Measuring the economic value of land degradation / desertification considering the effects of climate change. A study for Latin America and the Caribbean

La valeur économique de la dégradation des terres / désertification considérant les effets du changement climatique. Une étude pour l'Amérique Latine et les Caraïbes (ECLAC/GM)

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Mots clés
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Abstract
The Economic Commission of the United Nations for Latin America and the Caribbean (ECLAC), and the Global Mechanism of the Convention of United Nations to Combat Desertification (UNCCD), have implemented a joint project in order to measure the economic value of land degradation taking into account alternative scenarios of climate change.

Seven countries from Central America (Panama, Costa Rica, Nicaragua, Honduras, El Salvador, Guatemala and Belize) and seven from South America (Argentina, Bolivia, Chile, Colombia, Ecuador, Paraguay and Peru) are being analyzed; At the moment the first report about land degradation and a report on the effects of drought for Central American countries, plus and a report for Ecuador have been finished. Preliminary reports have been done for Chile, Bolivia and Peru, while Argentina and Colombia have been initiated.

The main objective of this research is to support the national economic and social authorities at different levels in the process of resource allocation to combat land degradation/desertification and the effects of drought.

In those terms, the project will end with a Base Line of the cost of degradation/ desertification for all the countries involved, and with an analysis on the potential effects derived from the long term climate change process.

Preliminary findings show that the cost of desertification varies between 8 to 14% of agricultural GDP, with significant differences within each country. The dynamics of degradation is an important issue, mainly in regions covered by tropical forests such as Ecuador and Peru.

In the Central American countries, degradation affects all the countries, but with different gradients of intensity. According to results, climate change will affect all the countries in a negative manner, reducing agricultural production till the end of the century affecting seriously affect basic crops, such as the case with corn, beans and rice.

Résumé
La Commission Economique des Nations Unies pour l'Amérique Latine et les Caraïbes, CEPALC, et le Mécanisme Mondial de la UNCCD, ont mis en œuvre un projet commun afin de mesurer la valeur économique de la dégradation des terres en tenant compte des scénarios de changement climat alternatives.

L'objectif principal est de soutenir les autorités nationaux au niveau central, régional et local dans le processus de d'allouer des ressources pour la lutte contre la dégradation, la désertification et les effets de la sécheresse.

Sept pays d'Amérique Centrale (Panama, Costa Rica, Nicaragua, Honduras, El Salvador, Guatemala et Belize) et sept d'Amérique du Sud (Argentine, Bolivie, Chili, Colombie, Equateur, Paraguay et Pérou) ont été analysées. À l'heure actuelle le premier rapport pour les pays d'Amérique Centrale, un rapport sur les effets de la sécheresse pour la même région ainsi qu'un rapport sur l'Équateur ont été achevés. Des rapports préliminaires ont été faits pour le Chili, la Bolivie et le Pérou, tandis que les études sur l'Argentine et sur la Colombie sont au commencement.

Le projet produira une ligne de base du coût de la dégradation pour tous les pays concernés, tout en incluant une analyse sur les effets possibles à long terme par rapport au processus de changement climat.
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Les résultats préliminaires montrent que le coût de la désertification varie entre 8 à 14% du PIB agricole, avec des différences significatives à l'intérieur de chaque pays. La dynamique de la dégradation est une question importante dans les régions couvertes par les forêts tropicales comme l'Équateur et le Pérou.

Dans la d'Amérique centrale, la dégradation affecte tous les pays, mais avec une intensité différente. Le changement climatique affectera négativement tous les pays à la fin du XXI, et en particulier les cultures de base comme le maïs, les haricots et du riz.

I INTRODUCTION

Desertification and land degradation is a relevant issue for LAC countries, affecting important areas where lives a significant part of the rural population.

As it was defined by the UNCCD, Desertification and land degradation is a result of climatic and anthropological factors that reduce economical and biological productivity. Climatic change influences this process and at the same time is reinforced by it.

In spite of the fact that all these countries are members of the UNCCD and have NAP to combat desertification and land degradation, the cost of inaction still remains almost unknown making it difficult to precede with accuracy the allocation of resources to combat desertification.

ECLAC and the GM are working in a joint project aiming to measure the economic and social value of desertification and land degradation in 7 countries in C. America and 7 countries of S. America.

Methodologies are based on micro data collected from agricultural censuses that have been developed for those countries that hold this information. With the other cases, an approach based on Time Series have been applied to measuring purposes, using specific production functions on the basis of the phenology of the main cultures in the affected areas.

For the impacts of climate change, estimations were made of the vulnerability of land to degradation, using criteria based on a combination of the Fournier modified index—a number of monthly drought indexes, and the aridity index. Other probabilistic projections were based on a Montecarlo model to estimate the range of values in terms of productivity for the main crops grown in affected areas.

II METHODOLOGY

The methodology is composed of different as well as complementary approaches;

1.-A geographical analysis based on GIS to:
- a) Provide an updated map of degraded/desertified areas
- b) to generate data for base line and climate projections in selected areas
- c) to establish land vulnerability to degradation/desertification

2. - A Phenological analysis for selected crops in affected areas to determine the specific requirements of water and temperature

3. - An Econometrical analysis for the base line to
- a) determine the effect of Land, Labor and Capital and climatic variables on production and productivity for selected crops
- b) to measure the differences between degraded and no degraded areas.

4. - A probabilistic projection considering impacts of climatic change for the scenarios A2 and B2 of the IPCC for the selected years

1. - Cross Section analysis

1.1. Econometric model formulation for the base line

An econometric model was formulated based on previously published and validated studies on economic impacts of desertification and land degradation.

Production functions were estimated for different types of Agricultural Productive Units (APUs) located in desertified/degraded and non desertified/degraded areas in countries that possess microdata from agricultural censuses and allow the access to it (Chile, Ecuador and Panama)

The estimated production functions were mainly in a Translogaritmic form, transformed to a Cobb-Douglas linear logarithmic form, in order to obtain directly the elasticities of output relative to each productive factor.

$Y = A\ \alpha L\ K\beta\ T\delta$

$ln(Y) = A + \alpha ln(L) + \beta ln(K) + \delta ln(T)$

Where;
A: independent term
α: coefficient of Land
β : coefficient for Capital
δ : coefficient for Labor
ln : logarithm

The quality of land was considered by including two different methodologies; in the first case a Dummy variable was used in order to differentiate if the analyzed APU were located or not in an affected area. In the same way, the interaction between each productive factor was specified for the land of affected areas. That reveals the impact of the desertification process on each specific productive factor.

$yi = \beta 0 + \beta 1{*}ti + \beta 2{*}ki + \beta 3{*}li + \beta 5{*}DES + \beta 6{*}DES{*}ti + \varepsilon i$

The other procedure consisted of creating separate estimations, one for affected areas and the other for unaffected areas, both of them with the same number of cases and inside the same geographical homogeneous region.

$y1i = \alpha 0 + \alpha 1{*}t1i + \alpha 2{*}k1i + \alpha 3{*}l1i + \varepsilon 1i$

$y2i = \beta 0 + \beta 1{*}t2i + \beta 2{*}k2i + \beta 3{*}l2i + \varepsilon 2i$

Where,

y1i if DESERTIFICATION = 0
y2i if DESERTIFICATION = 1

1.2. Calibrating and testing the model

Linear regressions were made using the STATA and EVIEWS software for agricultural areas of Chile, Ecuador and Panama. The database containing the information about the APUs, were redefined taking into consideration the different types of producers according to their assets and market relation links, desegregating it geographically according to their location on the national territory.

Through the results obtained from the regressions, it was possible to establish the relative importance of the different productive factors for each type of producer and gave way to the calibration of the model. A set of different tests were made in order to detect and correct problems of the unit roots, heterocedasticity, autocorrelation, and multicolineality. Problems with heterocedasticity were corrected through a White Covariance matrix.

1.3. Regressions analysis

Regressions were made at regional and sub regional levels, for provinces and minor entities for each country, including an interpretative analysis and selection of results.
On the basis of the obtained results and projections, estimations were made of the optimal potential production for APUs located in affected areas, obtaining good indicators of relative losses of agricultural production.

Specific estimations for each type of APU (subsistence unit, traditional commercial unit, and modern unit) at region, province, and county level, were made to establish the effect of degradation/desertification over the different ranges of productive capacity. For this procedure quantile regressions were used.

The following tables show the main results obtained, including Total Productive Factor level, losses in Production, Factors elasticity and the main test made to establish the significance of estimated coefficients and the adjusted global model.

2. Time series

Many countries do not have an updated agricultural census. In these cases, a methodology based in time series of production and productivity of main crops in the affected and unaffected areas were applied. The results were obtained through the comparison between affected and unaffected areas in terms of Agricultural Production Value.

That was the case for Paraguay where was not possible to obtain access to micro data from the agricultural census, and Peru in South America and all the Central American countries with the exception of Panama.

Time series include data of the time period between 1985 and 2008. The specification of productive functions, were made by taking into account the specific requirements, or the phenology, of each selected culture for each country and each region within the country.

Functions were mainly of Logarithmic, linear and quadratic form, and the used variables consisted of temperature, rainfall, and anomalies of both of them during the specific growth periods of plants. This implies that functions are different for each culture and even for each region.

Numerous regressions were made searching those that could represent in the best way the facts occurred in the analyzed period that was considered such as the Base Line.

Due to the fact that time series currently could present problems such as estacionarity of errors, a battery of different tests were applied with a special care for Unit Root indicators.

3. **Probabilistic projections**

In order to consider the possible impacts of climate change over cultural productivity in affected and unaffected areas probabilistic long term projections were used using a Montecarlo Model.

This model was fed with the coefficients obtained from the selected specifications for the Base Line, and with climatic data for variables such as temperature and rainfall (minimal, maximal, average, anomalies, etc) provided by selected General Circulation Models from the IPCC.

In the case of South America, the PRECIS model prepared by the INPE of Brazil for ECLAC for the ERECC Project[1] was used. The model PRECIS offers a resolution of 50 by 50 Kilometers. In the case of Central America, PRECIS was not available and a version 5 of ECHAM General Circulation Model of the IPCC was used, with a similar resolution.

The results were obtained in terms of variations of Productivity for each selected crop for scenarios A2 and B2 of IPCC for years 2030, 2050, 2070 and 2100.

4. Land degradation vulnerability

To establish the vulnerability of land to degradation taking into account climatic change, an analysis based on the following combined indicators was made;

<u>Aridity index</u>: that allows the measurement of land afflicted by drought, comparing rainfall with evapotranspiration within the same year

<u>Number of drought months:</u> measures dry and humid months through the relationship between rainfall and evapotranspiration

<u>Modified Fournier Index</u>: that gives an indication of rainfall's aggressive impacts on land

[1] Instituto Nacional de Pesquisas Espaciais
ERECC : Regional Studies of Clime Change Economy

Rain concentration Index: That gives an idea about rain concentration in some months

Using these indicators, different characteristics were identified for the base line and for the projection years in scenarios A2 and B2; where arid, semiarid, and sub-humid drought areas were affected by 1 to 3 drought months, 4 to 6 drought months, and more than 6 drought months, respectively.

The analysis was made at country and county level, measuring the affected areas for the years 2010, 2020, 2030, 2050, 2070, and 2100. All of these results were translated into maps for each country.

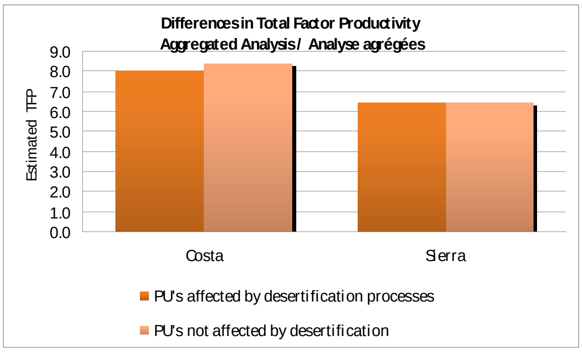
III MAIN FINDINGS

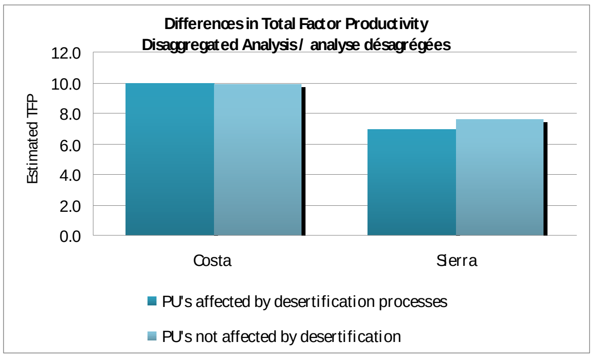
1. - Ecuador

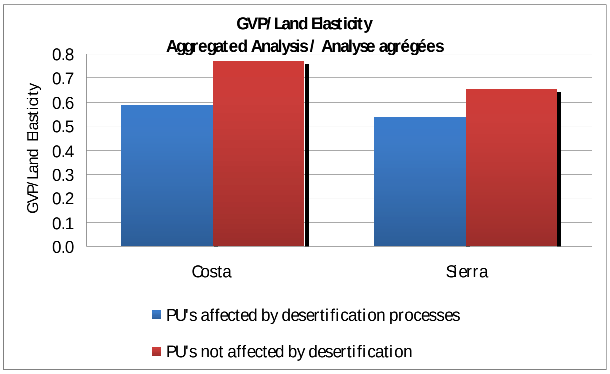
Affected APUs show a significant negative desertification effect over Total Productive Factors (TPF); Gross Value Product (GVP) -Land elasticity falls from 0,772% to 0,589%.

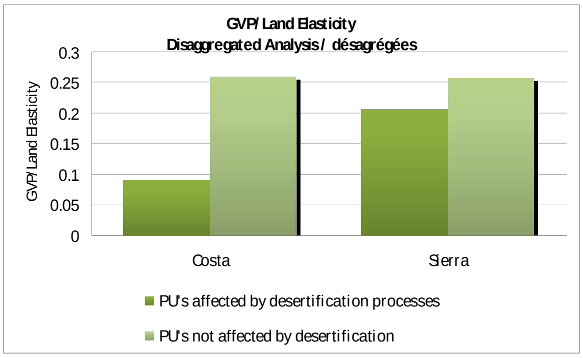
On the other hand, Labor-GVP and Capital-GVP reflect a higher APU in affected areas, highlighting the close relationship between intensive use of land and desertification.

In the case of the “Sierra” Region, desertification implies a reduction of Productivity only in terms of interaction with Land, denoting probably a very high degree of desertification and a very low previous level of TPF. In other words, a significant part of the Sierra Region had been intensively degraded and depleted of nutrients.









Losses due to degradation reach annually around 10,9 % of the Agricultural Gross Value Product as a result, 9,0 % due to the Sierra Region and 14,3 % for the Costa Region. Manabí is the most affected province followed by El Oro, Imbabura, Loja and Guayas.

At Cantones level, the most relevant losses correspond to Ibarra (Imbabura Province), Guaranda (Bolívar Province), Chone (Manabí Province), Arenillas (El Oro Province), Espejo (Carchi Province), Catamayo (Loja Province), Portoviejo (Manabí), and Celica (Loja).

In terms of dynamics, between 1982 and 2003 approximately 34.686,3 Km2 of Ecuador's territory was degraded; 25% corresponds to the Sierra Region, 30% to the Coastal Region, and the most surprising, 44.1% to the Amazonian Region.

Napo, Pastaza and Morona Santiago in the Amazonian Region, account for 36% of the total, while Manabí, Guayas and Esmeraldas in the Coastal Region contribute with 21.3% of the total. In the Sierra Region, Pichincha, Loja and Azuay represent 13%.

Almost 20% of the degraded land between 1982 and 2003, are affected by severe degradation. Again the Amazonian Region with a 46.1%, concentrate the most part of the lands affected by severe process of degradation.

In general, the majority of the Ecuadorian Provinces have an important proportion of their territories affected by severe degradation. In the first place is Cañar province with a 36% under severe degradation, followed by Morona Santiago, Carchi, Bolívar, Chimborazo, Loja, Sucumbíos, and Pastaza, with a proportion that fluctuates between 25 and 33% of the total.

2. - Chile

In the case of Chile data was processed from two Agricultural Censuses; from 1997 and 2007. In general terms in both cases, the APUs affected by degradation/desertification process present a lower TPF and lower elasticity GVP/Inputs, mainly with respect to Land.

According to the results obtained from the 2007 Census using both methodologies (Aggregated and desegregated analyses), losses vary between 6% and 16% of GVP in the 8Th Region de BioBio, to 42% in the 4th Region de Coquimbo, which is the most emblematic in terms of degradation. In the first case, data for 22,851 APUs and for the 4Th Region, 6,215 were processed.

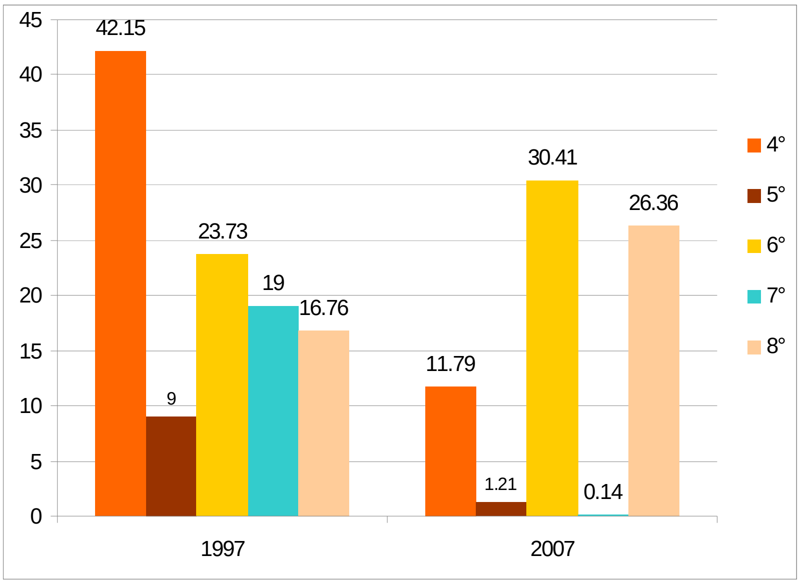
In between, the 6Th Region is the second most affected Region in terms of degradation with losses of GVP that varies around 26%. Processed data correspond to 8,036 APUs.

In terms of dynamics of degradation, and as can be observed in the graph, degradation/desertification diminish in the 4th and 5th Regions, remains equal in the 7Th Region, and increases in the 6Th and 8Th Regions. This is probably a consequence of different programs applied intensively to combat desertification and land degradation in the 4Th and 5Th Regions.

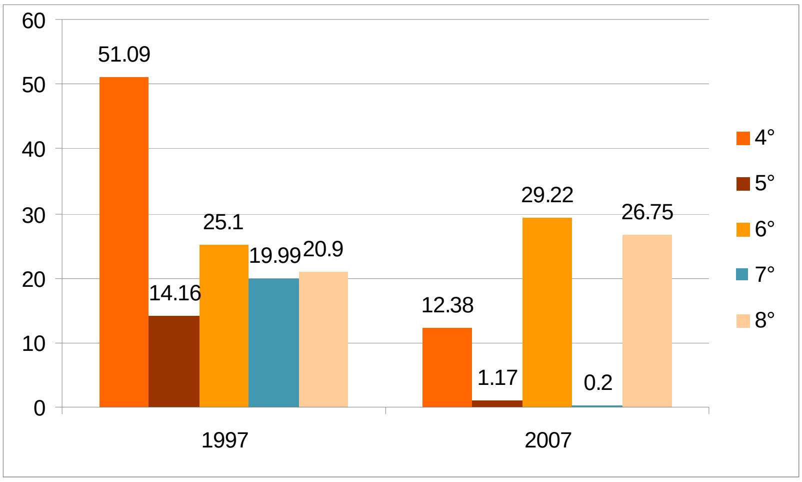
Table 1: Losses of TPF for studied Regions in Chile
Pertes de PTF pour les régions étudiés au Chili

Concept / Region	**III**	**IV**	**V**	**VI**	**VII**	**VIII**
Observations	923	6215	8036	23884	12807	22851
Losses A. Analysis (%)	183	192	13	25	17	6
Losses D. Analysis (%)	ns	42	9	27	20	16

Disaggregated Analysis / analyse désagrégées



Agreggated Analysis / Analyse agrégées



3.- Panama

As it was expected, the analysis reveals notorious differences between affected and unaffected APUs in terms of TPF. At the same time, the Optimal Production Frontier analysis reveals a differentiated degree of losses at macro regional levels of Pacifico, Caribe and Interior, and a similar situation for Provinces. The most affected Region is Caribe, that are double the Interior and almost double Pacifico region as can be appreciated in the following table.

Affected APUs show losses between 4.9% and 10.8% of their potential production in each specific region. In other words, the comparison between real production level and potential production levels show these differences.

Losses of Total Productive Factor (TPF) in terms of Potential Production
Pertes de Productivité Totale des Facteurs

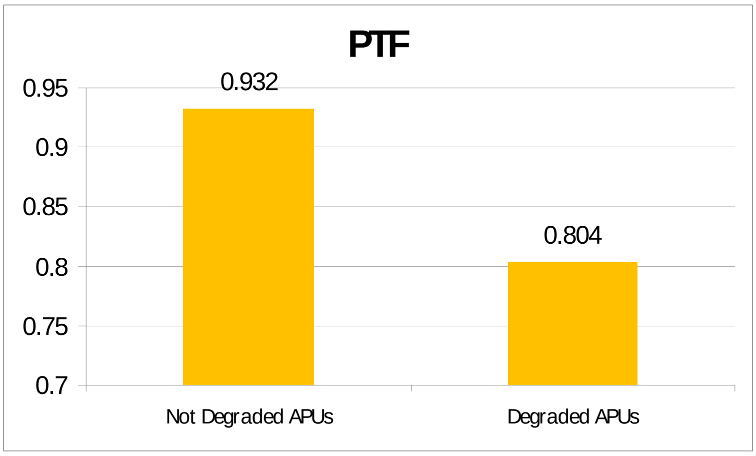


Table 2: Losses in TPF for main Regions of Panama by percentil
Pertes de PTF pour les principales régions du Panama par percentile

Percentil \ Macro-región	Pacífico	Caribe	Interior
1%	4.85%	9.24%	3.52%
25%	5.52%	10.28%	3.76%
50%	5.97%	10.79%	4.85%
75%	6.46%	11.34%	5.17%
99%	7.59%	14.82%	5.91%
Media	6.03%	10.79%	4.87%

In general terms, affected areas suffer a severe loss of TPF, and consequently, a loss of income level. Due to the fact that affected areas have a surplus of labor, elasticity GVP/Labor is negative.

4.- Other Central American Countries

4.1. - Dynamics of degradation

According to GLADA data, it is possible to distinguish three situations;

a) Guatemala is the country where degradation advances the fastest. Between 1982 and 2003, around 59% of its territory was degraded.

b) Costa Rica, El Salvador, Honduras and Nicaragua show a similar path and rate of degradation (29% to 38%).

c) Panamá and Belize have the lowest rate of degradation with 11% and 13%, respectively

4.2. - Current situation and projections

According to the obtained results, all the countries suffer losses due to degradation, as can be seen in the following table. Around the year 2020, Belize, Honduras, and Guatemala will be the most affected countries. Results appear in terms of percentage over the base line.

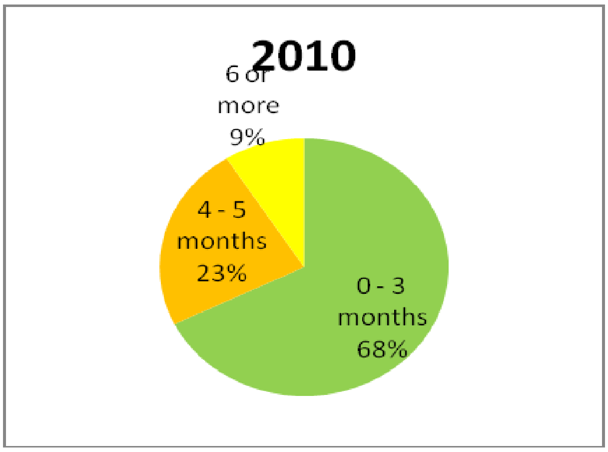
Till the end of the century, Belize will remain as the most affected country in proportional terms, while Guatemala and Costa Rica will be the countries that will increase their losses significantly.

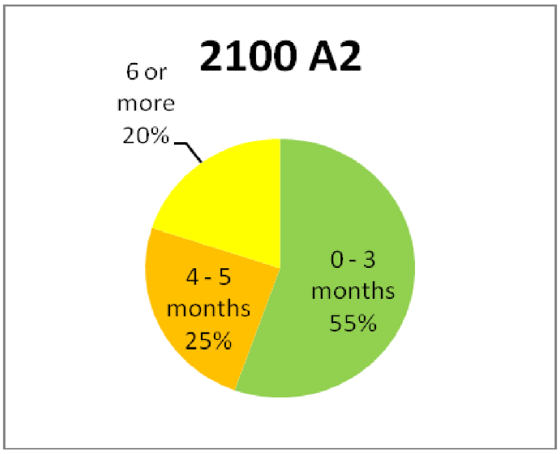
Table 3: Losses due to degradation in Central American countries with respect to the Base Line situation (% of Agricultural Gross Value Product)

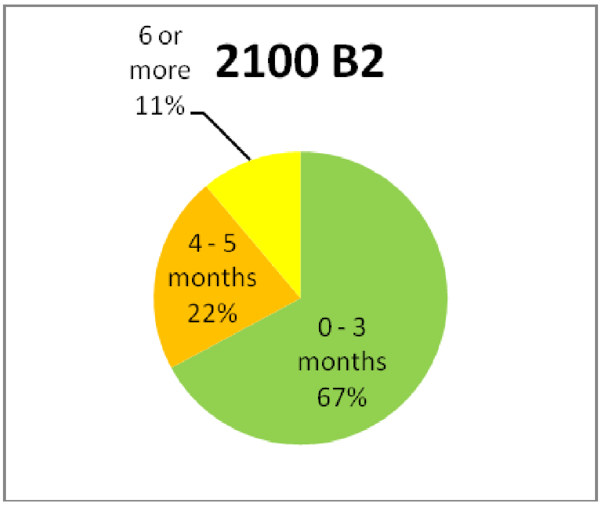
Les pertes dues à la dégradation dans les pays d'Amérique Centrale à l'égard de la situation Base Line

Country / Year	2020	2050	2100
El Salvador	1,29	3,97	6,67
Guatemala	-5,84	-4,56	-23,21
Panama	-5,56	-3,77	-4,27
Honduras	-10,5	-5,71	-7,71
Nicaragua	-0,20	-0.51	-4,26
Costa Rica	-4,79	-5,96	-11,20
Belize	-13,25	-16,63	-20,50

Relative to vulnerable areas to degradation due to climate change, affected areas by drought months will increase significantly for the year 2100 in scenarios A2 and B2, as can be observed in the following graphs. Between an 11 and 20% of land will suffer 6 or more drought months by the end of the century.

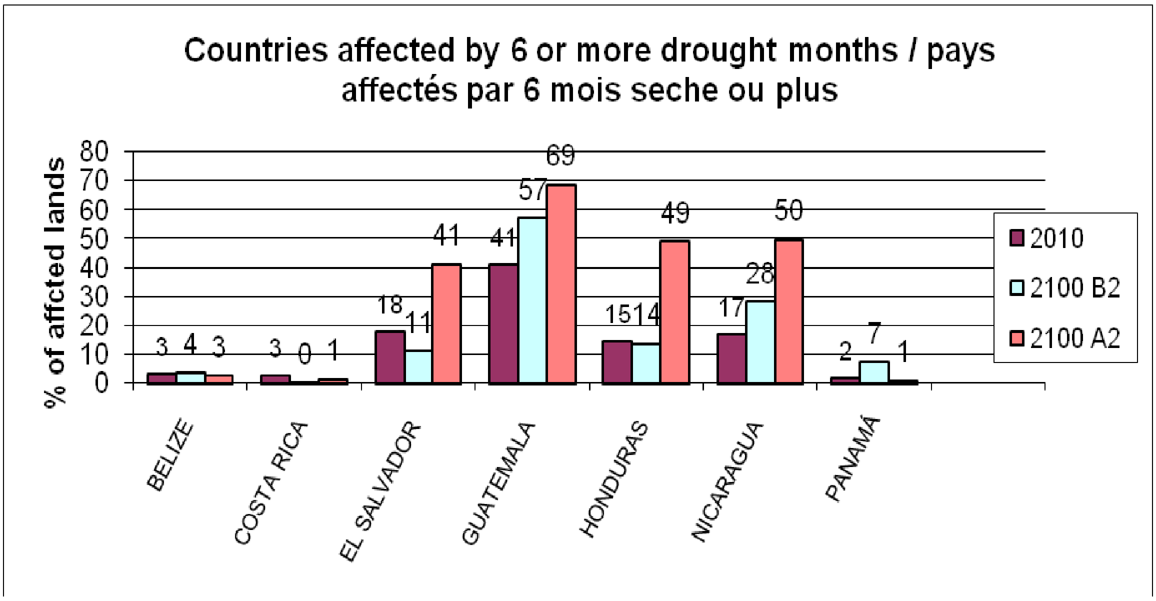






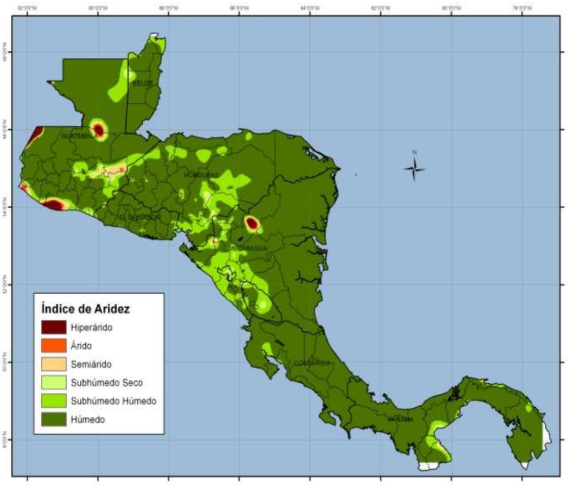
Between the years of 2010 and 2100, Guatemala and Nicaragua will increase their participation in the total affected areas by 6 or more drought months if scenario B2 is considered.

Within the countries, affected areas by 6 or more drought months will increase in El Salvador, Guatemala, Honduras and Nicaragua considering scenarios B2 and A2, as can be appreciatted in the following figure.

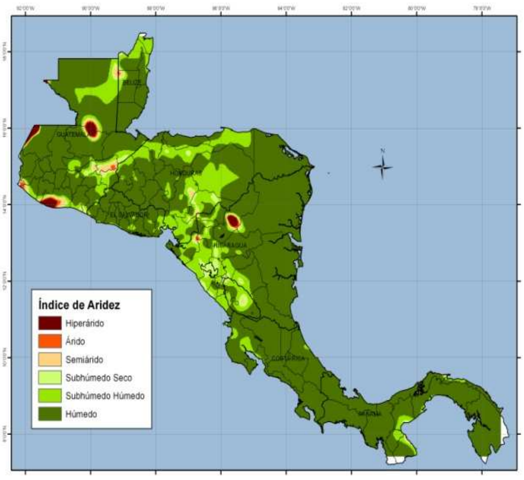


In conclusion, the area currently affected by drought will increase by the year 2050 and 2100, affecting all the countries as can be observed in the following maps that show the area as known as the “Arco Seco” Region.

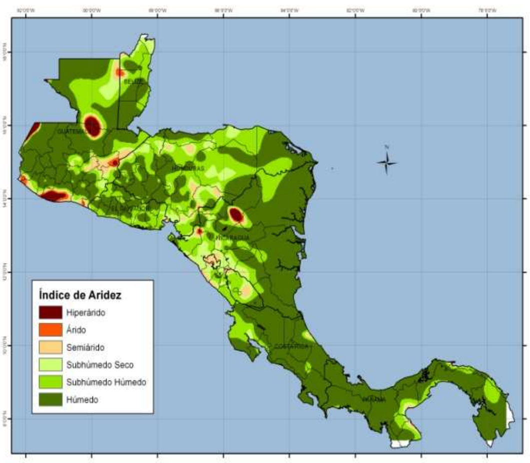
2010



2050



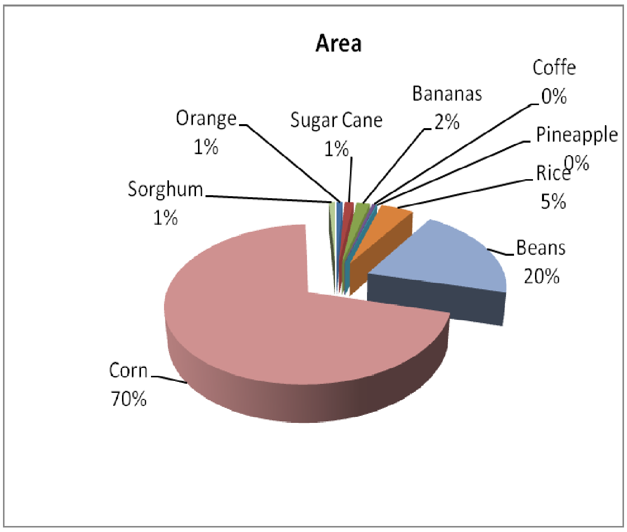
2100

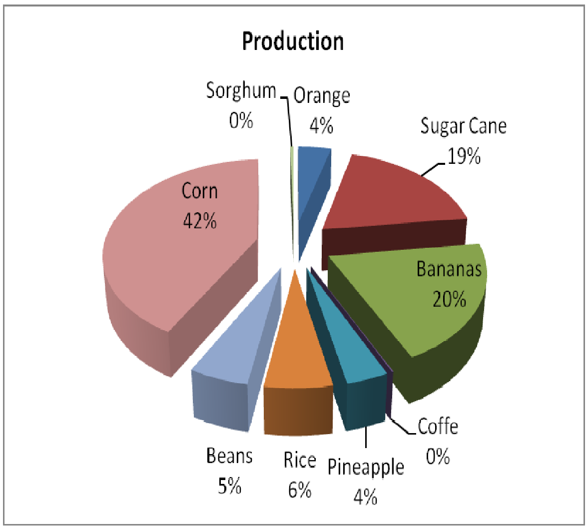


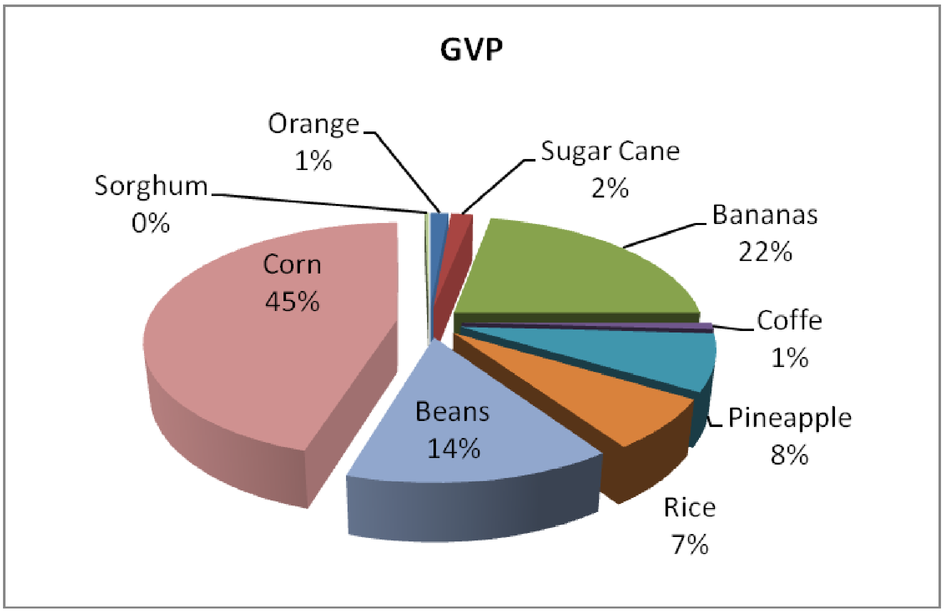
The final area, production and GVP losses in products, are presented in the following charts. As can be observed, losses in basic foods are quite significant. In terms of the area, corn, beans, and rice account for more than 90% of losses due to climate change and degradation. A loss in production for basic food implies around 53% of the total, and a similar figure is measured by the GVP.

Impacts of this magnitude for basic foods could be catastrophic for Central American countries, putting their population in extreme danger.

Losses in Area, Production and GVP in 2100, Scenario A2







IV Conclusions and final comments

The following conclusions and comments corresponds to a research that are still in course. In spite of, it is important to highlight that the applied methodoly, can be used to measure economic impacts and costs taking in account clime change scenarios. Access to agicultural microdata census, allows to obtain better and more robust estimations and at the same time, to construct new cathegories of producers, and to desaggregate information at different territorial levels.

Results must take such as a first indication about the magnitudes and direction of the degradation / desertification costs, but can be useful for desition makers at different levels making more detailed analysis according governmental priorities in each country.

It is important to declare that the obtained results reflect only externalities asociated to productive activities alocated in areas by degradation and desertification. Externalities related with social aspects are not yet included

The preliminary results obtained suggests that land degradation and desertification costs varies annually between 8 and 14% of the Agricultural GDP with significant differences between regions in almost all the examined countries.

Dynamics of degradation is relevant mainly in tropical forests such as Amazonian region from Ecuador and Peru due to the human productive activities, like informal gold mining

In Central America, Guatemala, El Salvador, Honduras and Nicaragua, are affected by serious problems of degradation and drought in areas with a high density of population.

Clime change is a factor that contributes to the degradation / desertification process, but human activities are quite significant and will continuous being the main factor for the first half of the century. In spite of this fact, combined effects of degradation and clime change could create a catastrophic situation in terms of basic foods, especially with corn, beans and rice in Guatemala, Honduras, El Salvador and Nicaragua.

In order to give a more efficient support to policy makers, it is necessary to make more detailed studies on the cost of inaction o degradation and desertification considering the impacts of clime change.

It is urgent to considerer a detailed research on the social costs associated to degradation / desertification process and the effects of drought, combined with clime change considerations, especially those related with food security, employment and migration.

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