

CLIMATE AND WEATHER FORECAST POTENTIALITY AS A DECISION SUPPORT SYSTEM FOR AGRICULTURE

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1. INTRODUCTION

Even with the great industrialization of the last decades, most of the Brazilian economy is still driven by agricultural activities. At the same time, Brazilian agriculture is subject to highly variable weather condition. Therefore, in order to deal with the adverse weather, the farmers and the policy makers need real time information services to help them in their decision-making process. The first step towards an implementation of rational strategies in agrometeorological management is to decide which variable would be considered in order to give the farmer the technical inputs needed for the decision-making process. Due to the plethora of factors determining crop growth and development, the concept of systems approaches is needed to provide an objective tool for the evaluation of crop management at yield, farm and regional scale levels (Costa et al.,1998). Between several others environmental factors, water and energy are fundamental to crop growth and development. Whereas in the tropical areas there are no limitations of solar energy for crop growth and development, the same can not be said about the water. Due to the big changes observed in the Brazilian agricultural practices in the last decades, water used by the Brazilian farmers has been growing exponentially. Irrigation is one of the greatest water consumers in Brazil, with around 70% of all water used. However, most of the irrigation practices in use in the Country is still based on empirical methods with severe damages to the environment. Therefore it is very useful to develop decision making support systems to provide the farmer with the required technical information to make proper choices on its crop and water management,

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leading to a greater productivity with a rational level of water use. On the other hand climate change and variability, including climate-related extremes, have a direct influence on the quantity and quality of agricultural production. In this sense it is very important to develop systems that can predict the loss of productivity caused by climate-extremes events. The results of such models will contribute to certainty decreases the vulnerability of the agricultural sectors through a more informed choice of policies, practices and technologies reducing, in many cases, the long-term vulnerability of these systems to climate change. For example, the introduction of seasonal climate forecasts into management decisions can reduce the vulnerability of agriculture to floods and droughts caused by El Niño – Southern Oscillation (ENSO) phenomena (WMO, 2004). However, for developing countries capacity building is needed to better use climate information and products as well as to improve and better understand how to downscale and interpret climates products. In this paper we describe a pilot project which will be extended to the whole Country. Minas Gerais is a State of the Brazilian Federation and was choose because has a large and heterogeneous area, with a variety of climate types. Furthermore the State of Minas Gerais economy is based on cattle and agriculture activities, with a variety of crops. The results of this system can be applied to a region or a particular farm.

2. OBJECTIVES

To develop a system which would supply the farmers and the police makers with the required information to make proper choices on its crop and water management. The System will also predict, based on the weather conditions, the yield loss for several crops in the State of Minas Gerais.

3. DATA AND METHODOLOGY

Climatological data were acquired from weather stations from CEMIG, SIMGE and INMET, located in Minas Gerais. In total, data were acquired for a total of 89 stations, Figure 1.a. The data were used to calculate the evapotranspiration of reference according to Penman-Monteith Method modified by Sedyama, 1996, and Pereira et al., 1997. In addition, the output from the numerical forecast for 24, 48 and 72 hours are used to estimate the amount of irrigation water needed for several crops. The seasonal

climate predictions are used to estimate the productivity for three different climate scenarios. The soil types and the topography of the Minas Gerais are also considered. Historical data of crop productivity from Agriculture Secretary of Minas Gerais State are used in order to test the system output.

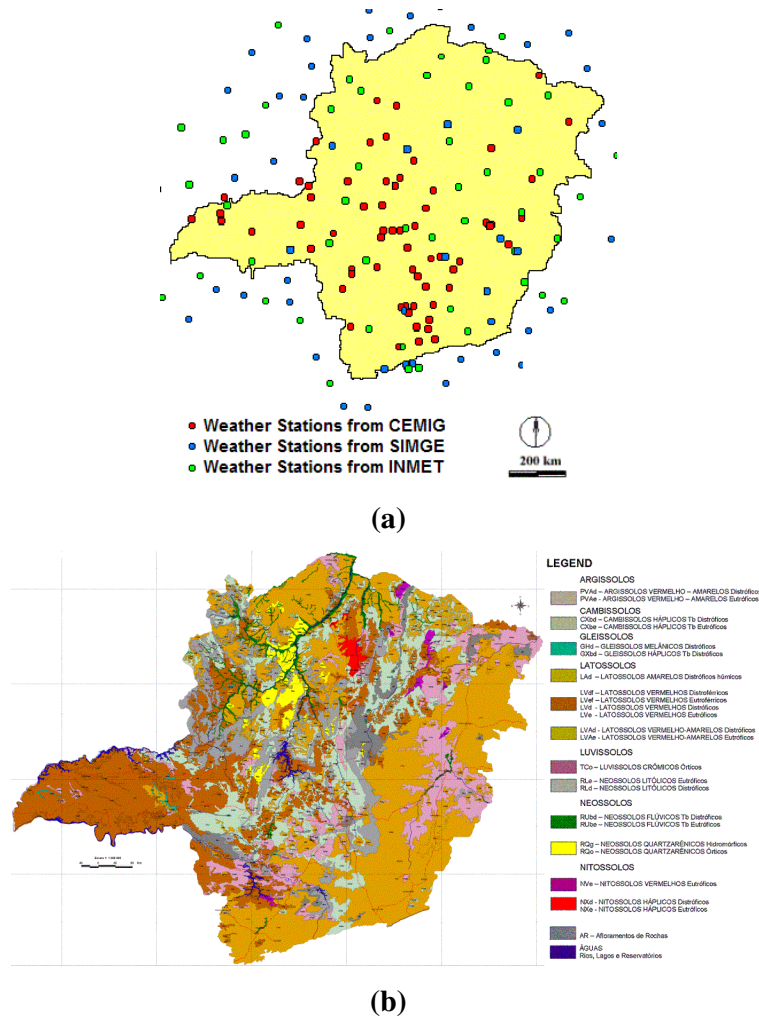


Figure 1 – Locations of the weather stations (a) and the soil types (b).

3.1. Theoretical Base

The reference evapotranspiration was estimated using the Penman-Monteith Method recommended by FAO in 1990, modified by Sedyama, 1966, and Pereira et al., 1997:

$$ET_o = \frac{s}{s + \gamma^*} (R_n - G) \frac{1}{\lambda} + \frac{\gamma}{(s + \gamma^*)} \frac{900}{(T_m + 275)} U_2 (e_a - e_d)$$

where

ETo = reference evapotranspiration [mm d^{-1}];

Rn = surface net radiation [$\text{MJ m}^{-2} \text{d}^{-1}$];

G = soil heat flux [$\text{MJ m}^{-2} \text{d}^{-1}$];

Tm = mean temperature [$^{\circ}\text{C}$];

U_2 = wind velocity at 2m height [m s^{-1}];

$(ea-ed)$ = water pressure deficit [kPa];

δ = water vapor pressure declivity [$\text{kPa } ^{\circ}\text{C}^{-1}$];

λ = latent heat of evaporation [MJ kg^{-1}];

γ^* = modified psychometric coefficient [$\text{kPa } ^{\circ}\text{C}^{-1}$] = $[1+0,33U_2]$;

900 = [$\text{kJ}^{-1} \text{kg K}$].

The daily water deficit was estimated as proposed by Santana et al. (2003a) e Santana et al. (2003b):

$$DA_i = DA_{i-1} + (ETr_i + Pp_i) - P_i$$

where

DA_i = soil water deficit in the day i (mm d^{-1});

DA_{i-1} = soil water deficit in the day before (mm d^{-1});

ETr_i = real evapotranspiration of the crop in the day i (mm d^{-1});

Pp_i = loss of water by percolation in the day i (mm d^{-1});

P_i = precipitation in the day i (mm d^{-1}).

The crop evapotranspiration was estimated according to Bernardo et al. (2005):

$$ETr = ks kc ETo$$

Where

ks = soil humidity coefficient;

kc = specific crop coefficient.

The loss of productivity was estimated by the ratio between the real and the potential evapotranspiration of the crop as proposed Doorenbos and Kassan (1979):

$$Y_i = a Yp_i ETr_i / ETP_i$$

where

Y_i = real production, kg d⁻¹;

a = constant of proportionality;

Yp_i = potential production (kg d⁻¹);

ETP_i = potential evapotranspiration of the crop in the day i, (mm d⁻¹);

ETr_i = real evapotranspiration of the crop in the day i, (mm d⁻¹).

Each variable was interpolated by using the inverse of the Euclidian Distance:

$$z_i = \frac{\sum_{j=1}^n w_{ij} z_{ij}}{\sum_{j=1}^n w_{ij}}$$

where

z_i = value of any variable in the i point of the grid, to be interpolated,

z_{ij} = value of the same variable in the j point near i in the grid.

The weighing factor, w_{ij} , is the inverse of the Euclidian Distance that is:

$$w_{ij} = \frac{1}{\left[(x_i - x_j)^2 + (y_i - y_j)^2 \right]^{\frac{k}{2}}}$$

It was used the Geographical Information System, GIS, in its version ArcGIS of ERSI to regionalize the results, using also the Kriging interpolation techniques, Figure 2, based on Amorim (2005).

3.2. The System

Overview of the System

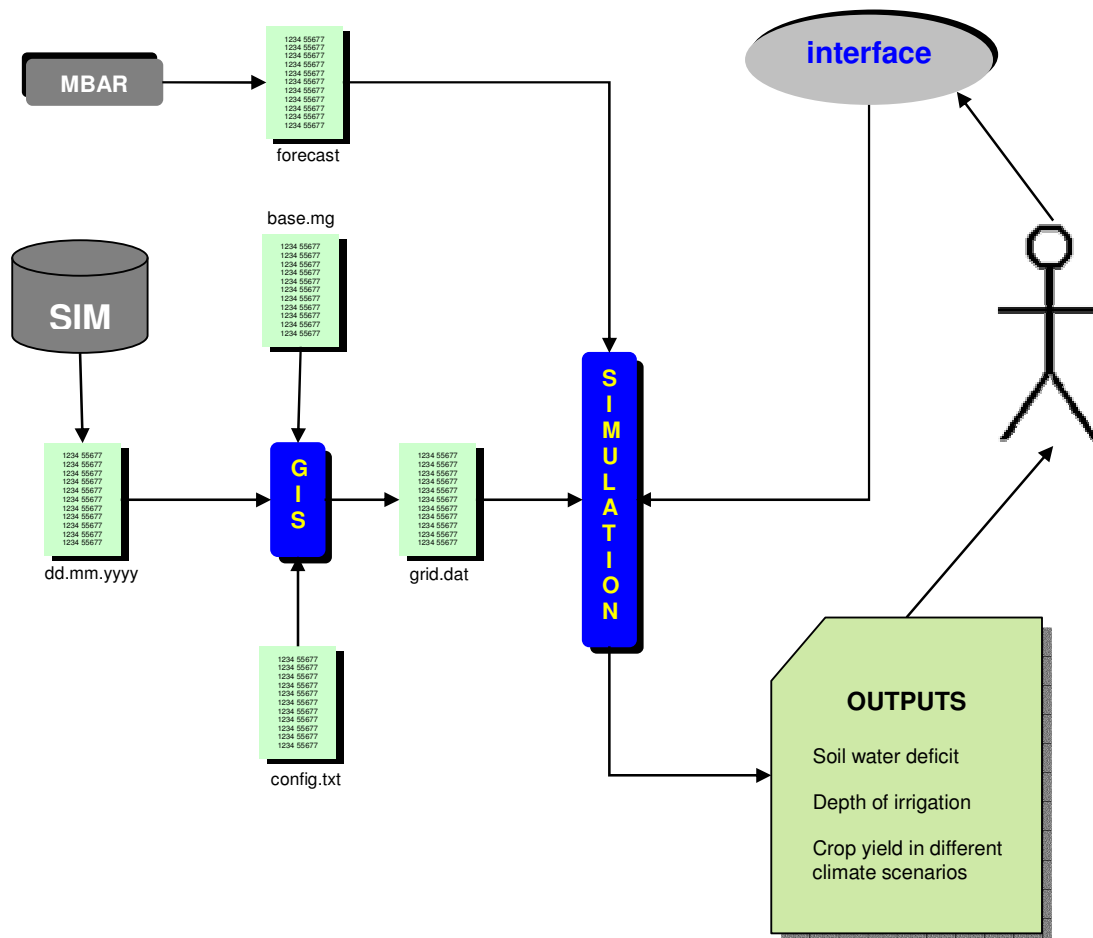


Figure 2 – An overview of the System

Figure 2 shows the algorithm developed to estimate the irrigation needed and the final crop productivity. The system inputs are: the geographical position of the farm, crop and its seeding date, soil type, observed rainfall; and the system output comprises a schedule of irrigation for the next three days in advance and the final productivity loss expected for three different scenarios according to the climate forecast. The crop productivity loss is expressed in a percentage scale corresponding to the same scale of the climate prediction, which is, “a normal climatic condition”, “a better expectation” and a “worst climate expectation”. The results are given for each region of the Minas Gerais State, allowing the policy makers to take advantage of these results for economical and social purposes. To produce forecast results, the system needs three

basic source of information: a) the Meteorological and Hydrological Information System, SIM, of the National Institute of Meteorology of Brazil, INMET, which provides the climatological data; b) the High Resolution Brazilian Model of Numerical Weather Forecast, MBAR, which provides the predicted variables to the next three days; c) the Ground information, such as the soil types and its characteristics, the altimetry and the plant parameters. The data base of Minas Gerais State enters into the GIS which generates a new grid with 25 km between the knots. Finally the system gives the results as diagnostic and prognostic, that is, the daily soil water deficit, the irrigation programmed three days ahead, the soil water excess, the production loss and the final percents of productivity loss for different climate predictions.

3.3. The Crop Cycle

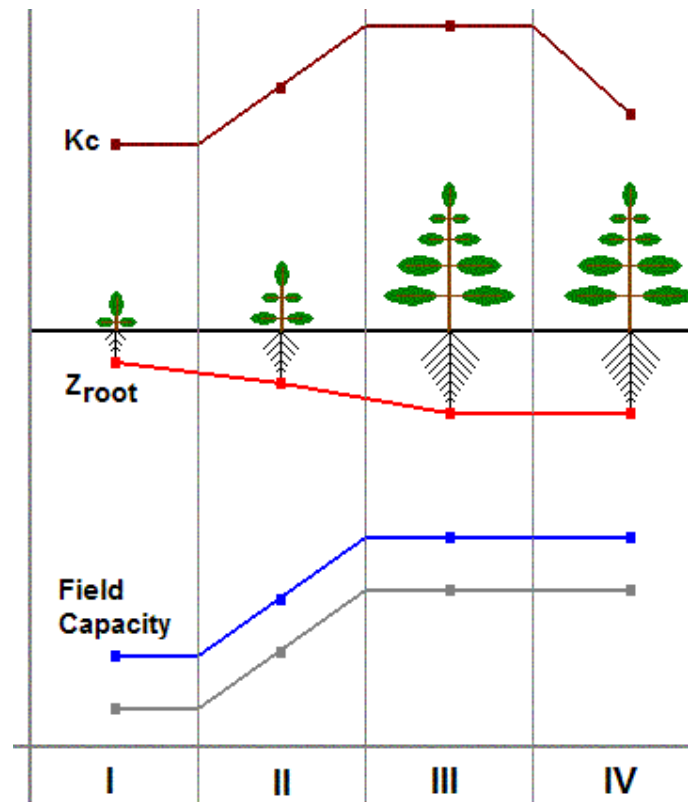


Figure 3 – Phenological Phases of the Crops.

Figure 3 shows the crop cycle in its four phenological stages used in this System. For each phase there are different values of K_c , root depth, soil water capacity and the

minimum water necessities below which the plant will be under stress. In addition, for each phenological cycle and for the complete cycle the System is able to calculate the degrees day, Kc, root depth, the soil humidity plus irrigation water or rain, the soil coefficient and all the parameters of the water balance, that is, the water soil deficit, the water soil excess, the potential evapotranspiration, the real evapotranspiration and the productivity. The final results can be seen in tables, graphical or maps.

3.4. The User interface

This System offers a user friendly interface which allows to the each farmer to enter with his specific information, such as crop and the seeding data, rainfall and the geographical position of his farm. He must also specify if he wants the productivity prediction and his preference for 24, 48 or 72 hours in advance for the irrigation program.

INMET - Instituto Nacional de Meteorologia
 Decision Support System

Project

Name:

Sowing date:

Irrigation frequency (day):

Country: Lat(°) Long(°)

Height (m):

Crop

Name:

Threshold Temperature (°C):

Depletion fraction for no stress (%):

Ky:

	Degree days (°C)	Kc	Root lenght
Phase 1:	<input type="text" value="240"/>	<input type="text" value="0.4"/>	<input type="text" value="0.1"/>
Phase 2:	<input type="text" value="640"/>	<input type="text" value="0.7"/>	<input type="text" value="0.15"/>
Phase 3:	<input type="text" value="1600"/>	<input type="text" value="1.05"/>	<input type="text" value="0.3"/>
Phase 4:	<input type="text" value="2080"/>	<input type="text" value="0.8"/>	<input type="text" value="0.3"/>

Soil

Filed Capacity (mm):

Initial Soil Water (mm):

Soil Depht (m):

Figure 4 – User Interface

4. PRELIMINARY RESULTS

Figure 5 is an example of a system output showing a predict yield loss of 32.96 % for a bean crop for a particular farmer. The table also shows a status of soil water availability. The yellow shadow is the forecast for the next three days.

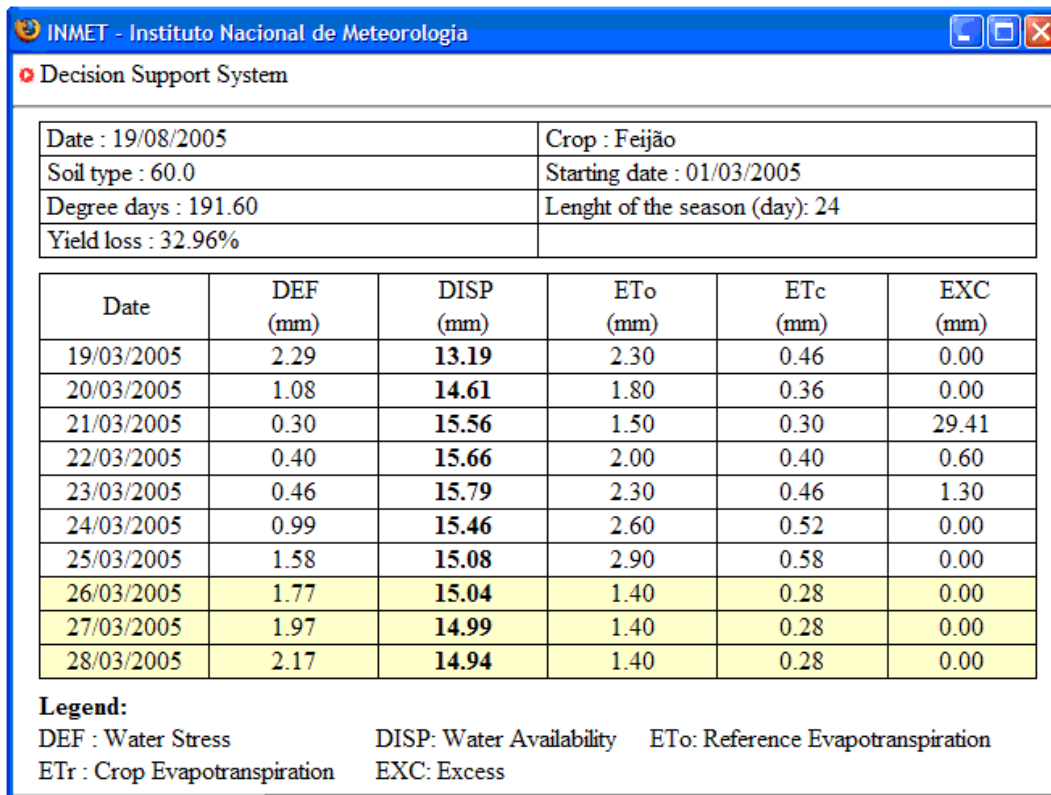


Figure 5 – Soil water availability and Productivity loss

Figure 6 shows a graphical monthly soil water balance for bean crop. The blue line is the soil water availability. The green line shows the bean optimum water needs and the red line the minimum limit under which the plant will be under water stress.

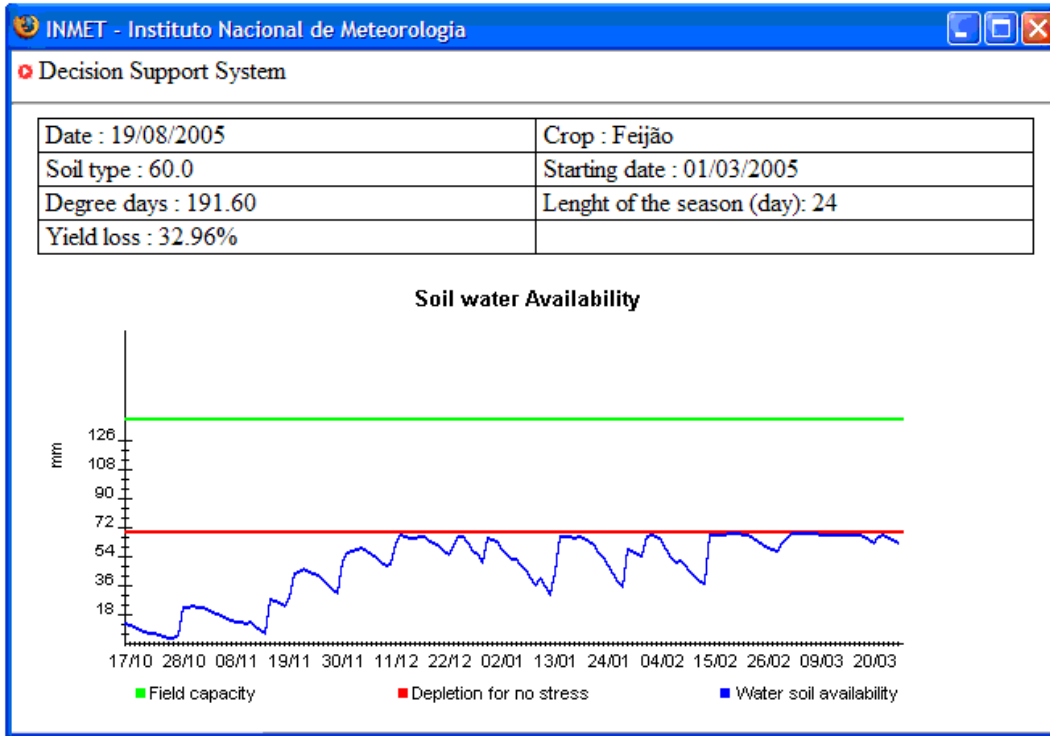


Figure 6 – Monthly Water Balance for Bean.

Figure 7 shows the maps of productivity loss based on different climate scenarios according to climate predictions for Minas Gerais State. The first one represents the potential productivity for bean crop. The others are estimated productivity loss for three different scenarios according to climate forecast. Similar results can be obtained for a specific region or a particular farm.

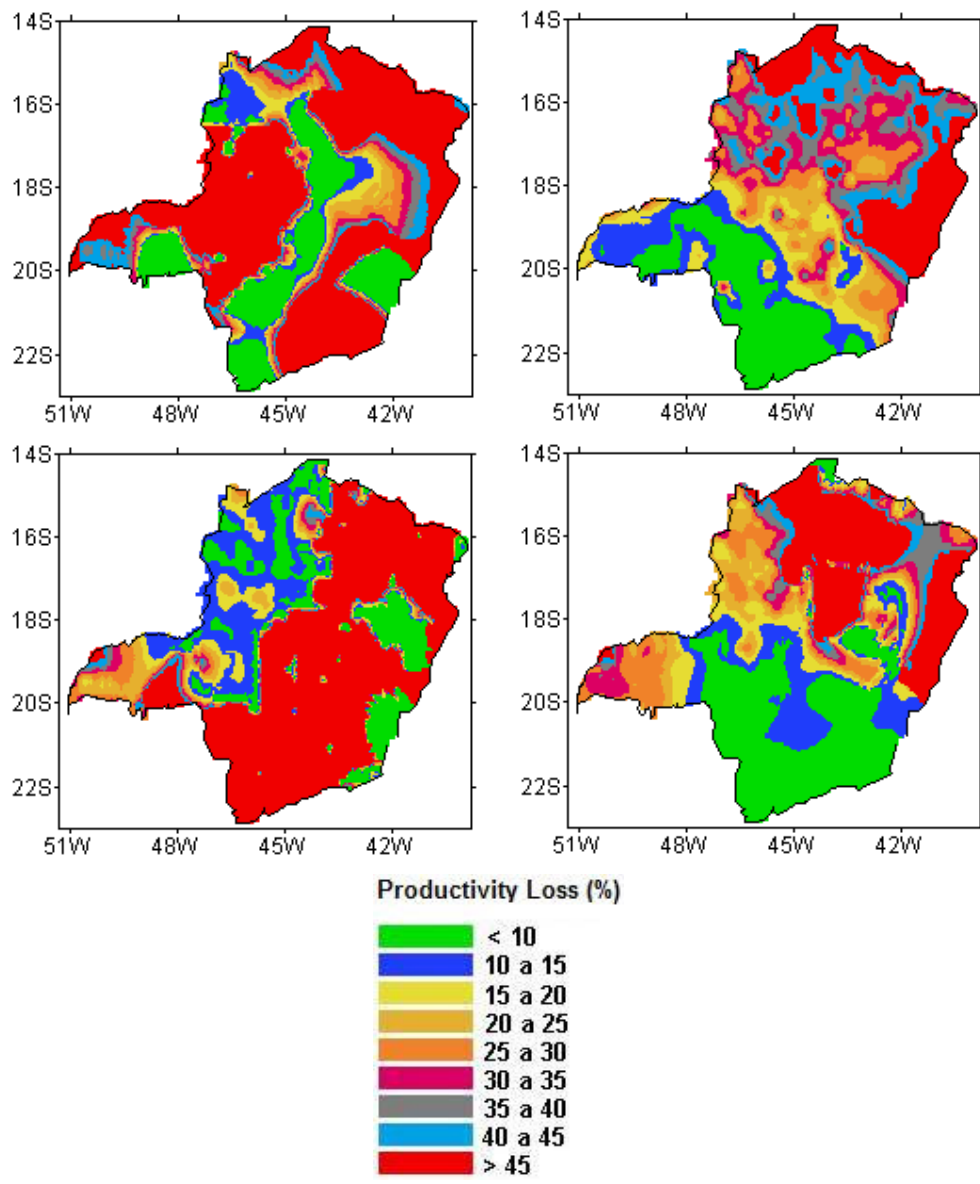


Figure 7 – Maps of Productivity Loss based on different Climate Scenarios.

5. NEXT STEPS

Gather statistical information from non-irrigated crops that are subject to adverse climate conditions.

Apply the model to such adverse conditions, comparing the model results with the actual observed crop productivity.

Calibrate the model to climatically homogeneous regions in Minas Gerais, adjusting the input parameters, particularly the precipitation deviations with respect to the mean precipitation.

Evaluate on the field the performance of the irrigation plan estimated by the model.

Install the system on the INMET webpage, making it available to farmers and decision makers.

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REFERENCES

Amorim, R.C.F. Espacialização de Variáveis Meteorológicas em Áreas de Relevo Ondulado na Bacia do Rio Doce. 2005. 83 f. Dissertação (Mestrado em Meteorologia Agrícola) - Universidade Federal de Viçosa. Orientador: Aristides Ribeiro.

Bernardo, S., Soares, A.A., Mantovani, E.C. Manual de Irrigação. 7. ed., Viçosa: Ed., Universidade Federal de Viçosa, 2005. 611p.

Costa, L.C., Mantovani, E.C., Soares, A.A., Leal, B.G. A Decision Support System for Agriculture in Brazil. Quantitative Approaches in Systems Analysis, 16, pp.33-39. Wageningen, 1998.

Doorenbos, J., Kassan, A.H. Yield response to water. FAO: Irrigation and Drainage Paper, 33, Rome, FAO, 1979. 172p.

Pereira, A.R., Villa Nova, N.A., Sedyama, G.C. Evapo(transpiração). Piracicaba: FEALQ, 1997. 183p.

Santana, M.O., Ribeiro, A., Sedyama, G.C. Sistema de Geoespacialização da Demanda de Irrigação Suplementar para o Estado de Minas Gerais I - Descrição. Revista Brasileira de Engenharia Agrícola e Ambiental, Campina Grande - PB, v. 7, n. 1, 2003a.

Santana, M.O., Ribeiro, A., Sedyama, G.C. Sistema de Geoespacialização da Demanda de Irrigação Suplementar para o Estado de Minas Gerais I - Avaliação. Revista Brasileira de Engenharia Agrícola e Ambiental, Campina Grande - PB, v. 7, n. 1, 2003b.

Sedyama, G.C. Estimativa da evapotranspiração: histórico, evolução e análise crítica. Revista Brasileira de Agrometeorologia, Santa Maria, v. 4, n. 1, p. i-xii.1996.

World Meteorological Organization, 2004: Actas de la Reunión Técnica de los Servicios de Información y Predicción del Clima (SIPC) y Aplicaciones Agrometeorológicas para los Países Andinos, WMO-TD No. 1234.