IMPACT OF CLIMATE SCENARIOS ON SOYBEAN YIELDS IN SOUTHERN BRAZIL

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Abstract
Soybean is a very important crop, cultivated mainly as stock feed for animal production, but also for other uses such as biodiesel. Brazil is the second largest producer of soybeans, and the main exporter. About 10% of the Brazilian total production is aimed for biodiesel production. The aim of this work is to assess the impact of climate change scenarios on soybean yield and evaluate two simple adaptation strategies: cultivar and planting date. Tests were done for soil profiles from two important producing regions: Chapecó – Red Oxisol, and Passo Fundo – Rodic Hapludox. Two commercial soybean cultivars (CD202 and CD204) and seven regional circulation models (RCM) were used. All simulations were done with DSSAT. After model calibration, eleven planting dates were run for two periods (2011-2040 and 2071-2100) using the RCM`s. There were no differences between cultivars. For Chapecó, the majority of RCM`s projected yield reductions, with few RCM`s projecting increments, and for only few planting dates (November). The response pattern for both time periods were identical, although the end-of-century period presented a further yield reduction. The main reason is reduced water holding capacity in soil, high temperatures and changes in rainfall distribution along the cropping season. For Passo Fundo, 2011-2040 yields are distinct, depending on the RCM. Simulated yields tend to follow the actual yield pattern along the different planting dates, besides discrepancies. For 2071-2100, all but one RCM indicate yields equal or lower to actual levels. Regarding planting dates, no significant changes were identified, although reductions were observed for the early planting dates (August-September). The scenarios suggest that soybean yields will be reduced, jeopardizing the viability of this crop and biodiesel production in the studied regions.

Keywords
Climate change, crop model, efficiency use.

1. Introduction

Climate change is a worldwide concern, and regardless of all the scientific improvements to comprehend and forecast changes, the determination of future climate is still a very hard task. The high level of complexity and the nature of climatic interactions is a challenge to forecasting, although there are scenarios that point to possible directions of change.

The impact of climate change on agricultural production is actually the core issue of several investigations. Rising seasonal temperatures are expected to increase more than the annual averages, with reduced precipitation expected to accompany higher temperatures in some regions. Additionally, heat waves are expected to increase in frequency, intensity, and duration (Tebaldi *et al.*, 2006). End-of-century growing season temperatures in the tropics and subtropics may exceed even the most extreme seasonal temperatures measured to date (Battisti and Naylor, 2009). Not considering all the inherent variability of crop production factors, all climate changes described above can lead to modifications of crop yields, posing a threat to agricultural systems that will affect the whole production and consumption chain, impacting especially agroecosystems and populations with low availability of or access to financial and natural resources. The global food and financial crises of 2007 and 2008, which have pushed an additional 115 million into hunger, highlight the severity of the hunger and poverty crisis that has challenged the world for decades (Viatte *et al.*, 2009). Price volatility remains a concern, with weather-related yield variability the main threat as long as stocks remain low (OECD *et al.*, 2012). This risky situation will be worsen by the present effects of drought on soybean yields of USA (UNL, 2012), which will impact the whole world food supply.

Increasing the prediction capacity of climate change impacts for stakeholders has become a major challenge in Southern Brazil, which economic wealth strongly depends on agriculture (AQUASTAT, 2010). In this region, the agricultural landscape have faced major changes during the last 30 years due to new technologies for crops, to a strong increase in cereal and oil crop world demand and also to favorable climate conditions with increases of about 20%-30% in annual precipitation over large parts of the region (Magrin *et al.*, 2005).

Crop models can be a useful tool to assess the influence of climatic and other environmental or management factors on crop development and yield (Reidsma *et al.*, 2010). The Decision Support System for Agrotechnology Transfer – DSSAT v. 4.5 contains the CROPGRO – Soybean model (Banterng *et al.*, 2010), and is used to a) determine best planting dates (d'Orgeval *et al.*, 2010), b) for fertilization timing (Asadi and Clemente, 2001), c) in precision agriculture (Thorp *et al.*, 2008), and d) also for detecting/investigating potential impacts of climate change on agriculture (Fischer *et al.*, 2005). In the embedded model the development and growth of the crop is simulated on a daily basis from the planting until the physiological maturity. The model calculations are based on environmental and physiological processes that control the phenology and dry matter accumulation in the different organs of the plant. The DSSAT also has other embedded models that can simulate the flow of nutrients and water balance in the soil. The minimum data set necessary to run DSSAT (Jones *et al.*, 2003) consists of daily weather data of maximum and minimum temperature, rainfall and solar radiation, soil chemical and physical parameters for each layer, genetic coefficients for each cultivar with information about development and biomass accumulation, and management information, such as soil preparation, planting dates, plant density, fertilization amounts and timing or other agricultural practices. Experimental data like soil available water, plant phenology, biomass partitioning and other morphological components like leaf area index are necessary to calibrate the genetic coefficients and check the accuracy of the model.

2. Materials and Methods

In order to run simulations for soybeans data from field experiments and literature were used. For simulation in the Brazilian sites data from literature was obtained from Dallacort et al. (2008), which conducted experiments in Parana State evaluating four soybean cultivars. The cultivars were characterized, calibrated and validated for the CROPGRO – Soybean. The four cultivars, namely CD 202, CD 204, CD 206 and CD 210, were tested for both Brazilian sites using census data and generic agronomic management. The two cultivars with lowest RMSE for yield were selected to run further analysis.

After calibrating and validating the genetic parameters and the model itself, scenarios provided by CLARIS LPB Project WP5 (2011-2040 and 2071-2100 periods) were downloaded and formatted for the DSSAT standard using Weatherman Software (Wilkens, 2004). From the CLARIS-LPB Project Data Archive Center seven weather series of RCM`s (and matching the same location of the study sites weather stations) were downloaded, converted and adjusted to be used as weather input for DSSAT using Weatherman software (Wilkens, 2004). The RCM`s are RCA1, RCA2 and RCA3, from the Rossby Centre Regional Climate model (Samuelsson *et al.*, 2011); PROMES, from Universidad de Castilla-La Mancha (Domínguez *et al.*, 2010); LMDZ version 4 Configuration South America with IPSLA1B and EC5OM-R3 boundaries, from Laboratoire de Meteorologie Dynamique (Hourdin *et al.*, 2006); and ETA, from Instituto Nacional de Pesquisas Espaciais (Marengo *et al.*, 2012). The crop model was run with each one of the seven RCM`s for the target periods (2011-2040 and 2071-2100).

3. Results and Discussion

The analysis (Fig. 1) showed the impact of seven RCM`s on the yield of the soybean cultivars CD202 and CD204 in two locations and two time periods (2011-2040 and 2071-2100). It is important to mention that both soybean cultivars, besides having differences in genetic coefficients, presented very similar results.

For Chapecó 2011-2040 period, the majority of RCM`s projected very low yields when compared with actual yields. Only ETA, IPSL and ECHAM5 presented a trend of increase in yields, and after the 01/Oct planting date. Even so, only IPSL could mimic the actual yields for the late planting dates. This assessment is also applicable for the 2071-2100 period, but with a further reduction of projections of all RCMs. An integrated analysis indicates with high level of agreement that early planting dates – prior to 01/Oct – will generate lower yields; planting after 01/Oct shows that three out of seven RCM`s (namely, ETA, ECHAM5 and IPSL) have a tendency to follow the actual yields, while the others remain with very low yields, jeopardizing the viability of this crop in the region.

The results presented for Passo Fundo showed significant difference from the ones of Chapecó, with RCM yields following the trend of actual yield. It also presents a situation where RCMs project even significant increments in yield for the 2011-2040 period. This can be observed especially in the early planting dates, where all but one RCM are equal or significantly higher than the actual yield. For the end-of-century period a generalized reduction of yield was calculated, with exception of IPSL, which showed significant increases. Though a trend of yield reduction, all RCMs presented at least one planting date that did not differ significantly from the actual best yields.

4. Conclusions

Both genotypes tested (CD202 and CD204) did not presented remarkable differences among them when in the same region. Unfortunately, no other suitable soybean data sets are available to calibrate and validate the crop model in the study region, undermining the assessment of the role of cultivar as adaptation strategy. The impact of climate scenarios on soybean yield was directly influenced by location: in Chapecó region yields tend to decrease, while for Passo Fundo region yields can even increase.

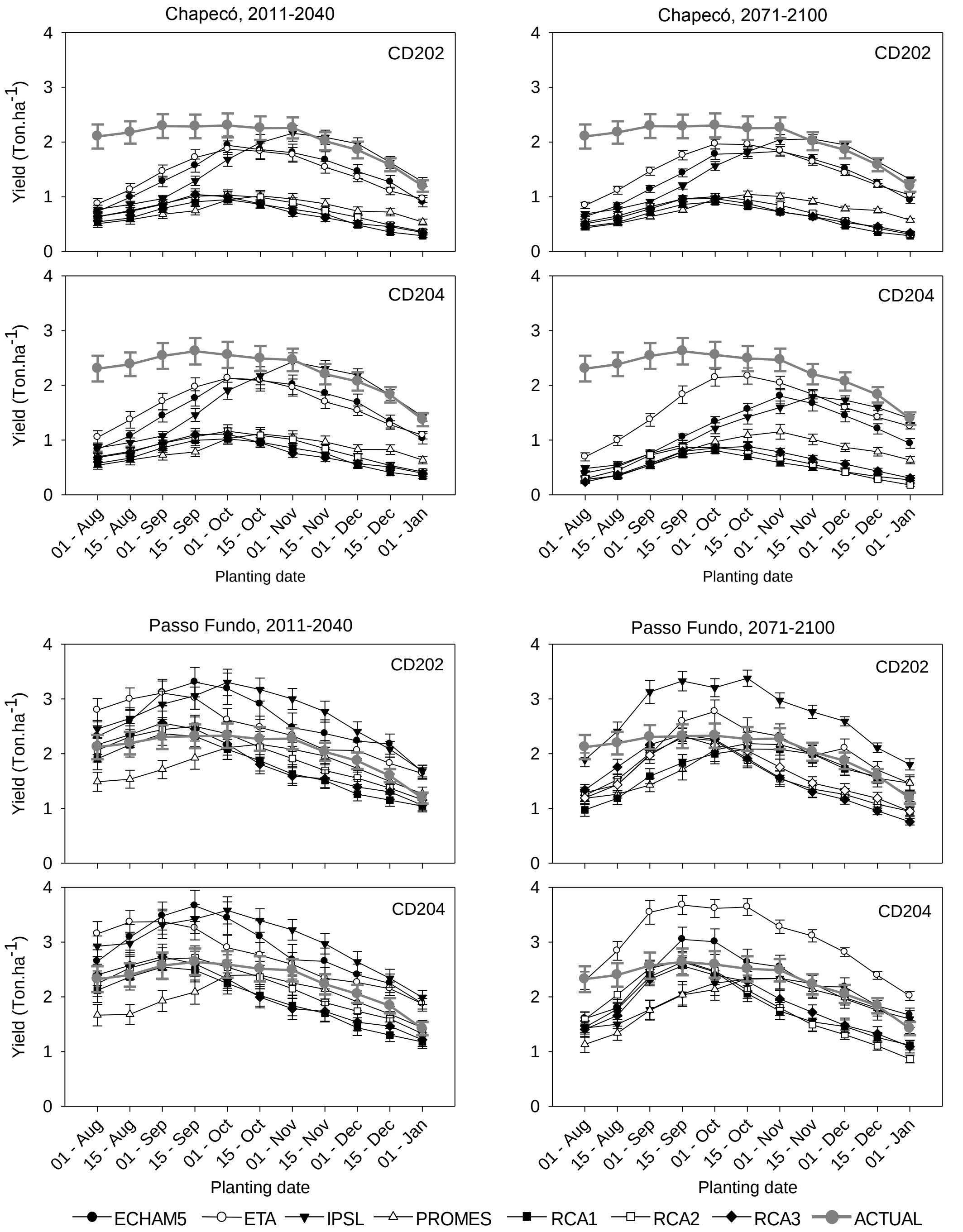

Figure 1 Simulations of the impact of RCM`s scenarios on soybean cultivars (CD202 and CD204) planted in eleven different dates, in two locations (Chapecó and Passo Fundo), and two time periods (2011-2040 and 2071-2100): black lines represent yields simulated with RCM`s and black bars represent the standard error of each planting date; the grey lines represent actual yields with respective planting dates and standard error.

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