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# Future Scenarios and agricultural strategies against climatic changes: the case of tropical savannas.

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## 1 - Introduction

Increasing concern is being expressed in scientific papers and conferences as well as in popular books, in newspaper articles, as well as in professional magazines regarding the increasing emission of gases to the atmosphere and its effects on human life. Global atmospheric carbon dioxide has risen from 315 ppm in 1958 to about 345 ppm currently, and is expected to double by the end of the next century. Population growth imposes a need for more food and fuel to be consumed. Consequently agriculture production must expand either vertically ( increasing productivity ) or horizontally ( increasing area ). In increasing productivity, more fuel is required to meet the new technological level ( equipament size, field operations, etc. ). In expanding horizontally new areas must be incorporated and deforestation is usually inevitable. In both cases a multitude of questions can be raised concerning carbon dioxide concentration. For example, i) will the gaseous emissions from the new technology be balanced by the crop plant ?; ii ) will the productivity of the successional vegetation be balanced by the replaced vegetation ?

Despite the complexity of these questions we will try to adress them in the case of the tropical savannas. The magnitude of these changes depends primarily on the ecosystem features, the size of the converted area, the productivity of the succeeding crop, and how long the area has been cropped. We will also look into the future trying to evaluate the effects of increasing carbon dioxide concentration and in increasing and decreasing temperature

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on the productivity of the major annual cash crops. Finally we suggest strategies to overcome the negatives effects, if any, of such changes.

## 2- Brief description of the Tropical Savannas

Tropical savannas cover several hundred million hectares in Brazil and in the high platteaus of Madagascar, Cameroon, Rwanda and Burundi. Due to a lack on information about African countries, this paper will concentrate its discussion on the Brazilian Savannas.

The Savannas Region of Brazil is a continuous area of about 1.8 million square kilometers. It ranges from 2 to 23 degrees of latitude South and from 45 to 63 of longitude West. Within this area a diversity of landscape formation, climate, soils and vegetation can be found.

The northwest border is a transitional area with the Amazon tropical rain forest. In this area of low altitude ( 200 to 300 meters ) the annual precipitation amounts 1900 mm with 2 or 3 months of dry season. In contrast, the northeast and the majority of the eastern limits of the Savannas Region are influenced by a semi-arid climate of the Brazilian Northeast region. Annual precipitation ranges from 600 to 800 mm with 5 to 7 months of dry season. The western limit is influenced by the Brazilian Pantanal area ( seasonal wetland ) and the Paraguaian Chacos. Annual rainfall in the Western Region is from 1700 to 1800 mm with 2 or 3 months of dry season. This area and also the south area are subject to periodic frost, whereas the other regions are frost-free. The pattern of annual precipitation in the south is influenced by air masses from southern Brazil ( continental or oceanic ) and ranges from 1300 to 1500 mm with 3 or 4 months of dry season. The core area of the Savannas Region is the Brazilian high plains ( altitude from

800 up to 1200 meters). In this area the continental climate is characterized by quasi-isothermic conditions with average annual temperatures ranging from 22 to 23 degrees Celsius. Annual precipitation ranges from 1500 to 1650 mm with 4 to 5 months of dry season. Our discussion will be mostly referred to this area.

Although, the annual rainfall totals seem to be adequate for rainfed cropping, most of the region is subjected to dryspells which may vary from 10 to 40 days. These dryspell periods are one of the main constraints to the establishment of a stable productive agriculture.

The solar radiation flux over most of the region is fairly constant throughout the year ( most of the Savannas are within low latitude ) and ranges from 400 to 500 langleys/day.

The soils predominant in the Savannas are characteristically Oxisols and Ultisols. These highly weathered soils have very low natural fertility (most of the bases and silica were leached away ) , high aluminum content, low pH, and pH dependent cation exchange capacity. The predominant clay type is 1:1 ( kaolinite ) and the clay content of these soils ranges from 9 to 90%, the great majority being in the range 40 to 45 %. Iron and aluminum oxides are the main cementing agents and responsible for the structure of these soils. The primary soil structure ( responsible for the microporosity ) results from the aggregation of fine soil particles in a granular form which in turn will aggregate into large particles ( responsible for the macroporosity ). As a consequence the soil acts as a sandy soil with high infiltration rates, despite their normally high clay content ( 40 to 50 % ).

Water resources in the Savannas Region are not well quantified. Preliminary studies indicate that a maximum of 10 % ( 0.18 million square kilometeres ) could be irrigated with superficial water and less than 10% could be irrigated with groundwater.

Since the establishment of the Savannas Agricultural Research Center, institutuin belonging to the Brazilian Organization for Agricultural Research - EMBRAPA, in 1975, research has produced technologies that eliminate constraints to crop production. The technological level developed so far has permitted the incorporation of these soils into a productive agriculture system. In 1970 4.5 million hectares were occupied with a total grain production of 5.2 million tons. In contrast, in 1988 10.5 million hectares were planted with a total grain production of 19.2 million tons. It can be seen that with the technologies generated the productivity at the farm level almost doubled. As a consequence, the natural scenario has changed and transformed this region into the most important and attractive Brazilian agricultural frontier ( only 10 % of the arable lands have been occupied so far), This fact has greatly alleviated the pressure for occupation of the Amazon tropical rain forest.

Irrigation is among the technologies which have increasingly been adopted by farmers in order to make a more effective use of capital ( land, machinery ), labor and consequently increase their profits. With irrigation it is possible to produce during the dry season ( were water is the main limiting factor) and to stabilize the production during the rainy season ( by minimizing effects of the dry-spells ).

### 3 - Carbon balance by substituting savannas by C3 and C4 plants

Adequate and precise information is lacking about net photosynthetic rates of natural savannas and crop plants in the savannas environment. values from the literature were used. Measurements obtained by numerous authors of average maximum values for net photosynthesis under conditions of 300 ppm of carbon dioxide, saturating light intensity, optimal temperature and adequate water supply indicate that the upper and lower net carbon dioxide uptake rates ( $mg\ dm^2\ h^{-1}$ ) ranges from 5-15; 20-40 and 50-80 for savannas, C3, and C4 plants ,respectively. Although this inference needs some caution, it can be seen that even if we consider that the savanna vegetation is operating at the upper limit, its carbon conversion capacity is less than a C3 plant ( soybean, snap bean, wheat ) and far less than a C4 plant ( corn, sorghum, tropical grasses, sugarcane ) operating at their lower limits. Consequently, by rationally replacing the natural vegetation by crop plants and pastures while preserving the vegetation of the slopes and gallery vegetation for conserving water and soil, produces a net gain in carbon dioxide conversion ( more carbon dioxide uptake than release ). Furthermore, during the dry season the rates of net photosynthesis of the savannas is even lower while that of the crop plant is high due to a better water control. Hence the practice of irrigation also brings a net gain in carbon dioxide conversion.

In conclusion it can be said that in replacing the savanna vegetation by cropped plants and pastures while observing conservationist principles, should produce a net gain in carbon conversion.

### 4 - Effects in raising atmospheric carbon dioxide

The effects of increasing carbon dioxide concentration in the atmosphere have been intensively studied from the plant physiological point of view. It is well known to stimulate plant growth, since under field conditions, carbon dioxide concentration is the limiting factor in photosynthesis. The atmospheric concentration of about 330 ppm is well below carbon dioxide saturation for most plants: some do not saturate until a concentration of 10 to 100 times is reached. Availability of light influences the plant's ability to respond to added $CO_2$. At solar energy fluxes approaching full sunlight, photosynthesis is often enhanced by concentrations up to 1000 ppm, i.e., 3 times the current level. Photosynthesis is enhanced more in C3 than in C4 plants. High $CO_2$ concentration supresses photorespiration in C3 plants. Consequently, photosynthetic rates ca increase more responsive in C3 than in C4 plants. However, the enhancement in photosynthetic rates, specially in $CO_2$ enrichment experiments, does not necessarily improve yield. Excessive levels ( above 1000 ppm ) are phytotoxic, but even below this injurious level, the long-term productivity of a plant population does not match short-term response due to a stomatal closure under higher $CO_2$ concentration, more in C4 than in C3 plants. Thus transpiration tends to be more reduced in C4 than in C3 plants. This fact was thought to increase water-use efficiency ( ratio of a unit of dry matter produced over a unit of water consumed ) more in C4 than in C3 plants. However, recent findings showed that rising $CO_2$ will increase water-use efficiency of both C3 and C4 plants, due to little or no change in crop transpiration or evapotranspiration. This nearly constant transpiration is because the effect of increase in individual leaf resistance is approximately offset by the increase in crop leaf area.

Considering the facts above, and that the $CO_2$ has important absorption peaks at 2.3 and 4.0 µm, therefore above the spectrum of the photosynthetically active radiation - PAR, an increasing of $CO_2$ concentration should have a beneficial effect for the savannas area, since productivity should be increased and water should be more efficiently used. This suggests that the productivity of grain, fiber and meat may be increased for the same amount of water used. However, if global temperatures rise due to an increase in $CO_2$ concentration, evapotranspiration rates are likely to increase rather than decrease and further experimental and simulation studies are needed to better understand the relationships between rising $CO_2$ environmental factors, and plant factors on crop evapotranspiration and water-use efficiency.

## 5 - Effects of rising temperature.

The effect of temperature on the processes of photosynthesis and respiration is exerted through the temperature dependence of various enzymes. The fixation and reduction of carbon dioxide occurs with increasing speed as the temperature rises, until a maximum value is reached; this rate is then maintained over a broad range of temperatures. Optimum range of temperature, i. e., where the net photosynthesis is more than 90% of the maximum obtainable differs for C3 and C4 plants. Although it is well known that the temperature regime under which a given plant is grown in association with crop morphology may have a pronounced influence on its photosynthetic temperature response characteristic, the optimum values of temperature cited in the literature for agricultural plants is between 20-30º C for C3 and between 30-40º C for C4

The average temperature during the growing season of rainfed crops in the Brazilian Savannas ( October to April ) is 22º C with an average maximum of 26.7 and an average minum of 17.6 º C ( Fig. 1 )

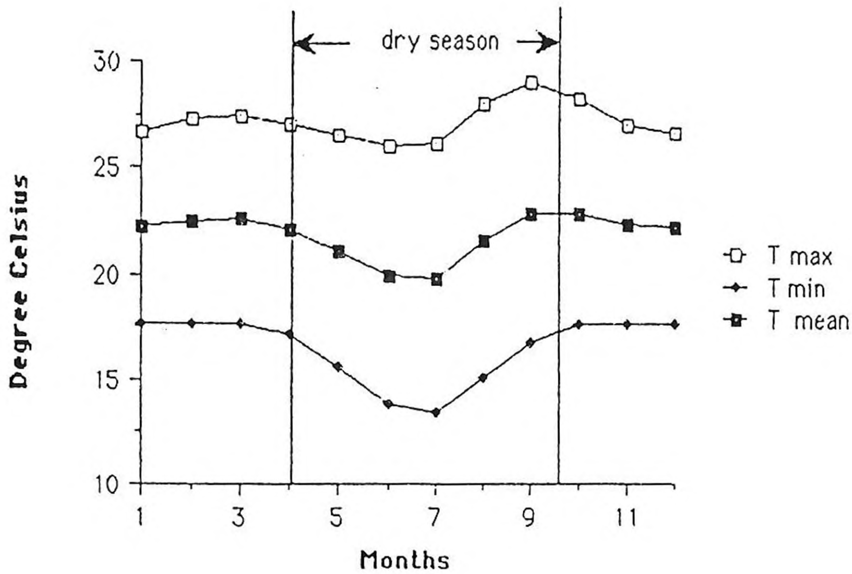


**Fig.1 - Annual variation of monthly mean air temperatures at the Savannas.**

Comparing the requirements of the major rainfed cash crops with the temperature predominant in the savannas it can be seen that soybean, snapbean and rice ( C3 plants ) are within the optimum temperature range while sorghum, corn and tropical grasses ( C4 plants) are below the optimum limits of temperature. If we also compare the values in the Figure 1 with the crop thermal requirements, the same conclusions hold, that the main irrigated crops: snapbean, soybean and wheat ( C3 ) are within the optmimum range while corn ( C4 ) is below.

In order to analyse the effects of increasing or decreasing the mean temperature a model for potential yield was used. This model simulates crop growth at non-limiting levels of soil water and soil nutrients, however, with limiting factors being solar radiation and temperature. The model attend ours purposes because the calculations are made on the basis of the standard meteorological observations. Results of simulations on a monthly basis are shown in Fig. 2 for corn and Fig. 3 for soybean.

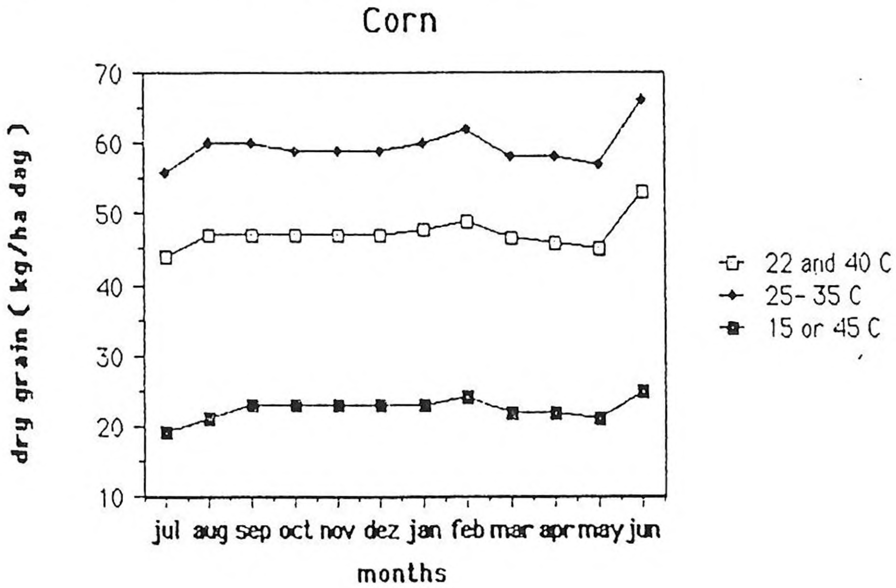


Fig.2- Simulated corn potential dry grain productivities ( kg/ha day ) as a function of temperature.( 22 ºC normal temperature )

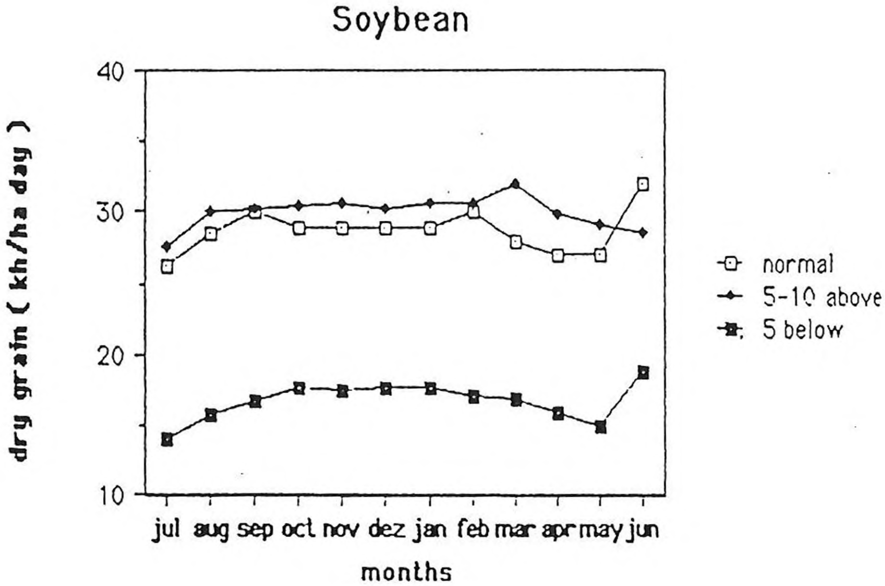


**Fig.3- Simulated soybean potential dry grain productivities ( kg/ha day ) as a function of temperature.**

If figures 2 and 3 are compared it can be seen that corn ( C4 ) is more productive than soybean ( C3 ) and that the productivities of these two species are almost constant throughout the year.

Analysing Fig. 2 it can be seen that the curves for 22 and 40 ºC are the same, indicating that if air temperature is suddenly increased to 40 ºC the productivity levels will be the same as currently. However, if air temperature is increased to 35 ºC it will increase in about 22% the current levels of productivity. Therefore warming would be expected to have a benefical effect for corn production. On the other hand if temperature decreases in 5 to 7 ºC it will reduce the current productivity levels in about 50%.

Analysing Fig. 3 it can be seen that if the air temperature increaseed to 30 degrees the increment in productivity would be around 5% but if temperature increases to 35 ºC the increment is zero. However, if the temperature is reduced to 15 ºC the productivity will be reduced by about 50%.

In conclusion, for both crops, the main concern is with temperature reduction rather than in increased temperature. If temperature is reduced due to climatic changes, the strategies to elimininate temperature constrains to crop production should be directed towards addaptation of new varieties and species with more efficient photosynthetic capacity at lower temperatures.

Another important factor in increasing temperature is that evapotranspiration will also be affected. In order to evaluate these effects calculations were made using the Priestley-Taylor formula. Assuming constant net radiation and proportionality but varying the term s/s+g indicate that for each 5 ºC of increment on average 1.25 mm is increased. This resul may not have a strong influence on crop water use during the wet season, but the area to be irrigated may suffer a reduction and pumping costs may be increased for irrigated crops.

## 6 - General comments on the paper and suggested strategies

This paper is an overview of some possible alterations in the tropical savannas if the current levels of $CO_2$ and temperature are increased. In general, the effects seem to be more positive than negative. However, caution is necessary since the results presented, were, in part, obtained on basis of the current stage of knowledgement. Considering that risk to agriculture should be minimized some strategies are recommended.

One strategy, is to minimize the increasing level of $CO_2$. It can be done by reducing fossil fuel emission. This can be done, in the Brazilian case, by substituting fossil fuel by alchool produced from sugarcane. On average 0.5 ha of sugarcane crop produces enough fuel for one vehicle per year. Other measures, related to reducing gaseous emission are: reducing burning in new areas to be incorporated for agriculture production an giving incentives to reforestation, and crop fruits production.

From the research point of view actions are necessary in order to gain knowledge in the following areas:

1 ) Development of methodologies in order to better quantify climatic changes by using meteorological satelites;

2 ) Experimental and simulation modeling studies in order to quantify the carbon balance of natural vegetation and crop plants;

3 ) Development of agroclimatic models on micro and regional scales in order to better understand the interactions of water, carbon dioxide and nutrients.

4) Development of boundary layer models in order to better understand the nature of gaseous emission and its effects on global circulation.