*CARIWIG Case Study Report 5*

# Assessment of Climate Change Impacts on Agriculture on Cayo District, Belize

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## Summary

- This report presents the results of a preliminary study on the potential impact of climate change on main staple crops in the region of Cayo District, Belize. Modelled crops included dry beans, maize, and vegetables. A preliminary analysis of the impacts on breeding animals was also undertaken.
- CARIWIG tools were used to provide the RCM outputs directly as climatic inputs for the climate models.
- The crops studied showed decreasing trends in their yields over the coming decades.
- An increase of the thermal stress suffered by breeding animals because of temperature rise is also foresee. The potential of natural grasslands to feed and support livestock is projected to be reduced with climate change, according to the results.
- Nevertheless, actual yields are far from potential yields, given that the technological efficiency is poor. Improving techniques and management may allow farmers to achieve yields nearer to potential values, resulting in a net increase in actual yields even if potential yields decline.

## Aim and objectives

After face-to-face conversations with farmers, we realized that they are concerned about the impacts that climate variability has on their crop production. They usually do not know much about climate change, but they are aware of climate changes that have already occurred. The major concern of farmers in the Cayo District is about flooding, some concerns about extended dry spells within the dry season, and for small farmers there is the problem of competitive prices of major producers with access to better machinery and resources. Smallholders are also worried about instability of climate, which could put them in a debt situation hard to deal with. Bigger farmers are concerned with the stability of regional markets and expanding their markets in the region.

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- National Livestock Association
- Belize Institute of Statistics
- National Resource Unit, Ministry of Agriculture
- Hydrological Unit, Ministry of Agriculture
- Caribbean Agriculture Research & Development Institute (CARDI)
- University of Belize
- Caribbean Community Climate Change Centre (CCCCC)

In this explorative study it is not possible to identify plausible solutions to all problems found in the preliminary situation characterization; therefore, it focused only on providing policy makers and stakeholders with insights into the implications of the plausible (but not definitive) climate changes identified here. Policy makers and other stakeholders may then empower themselves in knowing what to expect in the near and medium terms, so they can know how far ahead current crops can be maintained. With this information to guide them, they should be able to make decisions in a more informed manner.

# Which tools were used? How and why?

For crops, we employed DSSAT 4.5 (Jones et al., 2003; Hoogenboom et al., 2010), a suite of multiple biophysical crop models.

The SPUR2 v2.2 model was used (Benioff et al., 1986), emulating the presence of grazing animals over a rangeland. Only food (grasses and others plants) availability in grasslands and thermal stress conditions were addressed as impacted factors in livestock raising activities. The carbon dioxide fertilization effect was not considered in either case. Five functional plant species groups were addressed: warm season grasses, cold season grasses, warm season forbs, cold season forbs and shrubs.

The Dairy component of the LIFE-SIM model (León-Velarde et al., 2006 & 2008) was used to estimate milk production in a cow-calf producing system.

In the analysis, we used baseline Information from the National Livestock Association, the Belize Institute of Statistics, the National Resource Unit and the Hydrological Unit, both from the Ministry of Agriculture (2014), the Caribbean Agriculture Research & Development Institute (CARDI), the University of Belize, the Cuban Institute of Meteorology (INSMET), and the Caribbean Community Climate Change Centre (CCCCC).

Climatic data requirements comprises surface variables including daily mean, max and minimum surface temperature, relative humidity, wind speed or wind run, and solar radiation. Only a couple of rain fed analysis were performed, which required precipitation as well, but are not included on this report for the sake of simplicity.

Climate change scenarios were derived for 15 spatial cells (i.e., 25 km grid squares) from the PRECIS Regional Climate Model (RCM), nested in forcing fields from two GCMs, namely HadCM3 and ECHAM5, which are part of the CARIWIG tools and can be obtained from the CARIWIG Portal. This CARIWIG RCM outputs were used directly as climate input to the models. HadCM3 scenarios used the multi-parameter ensemble technology, for DSSAT (aka, crops) just the aenwh-pp ensemble was used, it was compared with the aexsa-pp for one crop and results were not dissimilar. All six available HadCM3 ensembles/scenarios (aenwh-pp, aexsa-pp, aexsc-pp, aexsk-pp, aexsl-pp and aexsm-pp) were used in the livestock analysis.

Other tools, like the weather generator (WG), were available, but the RCM outputs provided a more complete set of variables required for the impact models. Both the WG and the RCM are the most physically consistent sets of variables that are available at present for the period 1961 – 2100. Spatial resolution was also significantly better than the scarcer network of weather stations so the whole region could be studied in a more extensive manner.

Crop varieties were chosen from the pre-calibrated, already available varieties in the models based on different criteria. Seasonal behaviour, potential yields, and in some cases rain-fed yields were estimated. Potential yields are very useful as they indicate an upper limit for rain-fed yields and irrigated yields. Rain-fed yields, on the other hand, indicate the lower limit for irrigated yields.

FAO's software New LocClim v1.10 (Grieser *et al.*, 2006), was used as recommended by Rivero (2008) to provide inputs such as altitude and growing period.

SAMPA's mapping component (Rivero Jr. *et al.*, 2012) was adapted under the scope of this project to produce the spatial distribution maps for Cayo District.

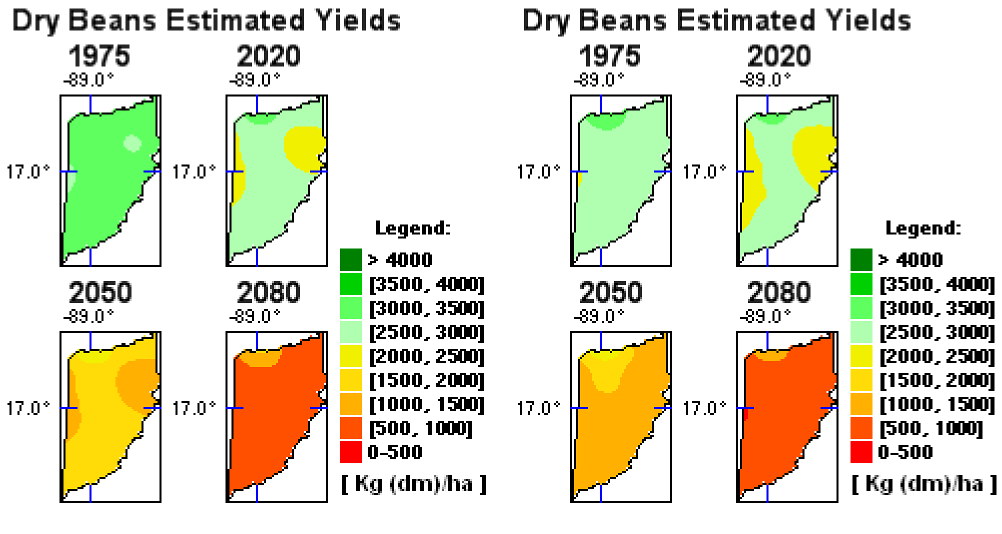
# The findings

According to New LocClim computations, the Cayo District has one humid period starting by mid-June and extending to mid-January. The growing season, including both the moist and the humid period, extends from the first days of May up to the first decade (10 days period) of February. Temperatures are higher from April to September and then decrease significantly reaching their minimum by January. On the other hand, maximum temperatures are high throughout the year. Annual mean daily temperature amplitude --also known as diurnal temperature range by climatologists-- for Belize is around 7.3 ˚C, though a consistent monthly amplitude of 10 to 12 ˚C is observed for some cells.

## DRY BEANS

Simulated dry matter yields in the 20th century (1975 in the plots range from 1500 to 4000 kg/ha (Fig. 1). This compares with reported mechanized dry bean production yields of around 1600 to 1700 kg/ha for Belize, and reported red kidney bean yields of around 1000 kg/ha.

Going into the future, dry bean crop yields are projected to decline.




a) HadCM3 (scenario aenwh-pp) b) ECHAM5

Fig. 1. Spatial distribution of the 30 years mean yield in kg/ha of top-yielding 5 varieties under climate change scenario aenwh-pp. Green boxes (cells) around year 2080 are the L Group. Represented years are the approximate centroid of the 30 years periods being averaged, actually, the centroids fall exactly at the end of the stated years.

The results clearly indicate that the projected future climate for Belize is not very suitable for the dry bean crop in Cayo District.

When modelling with the ECHAM5-forced RCM output, the situation is slightly worse, as projected yields over the 21[rst] century tend to decrease faster than in the HadCM3-based runs.

## CORN

Corn yield has been reported as 4200 lb/acre (around 4700 kg/ha) by MAF (2010). 2006 – 2007 yields were considerably lower, ~3000 kg/ha for mechanized practices and ~1900 kg/ha for other farmers (MAF, 2008). MAF stated that an effort to increase to 3500 lb/acre (~4000 kg/ha) was going to be carried out. According to data from the National Statistical Institute, mechanized maize production averaged around 3000 kg/ha, with districts averages ranging from 2200 to 3800 kg/ha.

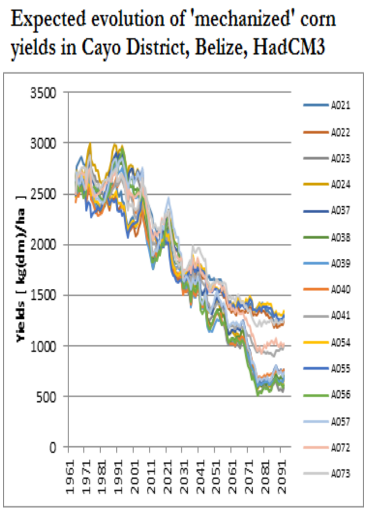



Fig 2. Projected evolution of maize yields with climate change for different spatial cells, showing a high degree of correlation.

Table 1. Yields at the end of 21[st] century compared to 20[th] century modelled yield for the selected varieties in this study.

| Variety | Name | Final Yields Relative to actual values |
|---|---|---|
| 1 | GL 482 | 23 % |
| 2 | PIO 3475 orig | 22 % |
| 3 | EXCELER | 23 % |
| 4 | CORNL281 | 25 % |
| 5 | V.SHORT SEASON | 26 % |
| 6 | PIO 31G98 | 25 % |

Simulated potential corn yields in this study using 172 maize varieties ranged from 850 kg/ha to as high as 12 000 kg/ha, with yearly peak values of around 14 000 kg/ha. So, in this case study a set of varieties were selected representative of present yields for different agricultural practices, but still capturing the variability from high to low yields.

For corn (Fig. 2), all cells show a major decrease in yields towards the end of the century. For mechanized corn, production is projected to be reduced to just over 25 % of 20[th] century values. Similar trends are found for all other varieties (Table 1).

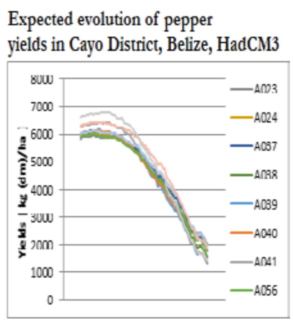



Fig 3. Projected evolution of pepper yields with climate change.

## VEGETABLES

Different vegetables (pepper, tomato) were modelled to assess impact of climate change on this sort of agricultural production.

### *PEPPER*

Pepper yields show the same decreasing trend as the other crops reported above (Fig. 3).

By the end of the century, we can expect a relatively large number of years when no yield is obtained at all (null yields). The same behaviour was found by Ramírez *et al.* (2013) for maize using the Production Function Approach.

Simulated rain-fed yields were lower than the potential yields by 500 to 1000 kg/ha, indicating an efficiency factor of around 0.84, and thus giving farmers scope for improvement by means of the use of proper irrigation systems.

### *TOMATO*

Simulated tomato yield estimates for 1975 range from 5.0 to 7.5 ton/ha. Future potential yields are projected to be halved by the end of the century (Fig. 4).

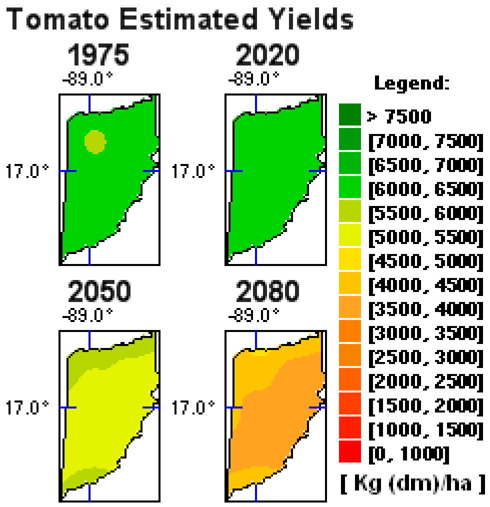



Fig. 4. Yield spatial distribution for tomato under HadCM3 climate change scenario. Yields are expressed in kg/ha.

GENERAL OBSERVATIONS REGARDING CROPS

In general, all simulations show a common trend towards an increase in the year-to-year variability of the yield as the 21st century advances.

That might be due to a number of factors, as the increased uncertainty in the climate modelling or a greater number of 'unlucky' years (a greater number of years in which yield is very poor or just null for a given period, for example, periods of 9 to 30 years).

## LIVESTOCK

Results show a decreasing trend for net primary productivity and standing biomass amount in Belizean grasslands during the 21$^{st}$ century even in the absence of grazing animals, especially for live biomass. The ratio between live biomass and dead biomass is projected to decrease from 2.0 to 1.6 under the HadCM3 scenarios and from 1.8 to 1.6 for the ECHAM scenarios. Bovines can consume both kinds of biomass, but live biomass is generally preferred and is available in larger amounts.

It is likely that aerial biomass, as the basic food for animals, will decrease during this century in all types of soils. For one out of the six HadCM3 scenarios there is an initial increase in biomass during 2006-2035 compared with the actual baseline climate, but rather abrupt decreases in aerial biomass are indicated for the rest of the century.

So, natural food availability for grazing animals will be stressed with climate change.

Currently, livestock managements involves practices in an extensive manner in Belize. Under these conditions, a modest 1.3% decrease in milk production was obtained at the end of the century.

In all cases, the mother cow ended her lactation cycle weighing less than at the beginning.

Our analysis suggests that livestock practices and obtained yields in actual climate are very far from their potential values. Consequently, even if climate change strongly affects grass yields and its nutritional value, a parallel increase in livestock production could be obtained by introducing better technological practices and management practices than those used today that are currently available.

As for thermal stress, conditions could become very harmful during this century, especially in the 10 am to 4 pm time window.

# Implications for policy and planning

As only potential yields were analysed, and considering that potential yields are related only with climatic conditions and not with soil properties distribution, the results obtained for Cayo District can be considered valid for the whole country as a first approach.

All results point in the direction of a decrease in land productivity during this century, which is in agreement with earlier studies (see Ramírez *et al.*, 2013). The Ministry of Agriculture with the lead of scientific institutions should implement and monitor a National Program to Cope with Climate Change negative and harmful impacts. This program should take into account that actions should be planned according to the fact that the entire Caribbean basin will be impacted in a similar way.

Modelled impact results show that there exist a so-called "yield gap" between simulated potential and water limited yields or productivity with actual ones. The ratio between these yields with actual yields is usually referred to as a "technological efficiency ratio". It is a very important consequence of any analysis that, by improving technological efficiency, we could in the future achieve higher agricultural production even if potential productivity is decreasing due to climate change.

Technological efficiency could be improved in many ways: by introducing irrigation systems, better adapted crop varieties and cattle breeds, using covered crops, a more rational use of fertilizers and through many other measures that could be implemented by agricultural and agronomical institutions.

It is important to support professional research, biotechnological research, or empirical tests at farm level, to obtain varieties better adapted to expected conditions. Effort could also be addressed to assess whether or not it would be advisable in some cases to replace crops with other crops coming from regions in which climate is now similar to the future conditions expected. This would require changing farmers and consumers' way of living, and building capacity into cropping different crops.

Efforts should also be addressed into building capacities in agro management practices among farmers, especially of newly incorporated ones, and promoting knowledge exchange between advanced farmers with better production levels and other farmers.

# Feedback on the tools

RCM outputs proved to provide good enough temporal and spatial resolutions. Nevertheless, for more specific analysis --like the influence of the diurnal temperature cycle on human and animal comfort-- it would be advisable to save at least daily maximum and minimum relative humidity. For a more complete set, surface air temperature, relative humidity, and wind speed could be saved for 3 to 1 hour time intervals.

Emphasis should be done in providing other formats for the climatic output. Especially in the form of point or cell time series. It can also be addressed to provide it fully compatible with most popular impact models like DSSAT, WOFOST, CENTURY, APSIM, and LIFE-SIM, among others, or to develop tools for data format interchange.

# What more could be done?

Rain fed yields could not be computed by using the real Cayo District soil information. A generic soil layer common for every cell was used instead when assessing rain fed yields. Though information could be retrieved separately as a GIS soil layer with general classification and, on the other side, with books found and scanned relating Belize's soils in some areas, the connection between both these sources of information could not be done due to several factors such as connectivity, time, and lack of personnel.

In the future, this is a must-be-done exercise that can significantly enhance the outcomes and give more meaningful results to stakeholders. Nevertheless, time and other resources need to be allocated when planning to do so in order to create the tools that should be used to do the connection between both these sources of information, as well as the connection with the DSSAT suite of models, which are point-intended tools, rather than spatial intended tools.

A comparative impact multi-model study using a different set of crop models like those provided in the WOFOST series should be implemented. This would provide more reliable and trusty results (Rosenzweig *et al.,* 2013).

In next future studies, the expected values for a Temperature Humidity Index (ITH), which can be computed with a subset of the variables provided by the RCMs for this study, should be computed and analysed in depth in order to find the seasonal and daily variation of such an index. This index can be correlated with many important behavioural traits of cattle as voluntary feed intake, new-born mortality and increase in weight gain rates.

Crop management under covered conditions might be evaluated as well.

It would be very important to calibrate models to varieties that are actually used in the country, so analysis tools may provide much more information on actual situation.

# References

Benioff, R., S. Guill, and J. Lee (1996): Vulnerability and Adaptation Assessments: An International Handbook, Version 1.1, U. S. Country Studies Management Team, Kluwer Academic Publishers, Dordrecht / Boston / London.

Grieser, J., R. Gommes, and M. Bernardi (2006): New LocClim - the Local Climate Estimator of FAO. Geophysical Research Abstracts, Vol. 8, 08305, 2006. SRef-ID: 1607-7962/gra/EGU06-A-08305

Hoogenboom, G., J.W. Jones, P.W. Wilkens, C.H. Porter, K.J. Boote, L.A. Hunt, U. Singh, J.L. Lizaso, J.W. White, O. Uryasev, F.S. Royce, R. Ogoshi, A.J. Gijsman, and G.Y. Tsuji. 2010: Decision Support System for Agrotechnology Transfer (DSSAT) Version 4.5 [CD -ROM]. Hawaii.

Jones, J.W., G. Hoogenboom, C.H. Porter, K.J. Boote, W.D. Batchelor, L.A. Hunt, P.W. Wilkens, U. Singh, A.J. Gijsman, and J.T. Ritchie. 2003: DSSAT Cropping System Model. European Journal of Agronomy 18:235 -265.

León-Velarde, Carlos, Roberto A. Quiroz, Raúl Cañas, Javier Osorio, José Guerrero and Danilo Pezo (2006): LIFE - SIM: Livestock Feeding Strategies Simulation Models. Natural Resources Management Division Working Paper No. 2005-6. International Potato Center.Ed. Peru by Comercial Gráfica Sucre, January 2006, ISBN 92-9060-267-8, 46 pp.

León-Velarde, Carlos, R., Roberto Q. G., Raul C. C., José G. R. and Javier O (2008): LIFE-SIM; Swine Simulation Model. Version 8.0. International Potato Center, CIP, Production Systems and the Environment Division. Av. La Molina, 1895, Apartado 1558, Lima 12, Peru. 19 pp.

MAF (2008): Annual Report 2008. Belizean Ministry of Agriculture and Fisheries (MAF), 89 pp.

MAF (2010): 2010 Annual General Meeting Report. March 18th and 19th, Emerald Paradise Resort, Yalbac Village, Cayo District, [Ed. Richard Merrill], 38 pp.

MAF (2014): Agriculture Related Maps. Located on the server: http://geoserver.bndsi.gov.bz, run by the Belizean Ministry of Agriculture and Fisheries (MAF).

Ramírez, Diana, Juan Luis Ordaz, Jorge Mora, Alicia Acosta and Braulio Serna (2013): BELIZE: Effects of Climate Change on Agriculture. Agricultural Department Unit of the Economic Commission for Latin America and the Caribbean (ECLAC), Subregional Headquarters in Mexico, Printed in United Nations, México, D. F., January 2013, 76 pp.

Rivero, Roger (2008): Workbook on Climate Change Impact Assessment in Agriculture: Basic Knowledge, Methodologies and Tools. Edited by THE COMMONWEALTH SECRETARIAT. ISBN 978-976-95260-1-3 (PBK), EAN 9789769526013, 142 pp.

Rivero Jr., R., A. Hernández, R. Rivero, G. García, Y. Echavarría, E. Plasencia, I. Pérez, A. Rodríguez, C. Ferrer, J. Morejón & I. Pérez (2012): SAMPA: Sistema de Apoyo Meteorológico a la Producción de Alimentos (aka. Meteorological Support System for Food Production). Proceedings of the III CONGRESS OF TROPICAL METEOROLOGY “Convención Trópico 2012”, Palacio de las Convenciones, La Habana, Cuba, may 14 – 18, 2012, 22 pp.

Rosenzweig, C., J. Elliott, D.Deryng, A. C. Ruane, C. Müller, A. Arneth, K. J. Boote, C. Folberth, M. Glotter, N. Khabarov, K. Neumann, F. Piontek, T. A. M. Pugh, E. Schmid, E. Stehfest, H. Yang, and J. W. Jones (2013): Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison. PNAS Early Edition, 23 pp.

Santos C. and S. Garcia (2008), “Climate change vulnerability and adaptation assessment for Sugarcane and Citrus.” Belize Second National Communication (SNC) Project UNDP, Caribbean Community Climate Change Center.

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