

Figure 44 shows the field distribution of the Risk of Sea Penetration in the AIP of the Central zone. The most dangerous CPs are La Panchita and El Perejil (MODERATE), and Lutgardita-Carahata (HIGH).

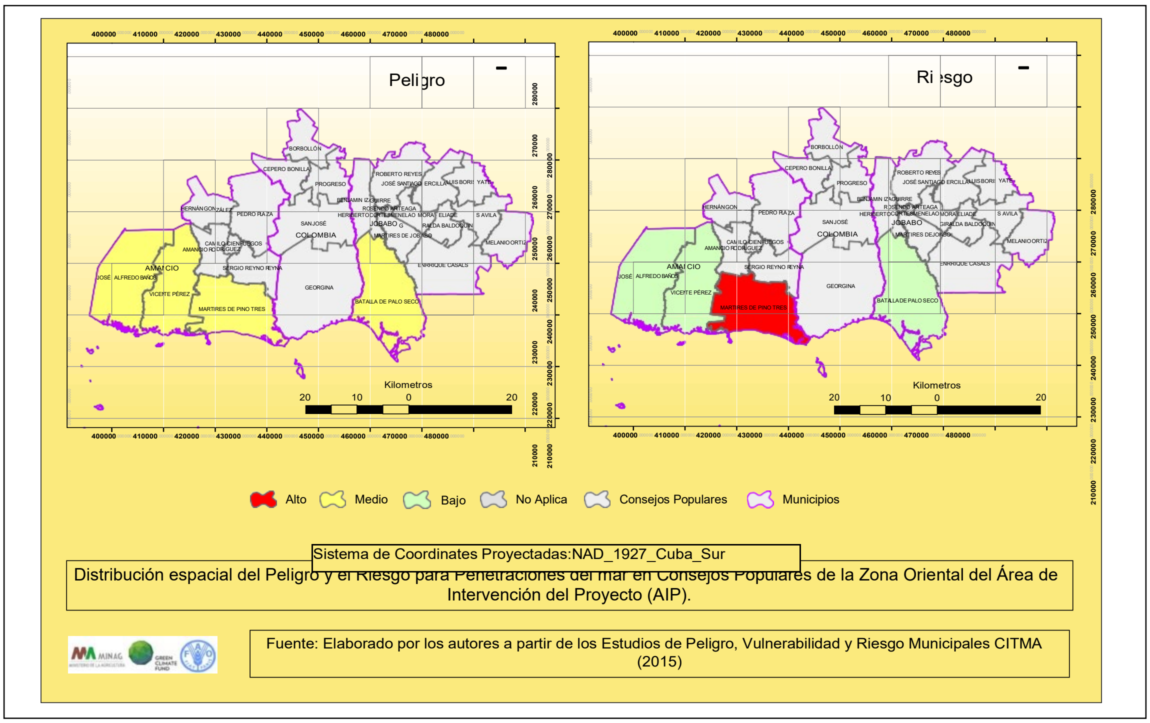
b) Hazard calculation and evaluation of vulnerability and risk in the Eastern Zone (South of Las Tunas)

Hazard

The calculation of Danger by penetration of the sea takes into account the values of sea elevation and the probability of occurrence of cyclones of different categories. In this case for a probability of occurrence of category I cyclones. Sea level rise will cause changes in plant cover, increased salinization of farmland and aquifers near the coast, affecting livelihoods of the communities settled in those areas.

In Figure 46, the field distribution of danger due to sea penetration in the AIP of the Eastern zone is presented. The level of danger is moderate in all the CPs with coasts, with the exception of Georgina, in the municipality of Colombia, where the danger is described as HIGH.

Figure 46. Field Distribution of Hazard and Risk of Floods by Penetrations of the Sea. Eastern Zone



Vulnerability

Table 41 and Figure 47 present the results of the vulnerability of the penetration of the sea in the AIP of the Eastern zone. With the exception of the CP Mártires de Pino Tres, which has a HIGH vulnerability level, the rest of the coastal CPs (four CPs) have a MODERATE degree of vulnerability to the penetration of the sea.

Table 41. Vulnerability to floods by penetration of the sea in the AIP, Eastern Zone

MUNICIPALITY	CP	TOTAL AREA	TOTAL HOUSEHOLDS	TOTAL POPULATION	TYPE OF VULNERABILITY
AMANCIO	José Alfredo Baños	19897.3	461	1803	MODERATE
AMANCIO	Vicente Pérez	16660.8	495	1630	MODERATE
AMANCIO	Mártires de Pino Tres	17015.6	1449	4254	HIGH
COLOMBIA	Georgina	25230.0	2574	1830	MODERATE
JOBABO	Batalla de Palo Seco	21769.0	373	1278	MODERATE
	Total	100573	5352	10795	MODERATE

Source: Prepared by the authors based on the Hazard, Vulnerability and Risk (PVR) Municipal Reports.

These CPs involve a total of 100 573 ha of total cultivated area, some 5352 households and some 10 795 people exposed to the danger of sea penetration. In the case of Mártires de Pino Tres, the HIGH vulnerability value is mainly due to the number of inhabitants exposed to the danger of being affected by the penetration of the sea. In Table 44, the comparison between AIP of both zones in terms of marine intrusion and coverage areas is presented. It can be seen that the intrusion area of the Eastern zone is almost 1.3 times greater than that of the Central zone (58830 versus 43670 ha). The greatest impacts are identified in the CP of Corralillo (Central zone), with 26780 ha, and Amancio Rodríguez (Eastern zone) with 33600 ha, the latter is 25% higher than that of Corralillo.

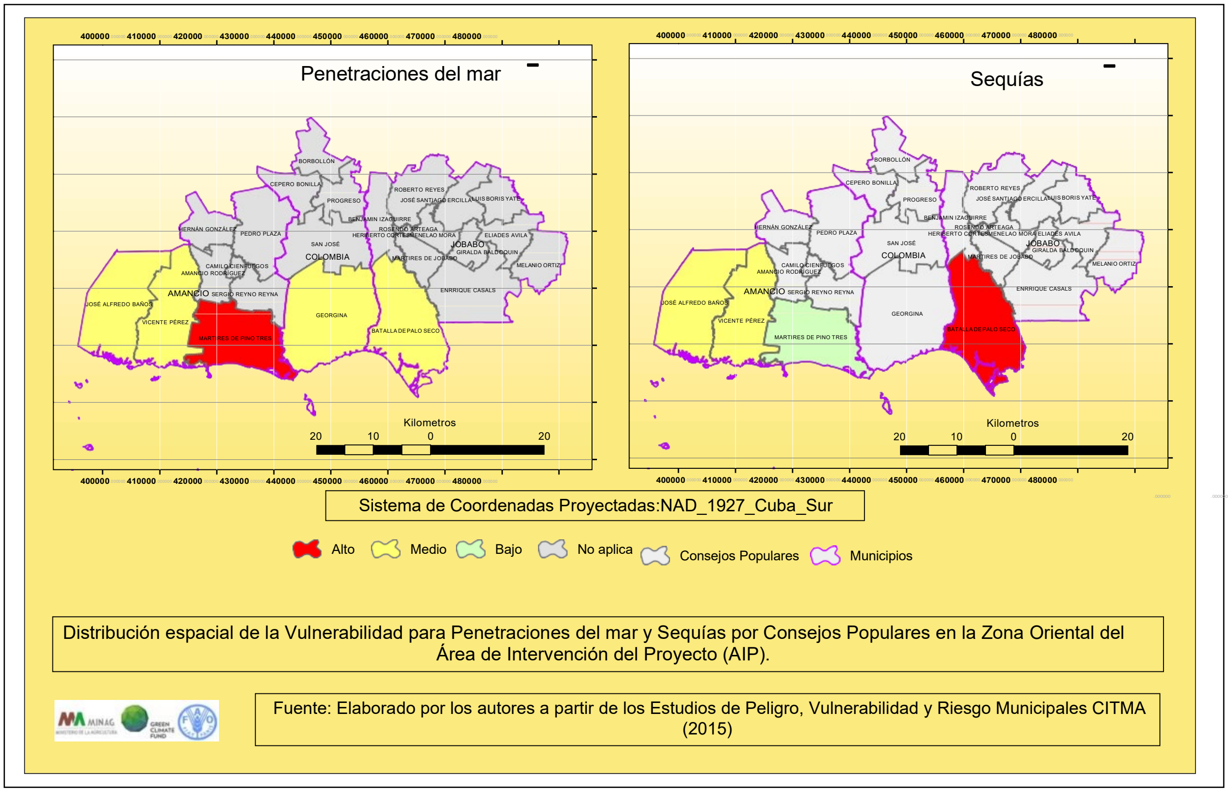
Table 42. Areas of intrusion and coverage in hectares[9]; both regions

		AIP Central Region				AIP Eastern Region				
Studied Parameters	AIP Both Zones	Corralillo	Quemado de Goines	Total	% AIP Total	Amancio	Colombia	Jobabo	Total	% AIP Total
Marine intrusion area	102500	26780	16890	43670	42.6	33600	13070	12160	58830	57.4
Mangrove cover in good condition	19942	4825	8368	13193	66.2	4732	1503	514	6749	33.8
Mangrove cover in deterioration	2809			0	0.0		154	2655	2809	100.0
Humid forest cover	3752	108	370	478	12.7	1324	31	1919	3274	87.3
Swamp herbage cover	12186	75	360	435	3.6	11263	5	483	11751	96.4

Source: Prepared by the authors based on the Technical Report of the Macro project (IPF, 2017)

9 Includes the areas of adjacent keys

Figure 47. Field distribution of flood vulnerability due to Penetrations of the Sea and Drought in AIP. Eastern zone



Risk

Figure 46 presents the field distribution of risk from penetrations of the sea in the AIP of the Eastern zone, by CP. The CP Mártires de Pino Tres is the only one that represents HIGH risk to the penetration of the sea.

II.2.4. Impacts due to intense drought

Drought is acknowledged by specialists in climatic and agricultural issues as the most important climate irregularity in the Eastern zone, particularly in the AIP.

The processes leading to drought are extremely complex and their immediate origins have been linked to the scarcity of humidity in the atmosphere, the influence of rain generating systems or the presence of a strong subsidence, the effects of the Southern oscillation ENSO, or the combination of some of these factors, whose causes continue to be studied in the context of the General Circulation of the

Atmosphere (Cutié Cancino and Lapinel Pedroso, 2013).

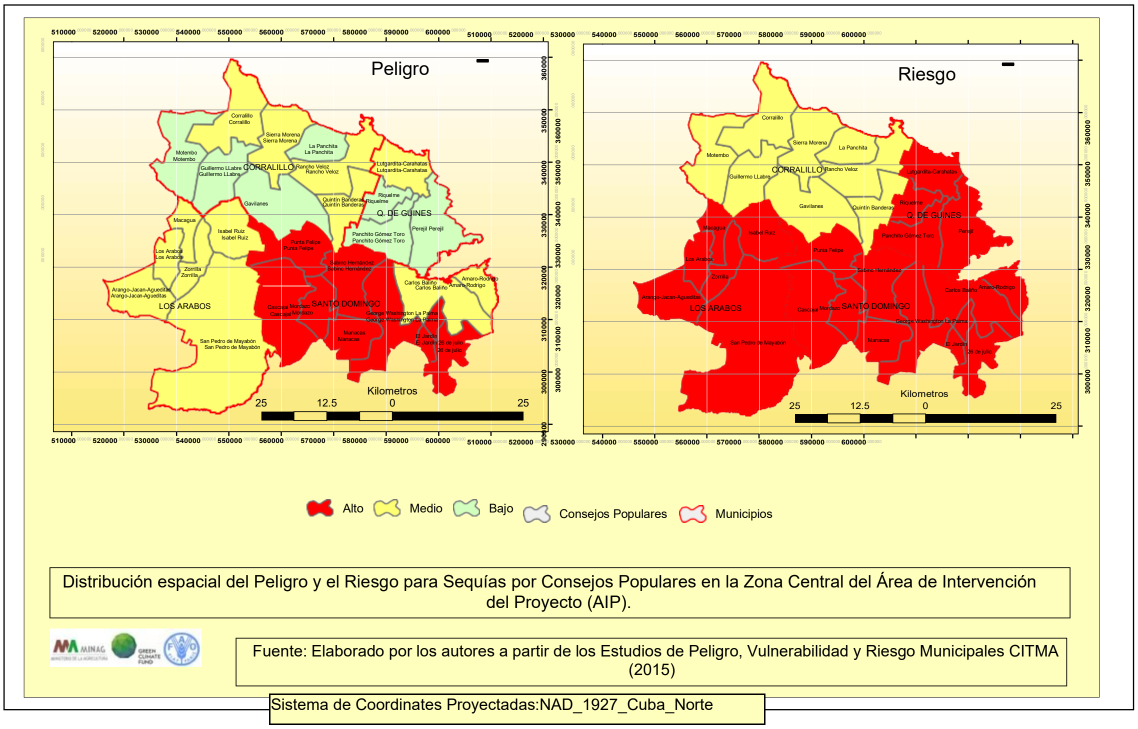
In Cuba, the deficit in the annual rainfall accumulations, classified as moderate and severe, doubled in the normal period 1961-1990, compared to the previous period, 1931-1960 (Lapinel et al., 1993). Extensive and intense drought events accompanied these three decades, such as occurred in the 60s and 70s, and 84 to 86 of the last centuries. In the summers of 93, 94, 98 and 2000, the effects by drought were remarkable especially in the Eastern zone of the country, being the 1998 drought the most intense for the period April-May-June (rainy period) registered in the statistics of the Climate Center of the Institute of Meteorology, available since 1941. In the years after 2000, in the Caribbean Region, there have been episodes of high intensity drought highlighting the event of the 2004 cataloged as the most critical for Cuba in the last 100 years, affecting the eastern region of the country with the utmost harshness.[10]

a) Hazard calculation and evaluation of vulnerability and risk - Central Region

In Figure 48, the field distribution of the drought hazard in the AIP of the Central Zone is presented by Popular Councils. Emphasis is made on three zones according to the results of the drought hazard calculation: the northern zone constituted by the coastal CPs of Corralillo and Quemado, with a medium hazard level, a central-eastern zone with the CPs of Santo Domingo, where HIGH danger predominates, and to a lesser extent, the MEDIUM or moderate danger; Between the two zones, a third characterized as LOW danger to drought is distinguished. The 6 CPs that make up the municipality of Los Arabos have MEDIUM levels of drought hazard

[10] This event implied important affectations to the economy and discomforts to the population; At times, it was necessary to supply water to the most critical regions transported by railroad, tank cars (pipes) and other means to more than 2 million people; The estimated economic losses resulting from this event amounted to over one billion US dollars.

Figure 48. Field distribution of danger and risk for droughts by Popular Councils in the Central Zone of the AIP



Vulnerability

Figure 45 shows the results of the vulnerability calculations and their field distribution in the AIP of the Central zone. The MODERATE category of vulnerability predominates in the Central zone, although the CPs of Corralillo, Sierra Morena, Rancho Veloz, La Panchita, Gavilanes, Riquelme and Lutgardita-Carahata show HIGH vulnerability to drought events. In those Popular Councils with HIGH vulnerability, 25% of the total surface area is concentrated in the Central zone. In addition, 21% of households and 22% of the population are located there (see Table 43).

Table 43. Popular Councils with high vulnerability to drought in the Central Zone

	Total Area (ha)	Total Households	Total Population
CP HIGH Vulnerability	681	12594	25210
% with respect to the Total Central zone	25	21	22

Source: Prepared by the authors based on the Hazard, Vulnerability and Risk (PVR) Municipal Reports.

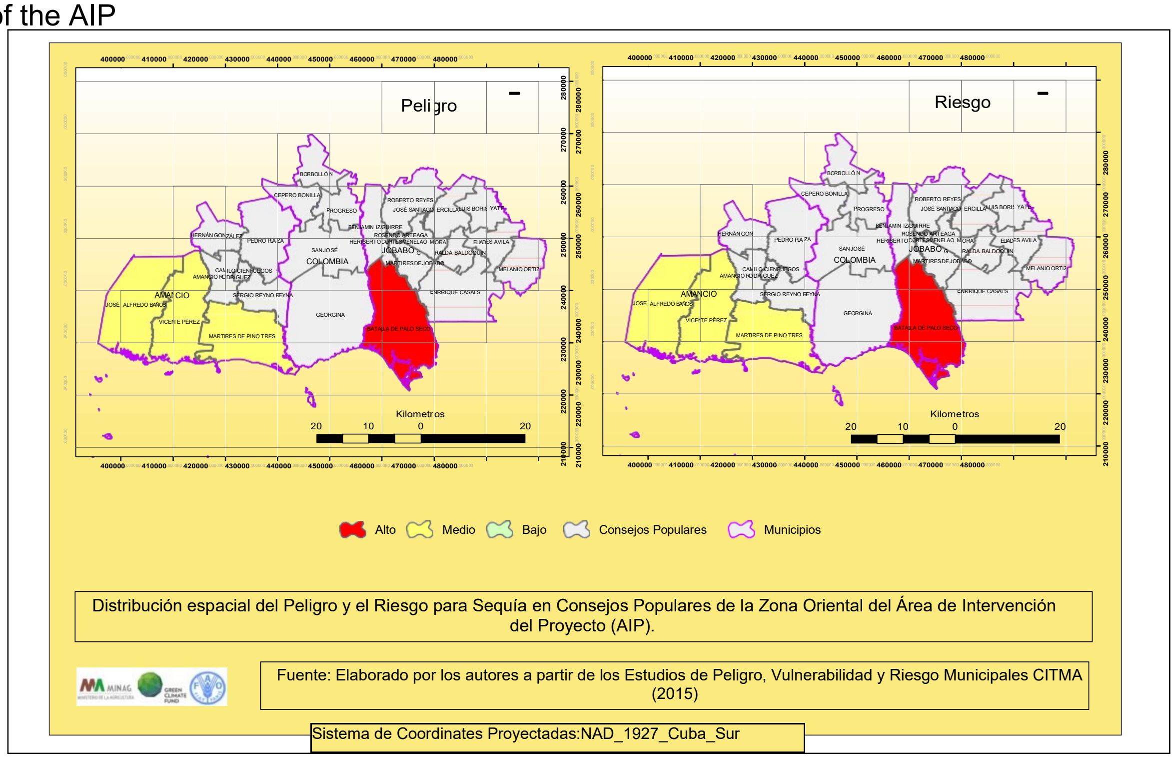
Risk

Figure 48 presents the field distribution of the AIP drought risk in the Central zone. It can be seen that the northwestern part, Corralillo, is characterized by presenting a medium or moderate level of risk, while in the Los Arabos Quemado de Güines and Santo Domingo the level of risk is HIGH.

b) Hazard calculation and evaluation of vulnerability and risk – Eastern Region (South of Las Tunas)

Figure 49, shows the level of danger of the AIP of the Eastern zone before processes of drought, all the CPs of Jobabo until the CP Georgina of Colombia are in danger HIGH; the rest of the CPs of Amancio face moderate levels of danger, except for CP Pedro Plaza and Hernán González, whose danger is LOW. As mentioned in previous paragraphs, in this region the drought is identified as the most worrisome climate anomaly due to the greater impact on the population and their livelihoods.

Figure 49. Field distribution by People's Councils of the danger and the risk of drought in the Eastern Zone of the AIP



Vulnerability

Table 44 and Figure 38 show the results of the calculation of drought vulnerability in the AIP of the Eastern zone. The area occupied by the CPs with HIGH Vulnerability to drought is practically half of the total area of the AIP of the Eastern zone.

Table 44. High vulnerability to drought processes by CP. Eastern zone

POPULAR COUNCIL	MUNICIPALITY	TOTAL AREA (HA)	TOTAL HOUSEHOLDS	POPULATION
GEORGINA	COLOMBIA	25231	2574	1830
HERIBERTO CORTES	JOBABO	255	2068	7197
BATALLA DE PALO SECO	JOBABO	20731	373	1278
BENJAMIN IZAGUIRRE	JOBABO	6719	527	1212
ROBERTO REYES	JOBABO	9217	847	2404
MARTIRES DE JOBABO	JOBABO	4450	1007	2675
MENELAO MORA	JOBABO	3684	1604	4751
ENRRIQUE CASALS	JOBABO	14984	347	1465
GIRALDA BALDOQUIN	JOBABO	3608	591	2169
LUIS BORIS YATE	JOBABO	5521	1268	4093
ELIADES AVILA	JOBABO	5770	1770	5523
MELANIO ORTIZ	JOBABO	6993	1541	5292
ROSENDO ARTEAGA	JOBABO	262	2221	7510
JOSÉ SANTIAGO ERCILLA	JOBABO	6365	730	2321
Total CP High vulnerability		113789	17468	49720

Source: Prepared by the authors based on the Hazard, Vulnerability and Risk (PVR) Municipal Reports.

II.2.5 Assessment of vulnerable households and their livelihoods

The estimation of crops and livelihoods for the communities located in the AIP constituted, perhaps the main challenge of this work. Avoiding double accounting of crops, households and the population at risk is a requirement of the greatest importance in order to allocate funds for resilience in the face of the vulnerability of the different threats posed by Climate Change.

For this purpose, a numerical classification based on cluster analysis applied to the field data matrix was used, composed of 55 popular councils, 4 threats and 3 variables: cultivated area, technical condition of the dwellings and population. The cluster analysis resulted in 5 groups that synthesize the total vulnerability, allowing to apply the following classification: very vulnerable, vulnerable, moderate vulnerability, low, and very low vulnerability.

a) Synthetic analysis. Summary table for the Central zone by Popular Councils

Table 45 shows the distribution of the CPs by vulnerability groups. Group I is equitably integrated, five CPs in each intervention zone, while in Group II, 89% of the CPs that comprise it are from the Eastern zone (16 of 18 CP).

Table 45. Distribution of the CPs by Vulnerability Groups in the AIP. Both zones

GROUPS	CP of AIP	Central Region		Eastern Region	
		No. CP	%	No. CP	%
Group I very vulnerable	10	5	50.0	5	50.0
Group II vulnerable	18	2	11.0	16	89.0
Group III moderate vulnerability	12	7	58.3	5	41.7
Group IV low vulnerability	7	7	100.0		
Group V very low vulnerability	8	8	100.0		
Total	55	29	52.7	26	47.3

Source: Prepared by the authors

There is representation of all the cluster classifications in the Central zone, however, in the Eastern zone the classifications correspond only to the very vulnerable, vulnerable and moderately or medium vulnerability groups. This result is ratifying that the CPs of the Eastern zone present a greater vulnerability to the combined effects of the threats coming from the Climate Change.

Table 46. Exposed area of coverage and relevant uses for AIP by vulnerability groups. Central Zone (in ha)

	Total Area	Arable Land	Cultivated Land	Sugar Cane	Crops	Natural Pastures	Forest	Idle Land
Group I Very vulnerable	47394	38616	13300	7609	4409	18201	1183	7115
Group II Vulnerable	28004	17215	7171	4794	2213	9705	179	6634
Total	75398	62361	20471	12433	6467	28242	1362	13648

Source: calculated by the authors based on the digital map of coverage and land use: IPF, 2013

In the CPs belonging to Groups I and II, some 20,400 hectares of cultivated area are affected, 33% of the total agricultural area of Groups I and II of the AIP of the central zone. In the AIP of the most vulnerable groups, pasture crops prevail with 37% of the total area, idle area with almost 18%, and sugarcane, with 16% of the total area corresponding to Groups I and II. The area devoted to cane and various crops is 25%. Finally, the area of natural forests barely makes up 2% of the most vulnerable area of the AIP in this area. (See Table 46).

On the other hand, Table 47 summarizes the number of totals, vulnerable households and the population belonging to each of the five vulnerability groups.

Table 47. Households and population by vulnerability groups. Central zone

Groups	Total Households	Population
Group I Very vulnerable	10621	20723
Group II Vulnerable	3667	12200
Group III Moderate Vulnerability	9052	23186
Group IV Low Vulnerability	6955	14363
Group V Very Low Vulnerability	7776	50457
Total	38071	120929

Source: Prepared by the authors

The households belonging to Groups I and II in the AIP of the Central zone represent almost 35% of the total number of households located in the intervention zone of the project, while the inhabitants amount to almost 32,923 and represent approximately a quarter of the population located in the AIP of the Central zone.

b) Synthetic Analysis. Summary table for the Eastern Zone by Popular Councils

Table 48 summarizes the area threatened by climate change in correspondence with the vulnerability groups.

Table 48. Exposed area of coverage and relevant uses for AIP by vulnerability groups. Eastern zone

	Total Area (ha)	Arable Land (ha)	Cultivated Land (ha)	Sugar Cane	Crops	Natural Pastures	Forest	Idle Land
Group I Very Vulnerable	100573	22573	9124	7942	1182	10015	54020	49875
Group II Vulnerable	114814	58108	25434	16086	9109	32675	10957	40515
Total	215387	80681	34557	24028	10291	42690	64977	90390

Source: Prepared by the authors

The total area belonging to Groups I and II amounts to 215 387 ha, almost triple the most vulnerable in the AIP of the Central zone. This area included in Groups I and II, represent 90.4% of the total area of the AIP of the Eastern zone. Predominant in this environment the idle surfaces (90390 ha), of which almost 81.4 thousand ha are occupied by marabou, some 22.9 thousand ha more than the total area belonging to Groups I and II of the area of intervention of the project in the Central zone and approximately 7 times more than the idle surface of the AIP of the Central zone. Table 49 shows a summary of the households and population according to the vulnerability groups in the AIP of this area.

Table 49. Households and population by vulnerability groups. Eastern zone

	Total Households	Population
Group I Very vulnerable	5352	10795
Group II Vulnerable	25287	86127
Group III Moderate Vulnerability	7391	24587
Group IV Low Vulnerability	N/A	N/A
Grupo V Very Low Vulnerability	N/A	N/A
Total	38030	121509

Source: Prepared by the authors

The most vulnerable households (Groups I and II) reach the figure of 30,639, occupied by 96922 inhabitants. The number of vulnerable households is equivalent to 80% of the total number of households that are located in Groups I, II and III. It is estimated that at the AIP level and for both zones there is a vulnerable housing fund (Groups I and II, very HIGH, and HIGH) of about 43 369 households, which together shelter about 127 500 people (see Table 47.49, 50 and 51).

c) Field Zoning. AIP Vulnerability Map - Central and Eastern Regions, by Popular Councils

The mapping of the vulnerability groups defined in the AIP shows that in the Central zone the five categories are represented, while in the Eastern zone the presence of the vulnerable to very vulnerable categories stands out (Groups I and II).

The number of very vulnerable and vulnerable households (Group I and II) in the areas of project implementation in both areas would reach 45,000 with an exposed population of 129,845 inhabitants.

Both in the Center and in the East the very vulnerable categories are concentrated in the coastal zones forming a compact strip that coincides with the Popular Councils most exposed to the threats studied and where the marine saline intrusion converges.

In the south of Las Tunas, the distribution of the vulnerability groups is homogeneous, transiting the very vulnerable zone located in the coastal zone and continuing with the adjacent vulnerable zones in the Central-North zone, however, in the Central AIP the distribution is more heterogeneous; The very vulnerable zone located in the northern coastal strip is interrupted by areas of medium to low vulnerability (See Figure 50).

On the other hand, Table 50 presents a summary of the Total, Agricultural and Cultivated area by CPs located in Groups I and II of integral vulnerability, that is, of the very vulnerable and vulnerable groups of the AIP, in both zones, as well as homes and the exposed population.

Table 50. Behavior of surface indicators[11], households and population, by Popular Councils of groups I and II – Both AIP Regions

	Total Area (ha)	Arable Land	Cultivated Land	Sugar Cane	Various Crops	Plantain	Rice	Fruit	Natural Pastures	Idle Land
Total CP AIP Central Region	**75398**	**62361**	**20471**	**12433**	**6467**	**438**	**233**	**900**	**28242**	**13648**
Very Vulnerable	**47394**	**38616**	**13300**	**7609**	**4409**	**377**	**89**	**817**	**18201**	**7115**
% In Respect to Total Very Vulnerable	**32.0**	**35.9**	**59.3**	**48.9**	**78.9**	**100.0**	**100.0**	**100.0**	**64.5**	**12.5**
Corralillo	12544	9323	2255	100	1252	136	36	730	5025	2043
Sierra Morena	10463	9278	2103	1313	775	11		4	5645	1530
Rancho Veloz	10539	8295	2980	2258	716	2	1	2	3701	1615
La Panchita	5930	5456	2861	1916	919	7		19	1736	859
Lugardita- Carahata	7918	6264	3102	2022	747	220	52	61	2093	1069
Vulnerable	**28004**	**23745**	**7171**	**4824**	**2058**	**62**	**144**	**84**	**10041**	**6533**
% In Respect to Total Vulnerable	**19.6**	**19.4**	**22.0**	**23.1**	**18.4**	**23.4**	**94.0**	**74.7**	**23.5**	**13.9**
Cascajal	15482	13278	2008	650	1177	34	127	21	6488	4782
George Washington	12522	10468	5163	4174	881	28	17	63	3553	1751
Total CP AIP Eastern Region	**215387**	**167635**	**34557**	**24028**	**10291**	**201**	**9**	**28**	**42690**	**90387**
Very Vulnerable	**100573**	**69012**	**9124**	**7942**	**1182**	**0**	**0**	**0**	**10015**	**49873**
% In Respect to Total Very Vulnerable	**71.8**	**68.1**	**47.2**	**58.7**	**24.4**	**0.0**	**0.0**	**0.0**	**38.3**	**89.2**
JOSÉ ALFREDO BAÑOS	19897	11995	2388	2157	231				916	8691
VICENTE PÉREZ	16661	14163	2196	2000	196				1180	10787
MARTIRES DE PINO TRES	17016	12796	2011	1703	308				2661	8124
GEORGINA	25230	19680	2347	2073	275				3859	13474
BATALLA DE PALO SECO	21769	10379	181	10	172				1401	8797
Vulnerable	**114814**	**98623**	**25434**	**16086**	**9109**	**201**	**9**	**28**	**32675**	**40515**
% In Respect to Total Vulnerable	**80.4**	**80.6**	**78.0**	**76.9**	**81.6**	**76.6**	**6.0**	**25.3**	**76.5**	**86.1**
CAMILO CIENFUEGOS	1047	616	226	51	173	1	0	0	217	174
SERGIO REYNO REYNA	6564	5996	1558	1029	487	40	1	0	968	3470
HERNÁN GONZÁLEZ	6113	5565	3272	2864	247	132	7	23	737	1556
AMANCIO RODRÍGUEZ	5576	4954	2159	1791	334	28	0	6	672	2123
PEDRO PLAZA	12405	10301	1129	228	901				5722	3451
CEPERO BONILLA	5343	4518	2207	1619	588				1897	414
SAN JOSÉ	13790	12547	4083	3163	920				3337	5127
BORBOLLÓN	5644	4095	2316	1840	476				919	859
PROGRESO	5988	5372	3284	2561	723				1693	394
HERIBERTO CORTES	476	191	15		15				54	122
BENJAMIN IZAGUIRRE	6714	5899	1118	656	463				3751	1030
ROBERTO REYES	10836	8868	1291	105	1186				5913	1663
MARTIRES DE JOBABO	5984	4760	229		229				1317	3215
MENELAO MORA	4744	3722	673		673				1822	1228
ENRRIQUE CASALS	16298	15216	526	52	474				1110	13580
JOSÉ SANTIAGO ERCILLA	7292	6004	1349	128	1222				2545	2110
TOTAL Very Vulnerable Both Regions	**147967**	**107628**	**22424**	**15550**	**5591**	**377**	**89**	**817**	**28216**	**56988**
TOTAL Vulnerable Both Regions	**142818**	**122368**	**32605**	**20911**	**11167**	**263**	**153**	**112**	**42716**	**47048**
TOTAL	**290785**	**229996**	**55028**	**36461**	**16757**	**640**	**242**	**929**	**70932**	**104036**
% VERY VULNERABLE/TOTAL	**50.9**	**46.8**	**40.7**	**42.6**	**33.4**	**58.9**	**36.9**	**87.9**	**39.8**	**54.8**
% VULNERABLE/TOTAL	**49.1**	**53.2**	**59.3**	**57.4**	**66.6**	**41.1**	**63.1**	**12.1**	**60.2**	**45.2**

[11] Surfaces are expressed in ha and were extracted from the Digital Map at a scale of 1: 25000 of the National Cadaster of the IPF, 2013.

Source: Prepared by the authors

Table 50. Behavior of surface, household and population indicators by Popular Councils of Groups I and II in both areas of the AIP. (Continuation)

	Non Agricultural Land	Latifolia	Natural Forest	Swamp Land	Mangrove	Households	Exposed Population
Total CP AIP Central Region	**13036**	**12581**	**1362**	**4535**	**2430**	**14288**	**32923**
Very Vulnerable	**8778**	**6048**	**1183**	**2493**	**2430**	**10621**	**20723**
% In Respect to Total Very Vulnerable	**21.8**	**10.8**	**22.2**	**12.4**	**100.0**		
Corralillo	3221	2043		1028	910	4587	6313
Sierra Morena	1185	1530	7	252	148	1293	3626
Rancho Veloz	2243	1615		1088	274	2164	6106
La Panchita	474	859		125	31	1019	2225
Lugardita- Carahata	1655	2	1176		1067	1558	2453
Vulnerable	**4259**	**6533**	**179**	**2042**	**0**	**3667**	**12200**
% In Respect to Total Vulnerable	**20.8**	**13.9**	**6.4**	**75.5**			
Cascajal	2204	4782		1413		2425	8200
George Washington	2054	1751	179	629		1242	4000
Total CP AIP Zona Oriental	**47753**	**90387**	**6782**	**18210**	**0**	**30639**	**96922**
Very Vulnerable	**31561**	**49873**	**4150**	**17549**	**0**	**5352**	**10795**
% In Respect to Total Very Vulnerable	**3.7**	**89.2**	**99.8**	**87.6**			
JOSÉ ALFREDO BAÑOS	7902	8691	178	6027		461	1803
VICENTE PÉREZ	2498	10787	160	1611		495	1630
MARTIRES DE PINO TRES	4220	8124	415	1776		1449	4254
GEORGINA	5550	13474	775	2337		2574	1830
BATALLA DE PALO SECO	11391	8797	2623	5799		373	1278
Vulnerable	**16191**	**40515**	**2632**	**661**	**0**	**25287**	**86127**
% In Respect to Total Vulnerable		**86.1**	**93.6**	**24.5**			
CAMILO CIENFUEGOS	431	174	91			2202	5506
SERGIO REYNO REYNA	568	3470	205			5156	12761
HERNÁN GONZÁLEZ	548	1556	140			700	1948
AMANCIO RODRÍGUEZ	622	2123	154			2848	9818
PEDRO PLAZA	2104	3451	697	358		1027	3165
CEPERO BONILLA	825	414	97	39		2574	8952
SAN JOSÉ	1243	5127	169	118		578	3508
BORBOLLÓN	1549	859	70	77		2027	10551
PROGRESO	616	394	104	69		1045	7893
HERIBERTO CORTES	286	122	4			2068	7197
BENJAMIN IZAGUIRRE	815	1030				527	1212
ROBERTO REYES	1969	1663	668			847	2404
MARTIRES DE JOBABO	1225	3215				1007	2675
MENELAO MORA	1021	1228				1604	4751
ENRRIQUE CASALS	1082	13580	233			347	1465
JOSÉ SANTIAGO ERCILLA	1288	2110				730	2321
TOTAL Very Vulnerable – Both Regions	**40339**	**55921**	**5333**	**20042**	**2430**	**15973**	**31518**
TOTAL Vulnerable – Both Regions	**20450**	**47048**	**2810**	**2703**	**0**	**28954**	**98327**
TOTAL	**60789**	**102968**	**8143**	**22745**	**2430**	**44927**	**129845**
% VERY VULNERABLE/TOTAL	**66.4**	**54.3**	**65.5**	**88.1**	**100.0**	**35.6**	**24.3**

Source: Prepared by the authors

Figure 50. Field Zoning of Vulnerability Groups in the AIP. Both Regions

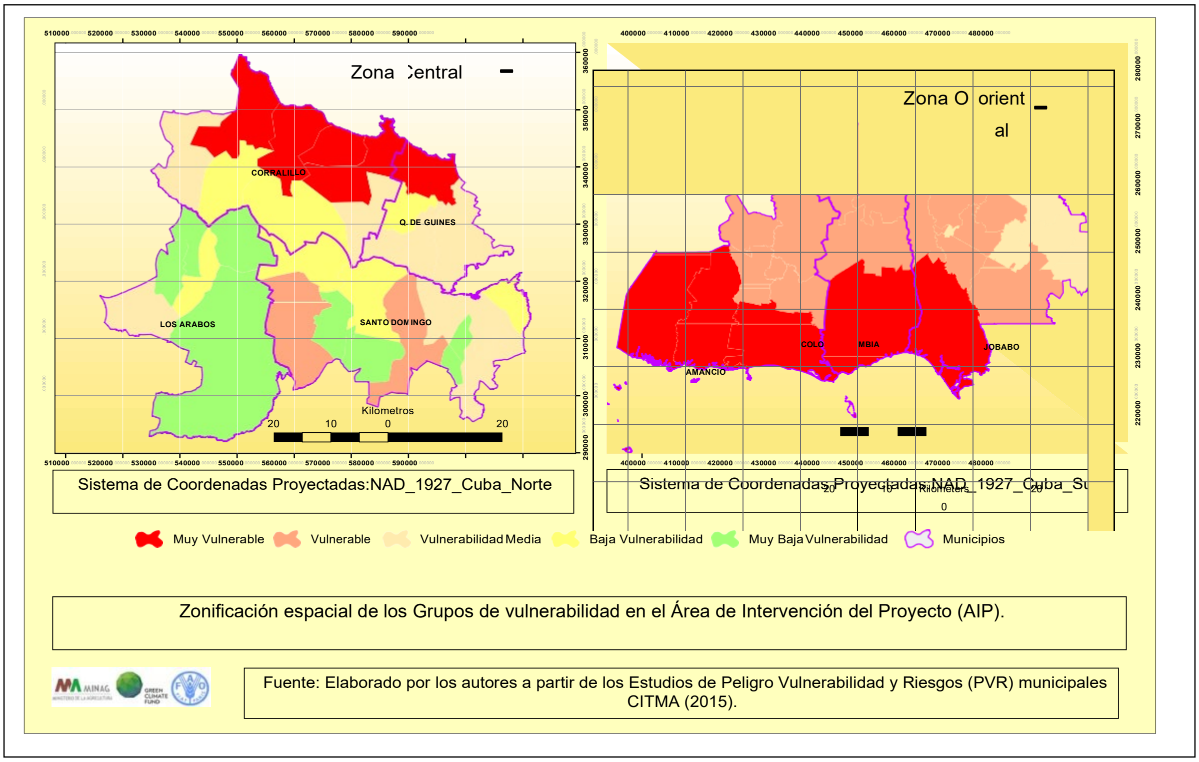


Table 51 shows the surface area cultivated between the agricultural area (land use), where you can observe very different values between AIP, favorable to the Central zone (something similar happened with the crop yields seen in the epigraph I.2.1), which must be affected by the amount of idle land covered by marabou and that becomes more critical in the AIP of the Eastern zone.

For its part, the area devoted to food production (calculated as the cultivated area excluding sugar cane), presents a less unfavorable situation in the Center's AIP compared to the AIP in the Eastern area. Certainly, the ratio of cultivated area to food in relation to the agricultural area for the CPs located in Groups I and II of integral vulnerability, is double in the Central zone with respect to that obtained for the Eastern zone (12.4% versus 6.3%).

In this sense, the higher incidence of the cultivated area of sugarcane within the cultivated area is precisely the reason why there is less availability of cultivated area for food. This situation could be understood as a reduction of the Capital of cultivated land for human consumption in the high and vulnerable areas studied. This capital is undoubtedly an important part of the livelihoods of the vulnerable population, where the project's actions focus primarily, through the application of agroforestry modules.

Table 51. "Endowment" of area by CPs belonging to Groups I and II of integral vulnerability for both areas of AIP

	Central Region			Eastern Region			Both Regions		
Hectares (ha)	Very Vulnerable	Vulnerable	Total	Very Vulnerable	Vulnerable	Total	Very Vulnerable	Vulnerable	Total
Agricultural land	38616	23745	62361	69011,8	98622,8	167634,6	107628	122368,2	229996
Cultivated land	13300	7171	20471	9123,6	25433,8	34557,4	22424	32604,7	55028
Idle land	7115	6533	13648	49872,8	40514,5	90387,3	56988	47047,6	104036
Inhabitants (inhabit.)									
Population	**20723**	**12200**	**32923**	**10795**	**86127**	**96922**	**31538**	**98327**	**129845**
Per capita (ha/inhabit)									
Agricultural land	1.86	1.95	1.89	6.39	1.15	1.73	3.41	1.24	1.77
Cultivated land	0.64	0.59	0.62	0.85	0.30	0.36	0.71	0.33	0.42
Idle land	0.34	0.54	0.41	4.62	0.47	0.93	1.81	0.48	0.80
Land Use									
Cultivated land/Agriculture (%)	34.4	30.2	32.8	13.2	25.8	20.6	20.8	26.6	23.9
Cultivated land for food									
Cultivated exc. Sugarcane/ Agriculture	14,3	9,9	12,4	1,7	9,5	6,3	5,7	9,6	7,8

Source: Prepared by the authors

CONCLUSIONS

The most relevant climatic elements are characterized by the occurrence of anomalies that reinforce the tendencies of the last decades to the increase of the average temperature and to the increase of the precipitations in the non-rainy season and its reduction in the rainy season.

The tendency to increase rainfall in the dry season is related to a decrease in the magnitude of negative anomalies from the mid-70s to the beginning of the 2000s. This fact is associated with a higher frequency of affectation of the ENSO events in this period of the year, and the reduction of the range of variation of the average values of precipitation. The reduction of rainfall accumulated in "Eastern" is largely due to the most frequent occurrence of meteorological drought processes in recent years.

The future climate of Cuba "can be described as more arid and extreme, characterized by prolonged and intense processes of drought and severe water deficit. The dry landscapes of the eastern zone will intensify and advance progressively towards the west, producing a transformation from the current climate (humid tropical) to dry sub humid with threats of occurrence of desertification processes. The current climate trends and the scenarios considered (A2 and B2 of the IPCC) for the next 100 years indicate that environmental quality deterioration will generally occur, as a consequence of the reduction of water potential, the loss of land in low-lying coastal areas, the impoverishment of the soil, the reduction of the agricultural yields, loss of biodiversity, and affectations to the coastal settlements, the increase of communicable diseases and the consequent negative impact on the economic activity".

The combined scenarios of rising temperatures, falling rainfall, decreased water potential and water quality, accompanied by the reduction of agricultural areas due to the retreat of the coast, the migration of coastal ecosystems and the expansion of the marabou, will lead to impacts higher than the estimates, on the total agricultural production and the breeding of animals in the AIP.

The potential agricultural and irrigated yields of all the crops will decrease progressively throughout the 21st century, between 10 and 25%; in the cane, between 5 and 10%; and those of the potato up to 50%. Total crop evapotranspiration will generally decrease except potato, but irrigation water needs would rise progressively (40-55% for short-cycle crops and 15-30% for long-cycle and perennial crops).

The main cause of the decrease in potential yields is the progressive rise in temperature, which not only leads to a progressive shortening of the duration of the crop cycle but also to a reduction in the intensity of gross photosynthesis and an increase in the intensity of respiratory processes.

The models of general circulation of the atmosphere and the ocean indicate an increase in the months with moderate and intense droughts, a lower availability of water

for crops compared to the current situation, and the increased vulnerability of grasslands to fires. Pasture yields will be reduced in all regions of the country; and the pasture growth process will move towards greater lignification and a lower content of proteins and carbohydrates.

The bio-productive indicators of cattle will experience, with climate change, considerable affectations with tendencies that point towards a lower birth rate, increase in the optimal age of the first parturition and the increase of the general mortality.

Although the effect of climate change on weeds would also be on rangelands, which in the case of Cuba are predominantly grasses, and could benefit from the expansion of invasive alien species such as marabou, the greater dominance of this species should be taken into account. increase in the biodiversity of pastures C 4 on grasses and shrubs C 3 in exploitation systems where the animal load is controlled, this element reaffirms the importance of the improvement of pastures and their management in systems of livestock exploitation in the conditions of AIP, where pastures are practically the only source of animal feed.

Changes and trends in the behavior of land cover and land use in the AIP detected a significant decrease in the areas of natural pastures (88508.4 ha) and cane (54625.9 ha) in the period analyzed from 2007 to 2013, a moderate growth of the various crops (21364.3 ha), notable of the forest cover (30797.4 ha) and very notable of the idle lands (78256.9 ha).

It can be considered that the increase of idle land areas, which in more than 90% are occupied by the invasive exotic species known as "marabou", is evidence that in the AIP and in particular with greater incidence in the area Eastern is a loop or spiral of environmental degradation and vulnerability aggravated by the impact and effect of climate change, particularly with the occurrence of periods of severe and intense droughts in the coastal areas concur and overlap with the threat of saline intrusion marine and requires a new paradigm of land management that contributes to increasing the resilience of the rural landscape, to reverse the processes of vulnerability and to increase the adaptation capacity of the communities.

The adaptation baseline study makes it possible to assert that both areas of the AIP are trapped in this spiral and loop of environmental degradation and vulnerability, in a process that will lead, under the effects and growing impacts of Climate Change, to a desertification of the rural landscape, what requires to begin to act immediately under the prism of a new paradigm of land management.

The results of the statistical models (Panel Data and Ordinary Least Squares), as well as the trend lines of the time trajectory of the relevant uses and coverage of the selected land in each AIP show that without a project and with the worsening of the impacts Negative on the agricultural yields derived from Climate Change of the current traditional systems of land management, cane areas and various crops in both areas are threatened with a drastic reduction or even disappear in future scenarios.

In the AIP, the surface of natural pastures, forest and idle land undergo growth trends, in the case of moderate natural pastures and in the case of forest and idle land with a notable growth trend, although there is evidence that pastures and forests can experience negative effects on their growth, varietal composition and biodiversity, which will give way to the invasion, growth and territorial dominance of marabou, which constitutes 90% of the idle lands.

The agroforestry modules proposed by the project constitute a paradigm shift in traditional forms of land management, and an alternative to face the challenge of breaking the environmental degradation-vulnerability loop and reducing and reversing the processes of desertification, degradation and salinization , creating adaptation capacities and local and territorial knowledge that increase the resilience of the most vulnerable population and households.

The effects of the drought are notable in both areas of intervention of the project, although the area affected in the CPs of the Center constitutes almost 41% of the total area of intervention, standing out in this the 7 coastal CP Corralillo and Quemado de Güines. In the Eastern zone, saline intrusion processes affect a larger area, and negatively impact the availability of water for the supply of the population and the productive characteristics of the soils.
In the AIP, approximately 60% of the soils are in a state of moderately degraded to degraded, and 67.2% of the AIP's surface classifies in the categories of areas of medium to very prone to desertification, degradation and salinization , standing out by this indicator the Central zone with

69.3%.

There is a difference between the Central and Eastern areas of the AIP. The Central zone, despite of having greater areas prone to desertification, degradation and salinization, has achieved a better environmental management of the negative effects of variability and of Climate Change that have been more associated with the incidence of extreme hydrometeorological events in which intense droughts are not excluded, while the Eastern Zone of the AIP experiences a severe process of environmental degradation and vulnerability, which requires increasing the adaptive capacity and resilience of the rural landscape in the face of climate change and the increase in the frequency and severity of droughts. Both zones require, therefore, a paradigm shift in land management.

The estimation of vulnerable households and their livelihoods, based on a numerical classification of cluster analysis applied to the field data matrix composed of the 55 popular councils, 4 threats (strong winds, intense rainfall, elevation of the mean sea level and intense droughts), and 3 variables: cultivated area, technical status of households and exposed population, identified in the AIP into five groups that synthesize the total vulnerability, categorized into: Very Vulnerable, Vulnerable, Moderate Vulnerability, Low, and Very Low.

In the CPs belonging to Groups I and II of the Central region, some 20471 ha of cultivated area are affected, meaning 33% of the total agricultural area of Groups I and II. The most vulnerable groups within the AIPs are natural pastures with 37% of the total territory, idle surface with 18%, and that of sugarcane, with 16% of the total area corresponding to these groups I and II. The area devoted to cane and various crops (25%) barely exceeds the idle area (18%). Finally, the forest area makes up only 2% of the most vulnerable area of the AIP in this area. The households belonging to Groups I and II in the AIP of the Central zone reach the figure of 14288, and represent almost 36% of the total number of households located in the area of intervention of the project. Whereas the population included in groups I and II amounts to 32923 inhabitants, and represents approximately a quarter of the population located in the AIP of the Central zone.

The total area belonging to Groups I and II of the Eastern amounts to 215 387 ha, which almost triple the most vulnerable in the AIP of the Central zone. This area included in Groups I and II, represent 90.4% of the total area of the AIP of this region. Idle surfaces (90397 ha) are predominant in this environment, of which almost 81.4 thousand ha are occupied by marabou, some 22.9 thousand ha more than the total area belonging to Groups I and II of the intervention area of the project in the Central zone and approximately 7 times more than the idle surface of the AIP of the Central zone. The households that are located in these groups reach the figure of 30,639 homes, occupied by a population, which would reach some 96922 people. The number of vulnerable households equals 80% of the total number of households that are located in Groups I, and II.

In the Center as in the East, very vulnerable categories are concentrated in the coastal areas, forming a compact strip that coincides with the Popular Councils most exposed to the threats studied and where marine saline intrusion converges. In the south of Las Tunas, the distribution of the vulnerability groups is homogeneous, transiting the very vulnerable zone located in the coastal zone and continuing with the adjacent vulnerable zones in the Central-North zone, however, in the Central AIP the distribution is more heterogeneous; the very vulnerable zone located in the northern coastal strip and is interrupted by areas of medium to low vulnerability.

As for the use of land, very different values between AIP can be observed, favorable to the Central zone, that is 33% versus 20% in the Eastern zone, which must be affected by the amount of idle land covered by marabou and which becomes more critical precisely in the AIP of the Eastern zone. On the other hand, the area dedicated to food production presents a less unfavorable situation in the Central AIP compared to the Eastern one. Certainly, the ratio of cultivated area in relation to the agricultural area for the CPs located in Groups I and II of integral vulnerability, is double in the Central zone with respect to that obtained for the Eastern zone (12.4% versus 6.3%). In this sense, the greater incidence of the cultivated area of sugarcane within the arable lands of these Groups, is what results in less availability of agricultural area for food. Such situation could be understood as a reduction of the capital of cultivated land for human consumption food in the high vulnerability and vulnerable zones studied. This capital is undoubtedly an important part of the livelihoods of the population, to which the project's actions focus primarily.

The agricultural and cultivated areas belonging to the very vulnerable and vulnerable categories of the AIP of both zones are in the order of 229 996 and 55 028 respectively. On the other hand, the number of very vulnerable and vulnerable households (Group I and II) in the regions of project implementation in both areas would reach 44,927 with an exposed population of 129,845 inhabitants.

REFERENCES AND BIBLIOGRAPHY

Centella Artola, A., Lapinel Pedroso, B., Solano Ojeda, O., 2006. The meteorological and agricultural drought in the Republic of Cuba and the Dominican Republic. Havana Cuba.

CITMA, 2013. Studies of danger, vulnerability and risks due to drought in Villa Clara.
Provincial Risk Assessment Group, CITMA, Villa Clara, Cuba.

Cuevas Valdés, L., 2016. Analysis of the behavior of the EC, SST and the Chlorides in the wells Rojas I and Rojas II. North of the Province of Villa Clara. (Diploma work). Central University "Marta Abreu" of Las Villas, Santa Clara, Villa Clara.

Cutie Cancino, V., Lapinel Pedroso, B. (Eds.), 2013. The drought in Cuba, a reference text. Institute of Meteorology, CITMA, Havana, CUBA.

Fonte, A., Rivero, R.R., Rivero, R.E., 2004. Manual of integrated study of the impacts of climate change and adaptation measures in the agricultural, livestock and forestry sector (Technical Report).

Meteorological Center of Camagüey. Scientific Department., Camagüey, Cuba.
GEPROP, 2009. Soil Map Improved at scale 1: 250,000.

Hutchinson, S., Gomes, C., Alleyne, D., Phillips, W., n.d. An assessment of the economic and social climate change in the sector in the Caribbean 87.

Institute of Physical Planning, 2013. Map of Land Use and Tenure.

IPF, 2017. Project Technical Report 8: Evaluation of the impact and vulnerability of coastal settlements due to the effects of climate change and severe weather events in the years 2050 and 2100. IPF, Havana.

Iturralde-Vinent, M.A., Serrano Méndez, H., 2015. Hazards and vulnerabilities of the marine-coastal zone of Cuba: current status and perspectives on climate change until 2100, first. ed. Academy, Havana, Cuba.

Jiménez Reyes, R., 2011. STUDY OF THE NATURAL VULNERABILITY OF AQUIFERS OF THE

NORTHEASTERN AQUIFER REGION OF VILLA CLARA, in: FOURTH CUBAN CONVENTION OF EARTH'S SCIENCES,
GEOSCIENCES'2011. Presented at the Workshop on Groundwater and Pollution, Havana, CUBA.

Lapinel, B., Rivero, R.E., Cutie, V., Rivero, R.R., Varela, N., 1993. National System of Drought Surveillance: Analysis of the Period 1931-1990 (Technical Report). Institute of Meteorology, Havana, CUBA.

Monteagudo Zamora, V., 2008. GEOCHEMISTRY OF THE SUBTERRANEAN WATERS OF THE PROVINCE OF LAS TUNAS (Thesis presented as an option to the scientific degree of Doctor of Chemical Sciences). University of Havana, Havana, Cuba.

Planos Gutiérrez, E.O., Rivero Vega, R., Guevara Velazco, V., 2012. Impact of Climate Change and Adaptation Measures in Cuba. Havana.

Republic of Cuba, 2015. Second National Communication to the United Nations Framework Convention on Climate Change (National). Havana. Cuba.

Rivero, R., Rivero, R., 2004. Integration of the impacts of climate change in the Camagüey province (Technical Report). Meteorological Center of Camagüey. Scientific Department., Camagüey, Cuba.
Rivero, R.E., Rivero, A.I., Rodríguez, A., Arredondo, I., Rivero, R.R., Agramonte, A., Barbería, M.A., Villalón, A., 2011. Case study from the South of Havana. Final Report Agriculture Sector of the Second National Communication. Meteorological Center of Camagüey. Scientific Department., Camagüey, Cuba.

Rivero, Z., Rivero, R.E., Varela, N., Perez, I., 2003. Impact of Climate Change on Forest Ecosystems (Technical Report). Meteorological Center of Camagüey. Scientific Department., Camagüey, Cuba.
Rodríguez Vega, A., Rivero Vega, RE, Zoltan, I., Rivero Jaspe, RR, Dositeo, R., Valera Garcia, N., Perez, I., 2003. Impact on pastures and cattle (Technical Report). Meteorological Center of Camagüey. Scientific Department., Camagüey, Cuba.

Somoza, J., Álvarez, P., Pérez, A., 2015. Scenario of agricultural development according to Climate Change trend (Technical Report). BASAL Project, Havana, CUBA.

Suárez Pecoso, O., 2015. Determination of the available water resources in the VC-I underground basin (Diploma Thesis). Central University "Marta Abreu" of Las Villas, Villa Clara, Cuba.

Urquiza Rodríguez, M.N., Alemán García, C., from the Rodríguez Hill, A.J., 2014.
Land Degradation. Case study: Cuba 2014 (Working Paper). DESERCUBA.

Valcarce, R.M., Rodríguez, W., 2011. CARTOGRAPHY OF THE VULNERABILITY OF CUBAN AQUIFERS USING THE MODIFIED EKV METHODOLOGY, in: IX CUBAN CONGRESS OF GEOLOGY. MEMOIRS. p. 7

Vantour Causse, A., Druz Díaz, R.O., Páez Moro, M., Martín Morales, G., Capote López, R.P., 2015. DIAGNOSIS OF DEGRADATION AND VULNERABILITY TO THE DESERTIFICATION OF LANDS IN CUBA.