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RESEARCH ARTICLE

PERSPECTIVES OF CLIMATE CHANGE IMPACTS FOR AGRICULTURAL CROP AREAS IN CENTRAL AMAZON

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ABSTRACT

Odontogenic This study aimed to assess the impact of warming up to 5 °C in air temperature in Santarém-PA region and other meteorological variables, such effect of climate change highlighted by IPCC (2007) using a biosphere-atmosphere interaction model (SiB2), using LBA data and calibration of the Biosphere-Atmosphere SiB2 interaction model proposed by Llopart (2009), in order to infer possible changes on soybeans and maize productivity in the region due to these changes. The study showed that the SiB2 model calibrated to the Tapajos National Forest can simulate real future scenarios for the region. The simulations enabled to realize that the changes in the scenarios will have a negative effect on soybean yield in the region when analyze the limiting factors. As for the maize, future scenarios don't present a major risk of production losses, given the physiologic and anatomical characteristics of the culture.

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INTRODUCTION

Santarém City, a Pará state city on central Amazonia where is localized production units, agribusinesses and hulling the multinational Cargill Agricultural S.A is today one of the most active in Pará agricultural production. According to the Agricultural Bulletin of Pará (BAEP, 2015), launched in 2015 by FAPESPA/SEDAP, Santarém participated with a significant state production of maize (*Zea mays* (L.)) in 2013, totaling 4.51% of state production. With regard to soybean (*Glycine max* (L.) Merrill) production, as BAEP (2015), the city appears in 4th place in the state ranking, with the highest yields of soybeans, accounting for 7.54% of the state production, and as stated El-Husny *et al* (2001), Santarém characterized as city-pole of the lower Amazon region. The agriculture, as says Gornall *et al,* (2010) is a highly influenced activity by weather and climate conditions. Climate changes potentially threaten the traditional farming systems, but also provide opportunities for improvements (GORNALL *et al,* 2010). So it's important to agricultural productivity, which is carried out new studies of the impact of climate change on agricultural ecosystems.

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There're prospects that these climate change intensify the occurrence of extreme weather events such as ENSO (El Niño Southern Oscillation) phenomenon, characterized by an anomalous warming of Pacific ocean surface waters, causing changes in wind patterns and moisture transport in South America (MARENGO, 2011). Such events can directly affect the agricultural productivity of certain crops. To Silva *et al.* (2001) in Pará State, the soybean crop is in full expansion in the Northeast and West as an alternative use of degraded areas by replacing the forest by pastures. With regard to the productivity of this crop, the harvest of 2014/2015 was obtained 3024 kg / ha and crop 2015/2016 3104 kg / ha, especially a small increase in the state's productivity against other regions of the country (CONAB, 2015). About the maize, Pará is an important production center of this grain in the Region North, with a productivity of 3232 kg/ha with a production area of 218 million hectares (CONAB, 2015).

Soybean agrometeorological needs

Soybean is one of the most important crops in the world economy. Its grains are widely used by the agricultural, chemical and food industry. (COSTA NETO & ROSSI, 2000 cited by FREITAS, 2011). Soybean needs water in all its biochemical and physiological phases for a good development to occur, since this mineral is 90% by weight of the plant (EMBRAPA, 2011). According to Embrapa (2011) and authors like Pereira (2002) it's essential that the availability of water occurs in two important periods of the plant, the time of germination/emergence and flowering/grain filling, being water deficit or excess cause disuniformities. It should be noted therefore that the need for water for the soybean crop varies between 450-800 mm/cycle, depending on weather conditions, management and duration of the cycle (Embrapa, 2011), always aiming at maximum efficiency. According to the Embrapa (2008) the soybean crop has good adaptability to temperatures between 20 °C and 30 °C, and optimal for the development and growth of the plant to rotate temperature around 30 °C. According Pellegrino *et al* (2007), soybean is considered sensitive culture, because it's a C3 plant, which in turn, doesn't support high temperatures and intense solar radiation, given that has low photosynthetic rates and higher degree their stomata opening having a greater water loss, showing low productivity in environments with such conditions.

Maize agrometeorological needs

The maize, as a C4 plant has high rates photosynthetic, and lower degree of openness of its stomata with a smaller loss fluid, it's quite demanding in water, but in contrast to this, using the water absorbed maximum way, besides being a culture that has broad adaptability. It's known that soil temperatures below 10 °C and above 40 °C cause damage to germination, with the optimal range lying between 25 °C and 30 °C, according to Cantele (2009). Embrapa (2009) emphasizes that the minimum range required by the plant is 350 to 500 mm for the culture to produce without the use of irrigation. Note also that in hot and dry weather conditions, water consumption rarely exceeds 3 mm/day, and the period of flower initiation of maturing, can reach values of 5 to 7 mm/day.

Climate change and its effects on agriculture

The human action on the environment over the years has accentuated the emission of polluting gases into the atmosphere, which in turn accentuate the effect of global climate change. In addition to Marengo (2009) as a result of climate change has been the increase in extreme weather events, both in terms of quantity and intensity, and these events came to be seen more clearly from the twentieth century. In studies related to the topic, authors such as Taiz & Zeiger (2004), claim that such increases in carbon dioxide concentration in the atmosphere, try to benefit the agricultural crops development, such as soybeans and maize given that CO_2 is the primary substrate for the process of photosynthesis of such cultures. The same authors, however, point out that if this increase is accompanied by a sharp increase in air temperature, there's possibility of a shortened development cycle and increased respiration of the plant tissue, which in turn, reduces or cancels the beneficial effects of CO_2. In addition, other studies include effects on pests, diseases, soil and other aspects of the agricultural production system (PELLEGRINO *et al,* 2007). In interaction between climate change and agriculture context, one can infer that, while these changes provoke strong and direct impacts on variables that influence the soybean and maize development, the temperature is mentioned, for example, sectors as food production ones, would be affected to the point of Brazilian production areas, gradually lose the productivity potential.

Interaction biosphere-atmosphere models

According to the Intergovernmental Panel on Climate Change (IPCC, 2007) average global temperatures have increased even faster rate of approximately 2 °C per decade, and is expected in the next 2 to 3 decades, with tendency to occur most likely in cultivated land areas (Cestaro, 2012). A tool that is being improved to just the last decades to better understand the dynamics of the biosphere-atmosphere interaction is the development of models that represent the terrestrial vegetation (Sellers *et al*, 1986). In accordance with Domingues (2014) it would be great important have a model that could diagnostic unit surface area "fed" weather data in time step, comprising physical modules that describe the transfer momentum, the radioactive transfer in the canopy, water diffusion in the soil and the assimilation of carbon. In agriculture, the application of these models constitutes a tool that allows us to quantitatively evaluate the influence of climatic conditions on the growth, development and productivity of agricultural crops (Rio, 2014).

OBJECTIVES

General Objective

Assess the impact of warming up to 5 °C in air temperature in Santarém-PA region and other meteorological variables, the effect of climate change highlighted by the IPCC (2007), using a model of biosphere-atmosphere interaction (SiB2), in order to infer possible changes in crop yields of soybeans and maize in the region due to this heating.

Specific Objectives

- Use SiB2 model (Simple Biosphere Model), to produce climate change scenarios due to the increase in air temperature.
- Assess the impact of the conditioning parameters of productivity of soybean and maize due to future climate change.

MATERIALS AND METHODS

Study Area

The study area is located in Tapajos National Forest (FLONA) in Para State, according to Llopart (2009). The micrometeorological tower (02° 51'S, 54° 58' W) located in the Primary Forest is located at a distance of approximately 67 km from Santarém-PA, and was instrumented with the main objective to verify the physical, biophysical and biological biosphere-atmosphere (Saleska *et al* 2003; Hutyra *et al,* 2007). The set of data used in this work belongs to LBA (Large Scale Biosphere-Atmosphere Experiment in Amazonia), whose daily averages are from 2006 year. The instrumentation was fixed on a tower 67m high (type Rohn 55G-Peoria IL with triangular base, 46 cm cross section and fed 1000W / 120V / 60Hz) in the soil and tripods 2m high into the forest.

Description sib2 model

The SiB2 model (Simple Biosphere Model; SELLERS *et al*, 1986) is considered at biophysical point of view, a pioneer and realistic model to be based on the physical processes of surface-atmosphere interaction, designed to interact with general circulation models atmosphere. The model requires that prescribe, for each grid point, the physical, physiological and morphological parameters of the surface, assumed an average representation of vegetation and soil in the area of the cell (LLOPART, 2009). The momentum transfer in SiB2 model uses the morphological parameters of vegetation and describes the exchanges within and above the canopy by trajectories that the aerodynamic resistance of each layer is associated, employing a closure scheme of the first order, implemented in Fortran 77 routines (SiBX / MOMOPT, SELLERS *et al*, 1989). The SiB2 model is prescribed for eleven prognostic variables and a set of equations that control energy balance in the canopy on the soil surface and deep soil, intercepted water storage (soil and canopy) and the water balance in the layers soil model, in addition to the vapor conductance of water by the canopy (DOMINGUES, 2014).The prognostic equations, for example, have a surface temperature equation:

$$C_g \frac{\partial T_g}{\partial t} = Rn_g - H_g - \lambda E_g - \frac{2\pi C_d}{\tau_d}(T_g - T_d) - \xi_{gs}$$

Where we have: C_g: heat Capacity; Rn_g: available radiation; H_g: Sensitive Heat Flow; λE_g: Latent Heat Flow; T_g - T_d: temperature; ξ_{gs}: Energy Exchange in phase changes of intercepted water. The calibration of SiB2 model used in the preparation of this work is given in Llopart (2009).

Biome Parameters

To Llopart (2009), the parameters that define the classes of vegetation and soil in SiB2 model are divided into invariant parameters and variations with time. The first group came phenology or just seasonal or temporal change of vegetation variations, which can be exploited with satellite data, since the second group did not. The physical properties of vegetation and soil and physiological parameters that were used in the preparation of this work can be found in the study of Llopoart (2009) being the same used by Sellers *et al*. (1989) and Rocha *et al*. (1996).

Simulation

With the number of times 1-year data using the model calibrated by Llopart (2009), it was created a first output data to the current temperature conditions. After the creation of this series called "out", it was added 1 °C at any given air temperature in the data input file used by the model and made it a new spin, creating new outlets with temperature rise scenarios air, up to a maximum of 5 °C. In each round, the other model output variables has a different response to increasing temperature, and compared between each round.

REUSLTS AND DICUSSIONS

Air Temperature

Figure 01 shows the series of temperature increase of simulations to 5 °C from data measured in the tower (observed data, here called "Original"). Is showed that the highest temperatures occurred from July, when the accumulated of rainfalls decrease. Based on these scenarios, it's possible to infer that from an increase of 4 °C in air temperature, the culture of soybean would decrease productivity in the region, since being a C3 plant, has low yields when subjected to high temperatures (Pellegrino *et al*, 2007). In this type of environment is the phenomenon known as photorespiration in C3 species that is considered as a self-defense process of the photosynthetic apparatus, especially in plants exposed to high light intensities (Pellegrino *et al*, 2007). As for maize, because the air temperature doesn't reach the threshold level of 35 °C, productivity wouldn't be compromised, according to Pellegrino *et al* (2007), due to the fact of being a C4 plant, and possess anatomical and physiological characteristics that imply a greater ability to live in warmer environments with high solar irradiance, making it reportedly better able to withstand the summer conditions in temperate regions. In this scenario, you can infer that the C3 species are less prepared for the temperature rise of the C4 species.

Model Calibration

Figure 02 shows a comparison between the net radiation measured in the tower (observed Rn) and the estimated Rn by

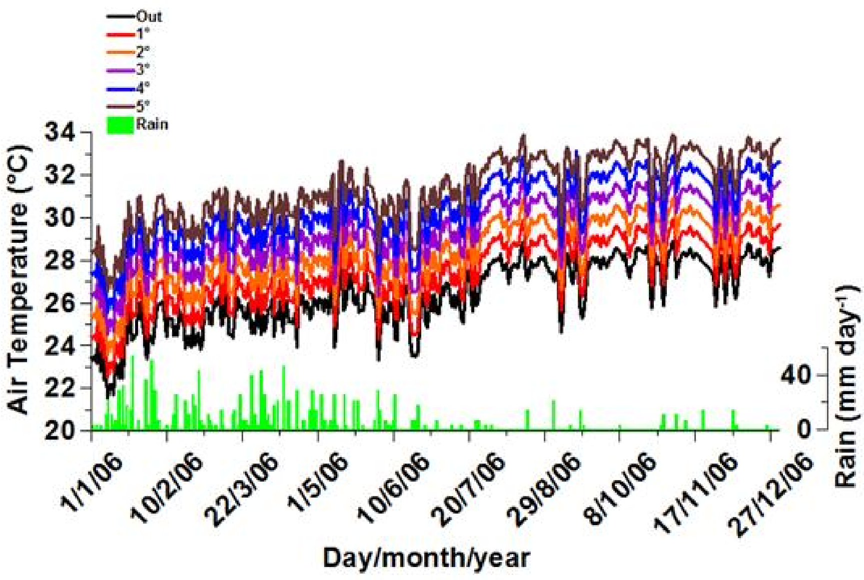

Figure 1. Climate change scenarios for temperature and precipitation (PRP) with the increase up to 5 °C

the model used in the preparation of this work. Is showed that are a good calibration and close aproximation between de data simulated and observed. Not only the change over the average time profile is similar as the absolute values are very close, showing that the model calibration can satisfactorily reproduce the present conditions, making it possible to make inferences to the changes in air temperature due to future climate change.

Radiation Net

Figure 03 indicate that the net radiation scenarios will tend to increase in virtually all times of the day, probably as a result of increased greenhouse altering the radiation balance on Earth causing part of the radiation that would be lost to space return to the surface (PEREIRA, 2007), due to increased concentration of greenhouse gases. This confirms the involvement of the type C3 crops like soybean, and not affecting crops as maize, since it has adaptable characteristics as said before.

Latent Heat Flux

Figure 4 indicate that more energy is used to change the physical state of water in the form of latent heat. This effect is more pronounced in the early hours of the day and decreases throughout the afternoon, indicating that the model assimilates a likely estomatal control of vegetation, because due to the large increase in evapotranspiration plants tend to decrease their gas exchange with the atmosphere not to miss much water (COSTA, 2015). Moreover, this increase in evapotranspiration (Figure 5) implies that there will be more water demand of crops in the region, and the climate change scenario indicate reduced rainfall in it, as stated by Saad *et al*, (2010), probably the cost of production will significantly increase due to the need of the use of irrigation technologies, and harm family farming that has both access and resources for the use of these techniques.

Sensible Heat Flux

Figure 06 indicate a decrease of the sensible heat as the temperature increases. This is probably due will most of the available energy is converted to change of physical state of the water, as shown above. This pattern of decreasing sensible heat and latent heat increase shows how would be made to partition the available power in the temperature increase scenarios, showing the energy privileging available to evaporate water at the expense of heating the air, causing local evaporative

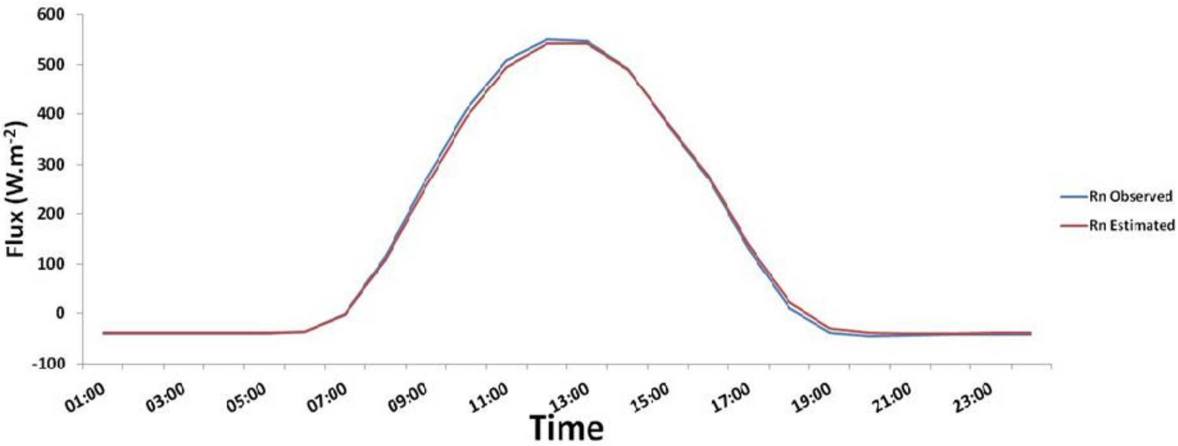

Figure 2. SiB2 model Calibration, managing to satisfactorily reproduce the present conditions

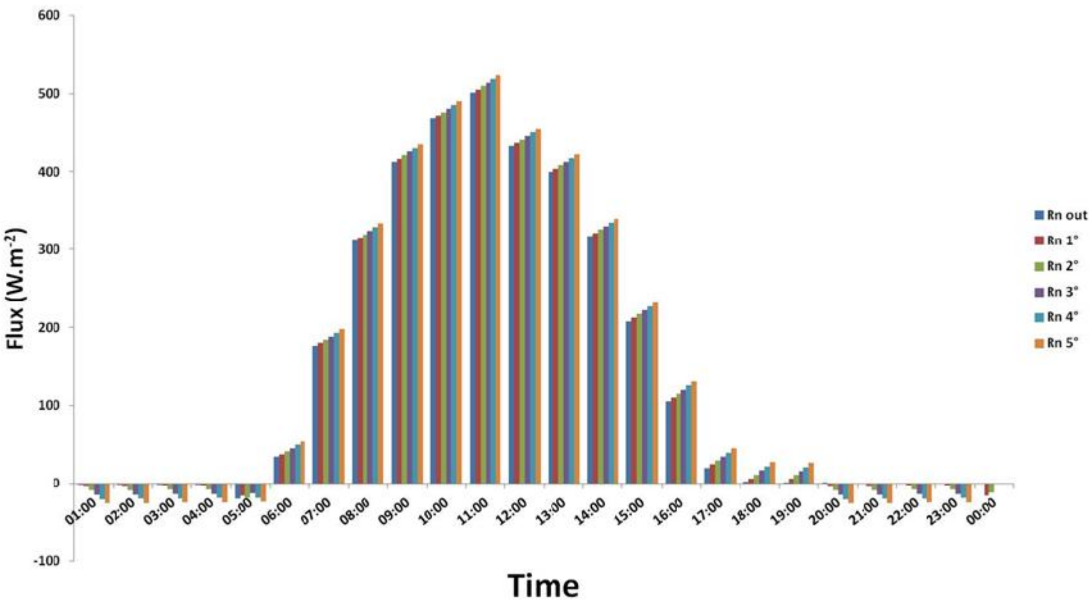

Figure 3. Climate change scenarios for the radiation balance hourly

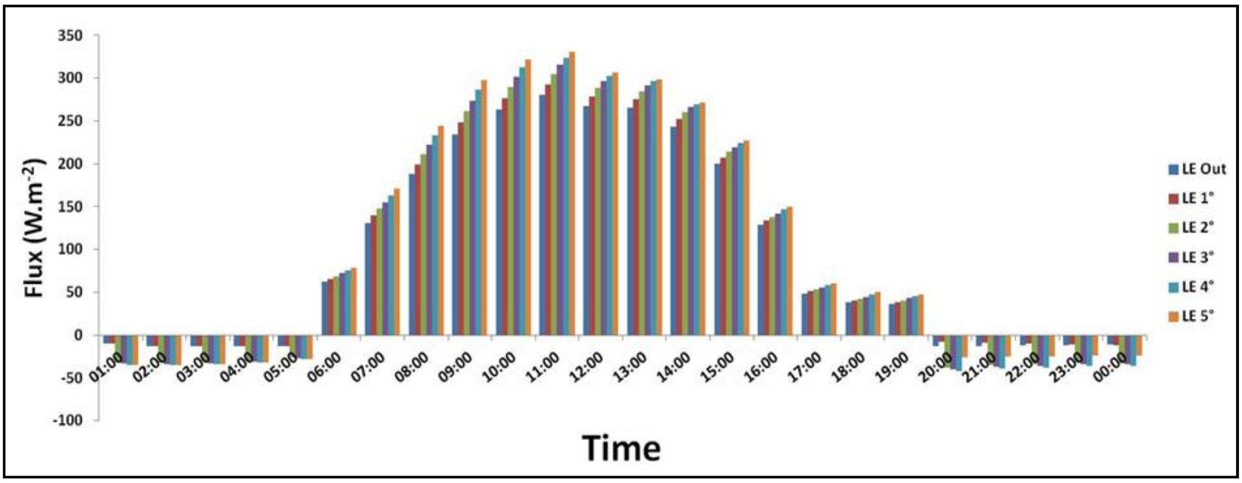

Figure 4. Climate change scenarios for the latent heat flux hourly

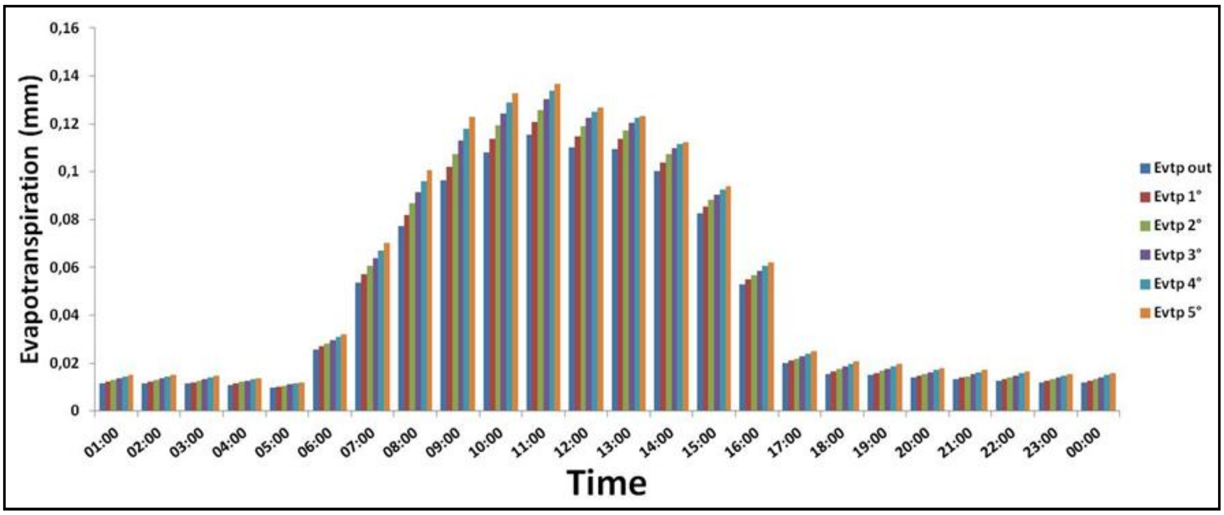

Figure 5. Climate change scenarios for evapotranspiration

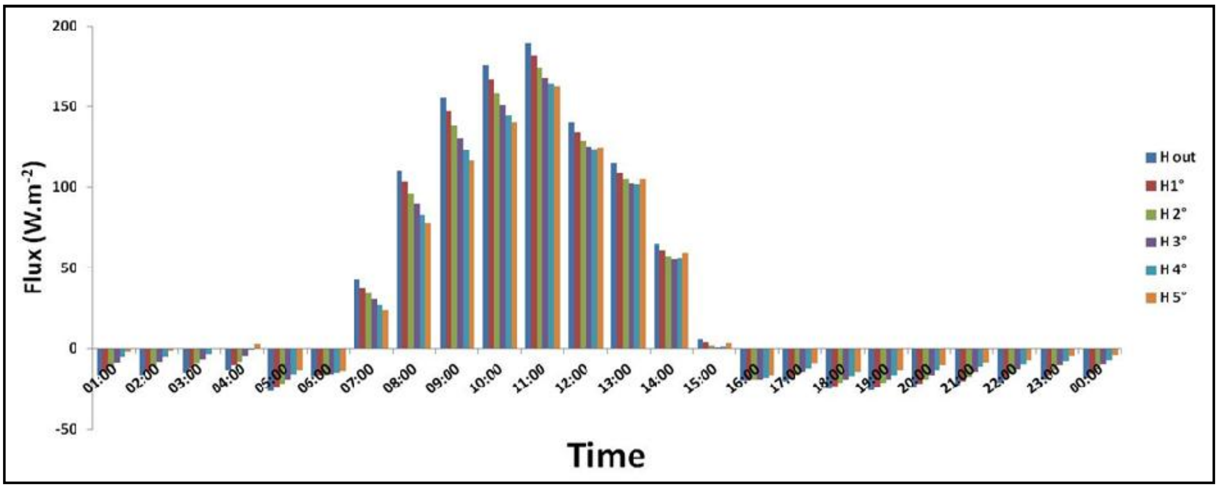

Figure 6. Climate change scenarios for the heat sensitive flow hourly

demand increase substantially and requiring higher fluid intake, which probably will not happen by rain but by increased demand for irrigation, raising production costs of local cultures.

CO_2 Flux

Figure 07 indicate that the temperature increase becomes greater nighttime breathing forest and diurnal decrease photosynthetic capacity with lower CO_2 assimilation.

These temperature effects on CO_2 standards have been commented on in other works as Costa (2015) and show a worrying scenario, where the forest, which is usually responsible for capturing atmospheric CO_2, will be not a CO_2 sinkhole and become a source of CO_2 into the atmosphere. This has serious implications for the region's agriculture, as the advance of the agricultural frontier would be an enhancer factor of the problem, since the current land use change and its consequences, such as claims Balsan (2006) "the destruction of forests and genetic biodiversity, soil erosion and contamination

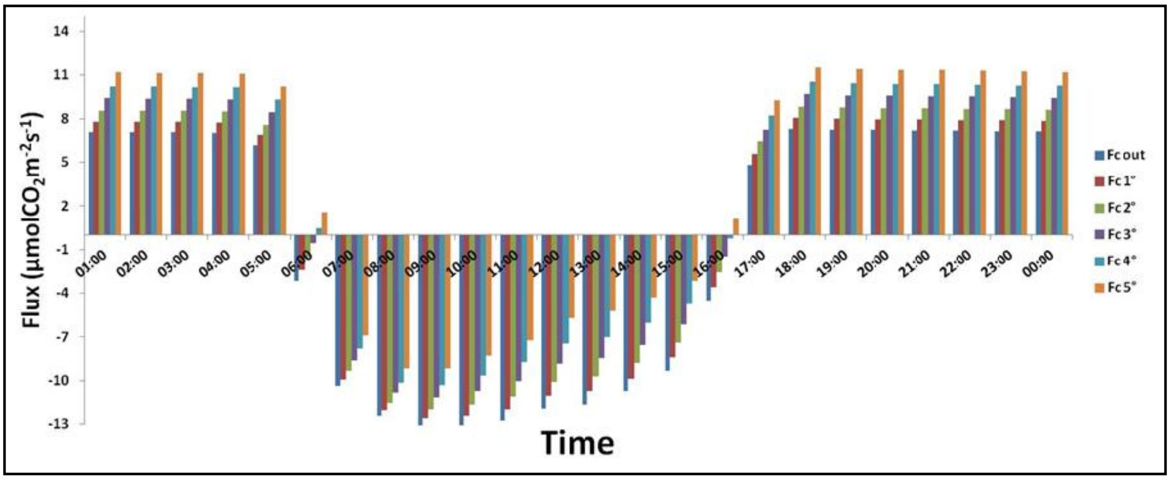

Figure 7. Climate change CO2 for time flow

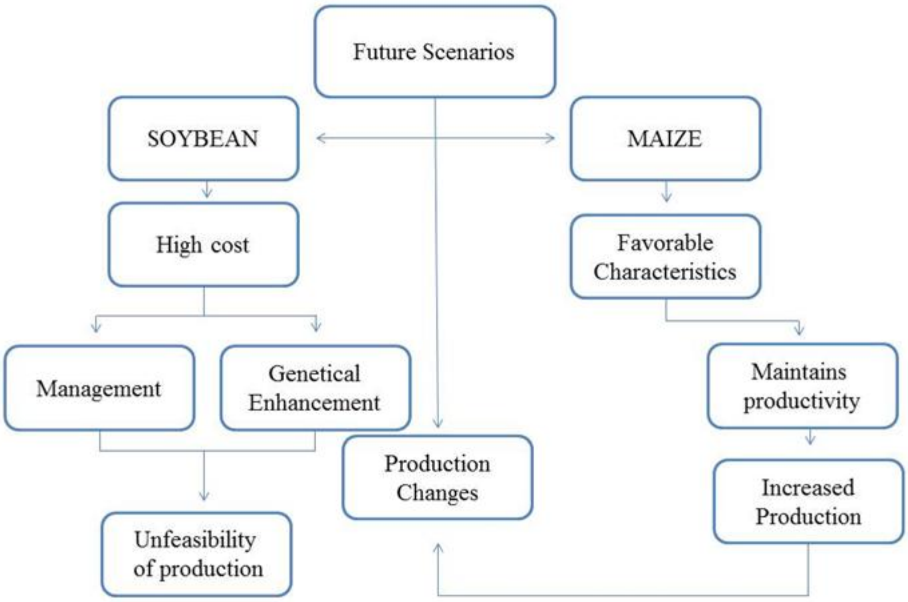

Figure 8. Flowchart for future scenarios

of natural resources"; greatly affect the intensification of climate change which would undermine food production not only at the local but also regional.

Conclusion

This study showed that the SiB2 model calibrated to the Tapajos National Forest represented satisfactorily the latent heat flux, sensible heat, CO2, evapotranspiration, net radiation and can be real scenarios simulated future for the region. The simulations made it possible to realize that the changes in the scenarios will have a negative effect on soybean yield in the region, when analyzing temperature and evapotranspiration as a limiting factor for crop productivity. As for the maize crop, future scenarios don't present a major risk of production losses, given the physiologic anatomical characteristics of the culture. With the results projected by SiB2 model and considering the high cost of any technological developments in both the crop management and in its breeding, it's inferred that it would be impractical to continue with the production of soybean in the Santarém region. For maize, however, the possibility of production is acceptable and may even be inferred that in future maize exceed the production of the commodity flagship of agricultural production in the region.

As the influence the weather has on cultures is through a combination of different climatic elements, it's important that all these climate interactions are analyzed, as well as appropriate management practices for crops, soil influences and the availability of nutrients for plant reaches the optimum productivity, among other important features for the development of economic crops. Thus, it's possible to estimate future scenarios for agricultural production in the region, and through them, to study new possibilities for mitigation, in the best possible use of available resources through appropriate techniques. There's enough time and technology to do so, being necessary to develop appropriate public policies and invest more in research to meet the aforementioned demand.

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