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Calibration of EPIC for Simulation of Crop Growth in Northeast Brazil

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Abstract

Agriculture in the Northeast of Brazil is strongly handicapped by adverse conditions. Global change may aggravate the situation in this area, where even under present conditions soil degradation and rural exodus are high. Predicting crop production by using simulation models is an important tool to improve rural development and food security for this area in the future. Data from field trials in Northeast Brazil were used to test EPIC for predicting growth and yields of regionally important food crops. The simulation results were promising for some treatments, but further adjustment for local maize and cowpea varieties is required, particular on acid soils.

Keywords: global change, maize, rice, cowpea, simulation models

Introduction

Agriculture in Northeast Brazil is often strongly handicapped by adverse site conditions such as erratic rainfall and low inherent soil fertility. In this region, the *EL Niño* phenomenon leads to disrupted rainy seasons with dry spells of up to three weeks and more. In years with unfavourable rainfall distribution, food and water supply is a severe problem, particularly for the rural poor. As a consequence, many of them migrate to the Amazon basin or the urban centres, leading to strong environmental impacts and social tensions within the Brazilian society.

Global change which is widely accepted as a major threat to our earth in the next century stands for the net effect of individual and interactive changes in land use, atmospheric composition, biological diversity, and climate (Walker and Steffen, 1997). The predicted changes of some of its components, i.e. the climate change, may appear being small when looking at a global scale. But these comparatively small changes of the global averages mask the large geographical variations which will occur at regional levels (Walker and Steffen, 1999).

Due to Global Change, severe consequences for the agriculture in the North and Northeast of Brazil are expected as the deforestation of Amazonian rain forests will strongly reduce the probability of rainfall in both areas (Nisbet, 1994). For a better understanding of the Global Change effects on individual ecosystems and their peculiar responses to these changes, integrated simulation models are considered as important tools to study the functioning of ecosystems under varying conditions and to assess the impact of Global Change in a specific environment.

The interdisciplinary Brazilian-German research programme WAVES (Water Availability and Vulnerability of Ecosystems and Society in the Northeast of Brazil) aims at developing an integrated regional model (SIM) for identifying sustainable management strategies at a regional scale under various scenarios and for improving rural development, food security and life quality in this area.

Among 13 crop growth models, EPIC (*Environmental Policy Integrated Climate Model)* has been selected to simulate the crop production within SIM as it considers soil acidity, Al toxicity, and various cropping systems and intensities. To date, EPIC is tested for a wide range of crops, cropping patterns, and environments and showed good simulation results (Cabelguenne and Debaeke, 1998; Cavero *et al.*, 1998; Kramer et al. 1993; Roloff et al., 1998). But before applying EPIC to a new environment, its validation is strongly recommended.

The objectives of this study were (i) to test the reliability of EPIC and its derivative ALMANAC for predicting the crop production under the site conditions of the Brazilian federal states of Piauí and Ceará,. (ii) to validate the models under traditional and improved crop management, and (iii) to calibrate the maize, rice and cowpea cropfiles if necessary.

Materials and Methods

Data on yield and crop growth of local rice, maize and cowpea varieties, and soil and climate were collected from field trials in Piauí (Chapada Grande, Picos) and Ceará (Tauá). Growth and yield data on rice were collected in the 1986 and 1987 growing seasons, whereas data on maize and cowpea were collected during 1998 and 1999. Soils of the test sites in Piauí were strongly weathered (>5% weatherable minerals), very acid (pH 4.0) and presented toxic Al concentrations (Al saturation of CEC: >85%), whereas the trials in Ceará were carried out on nutrient-rich alluvial soils.

Traditional and improved cropping practices such as burning, mulch and fertiliser application, weeding, sole and mixed cropping, various planting densities and patterns were included in the test programme. Yield components, dry matter production and leaf area development were periodically determined for comparisons of observed and simulated data.

The simulations were run with EPIC v. 0941 and its derivative ALMANAC v. 1364 by using a cowpea crop file recently developed by the Federal University of Ceará (UFC) and the existing maize and rice crop files.

Statistical analysis was carried out using SPSS.

Results and Discussion

In Piauí, the first simulation runs with the original maize and rice files and the recently developed cowpea file showed low correlations between simulated and observed data in a comparison of all treatments (rice: R^2=0.35; maize: R^2=0.38; cowpea: R^2=0.33; data not shown). The fit of regression increased when some of the treatments were excluded from the regression analyses. In the case of rice, fit of regression significantly improved when burning and mulching was excluded, whereas fertiliser application and final spacing had to be excluded for improving fit of regression in the case of maize and cowpea (Fig. 1-3).

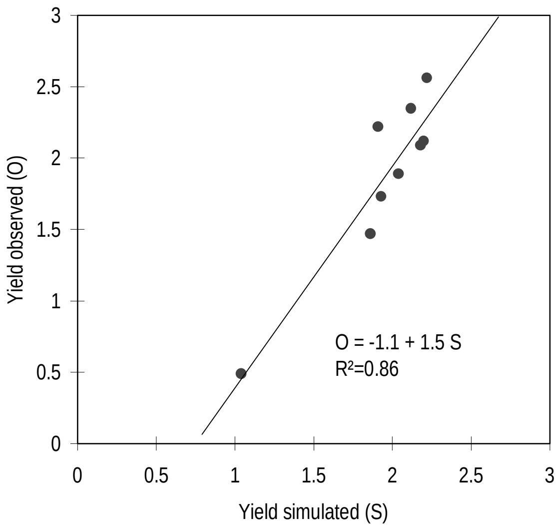

Figure 1. Simulated *vs.* observed yields of a local upland rice variety. Data were recorded in 1986 and 1987 at the Chapada Grande PI, NE Brazil.

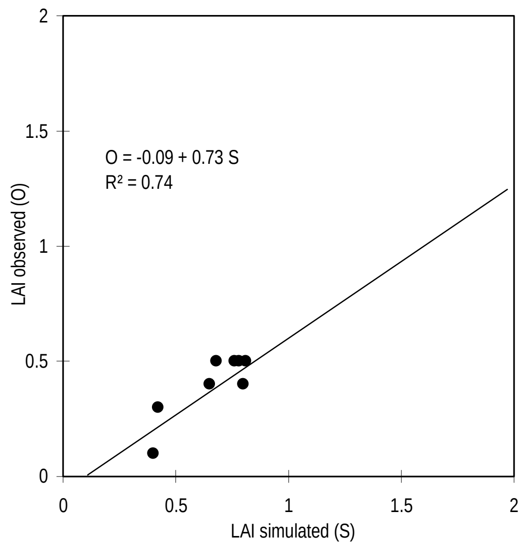

Figure 2. Simulated *vs.* observed LAI of a local maize variety under traditional crop management. Data were recorded in 1998 and 1999 at Picos PI, NE Brazil.

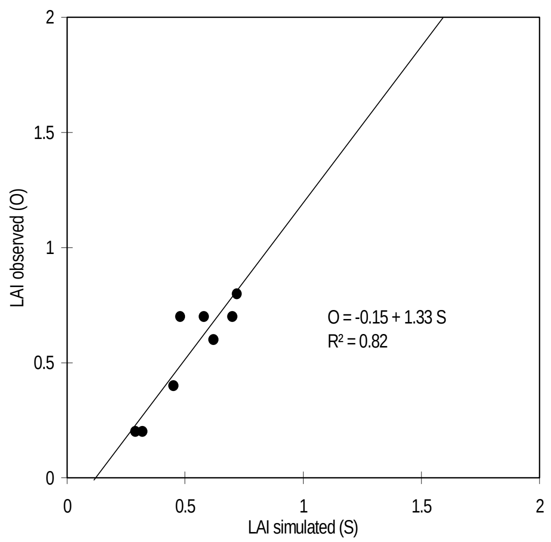

Figure 3. Simulated *vs.* observed LAI of a local cowpea variety under traditional crop management. Data were recorded in 1998 and 1999 at Picos PI, NE Brazil.

Contrasting results, however, were found in Ceará (Fig. 4 and 5), where growth and yield of cowpea was well predicted even under improved crop management. Even the simulated and observed maize data corresponded much better at this site when compared to Piauí. These results indicated that EPIC/ALMANAC performs well at more fertile sites represented by the test site in Ceará, but it may completely fail to predict the positive fertiliser response of maize and cowpea under less favourable site conditions as they were found in Piauí.

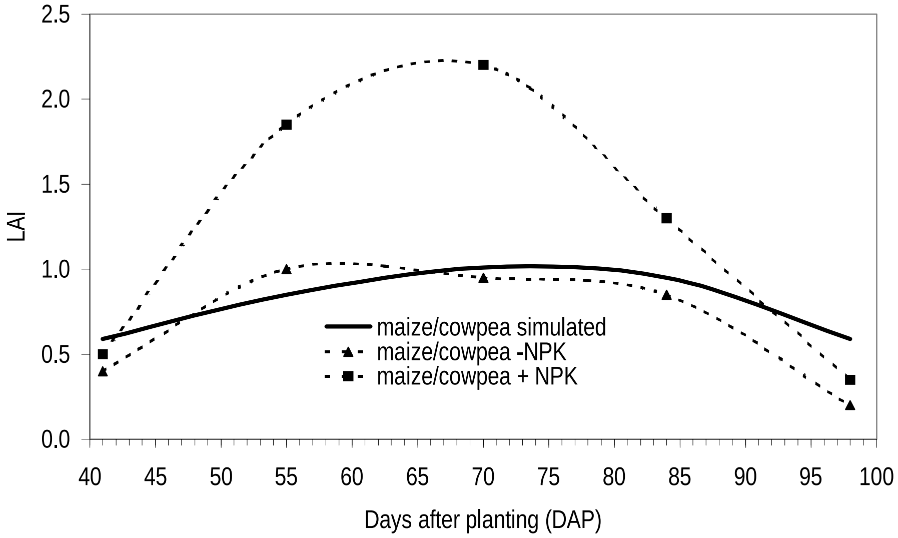

Figure 4. Simulated (EPIC/ALMANAC) and observed LAI (Delta T SunScan Canopy Analysis System) of intercropped maize and cowpea. Data were collected between March 3 and April 29, 1998 at Picos PI, NE Brazil.

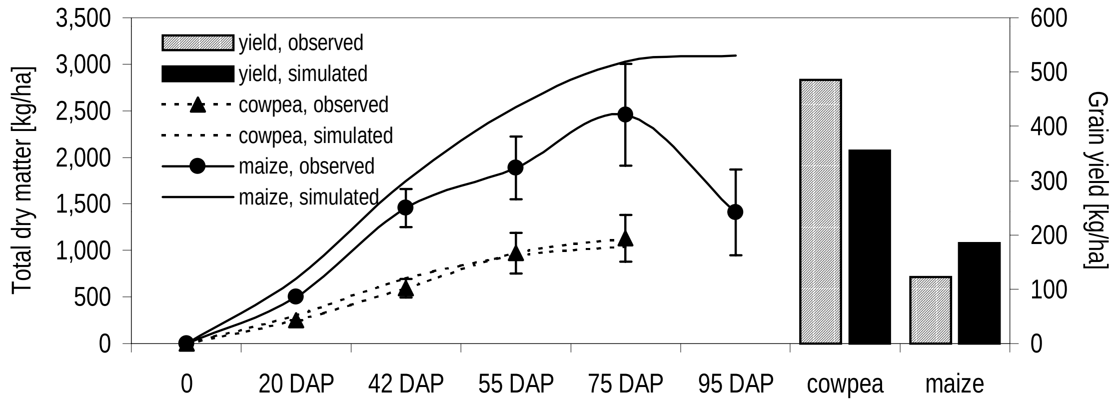

Figure 5. Simulated and measured TDM and grain yield of maize and cowpea (Treatment 1: weeding and NPK application). Data were recorded in 1999 at Tauá CE, NE Brazil.

For improving the simulation results, the structure of both models was analysed in a next step. The analyses of the crop files and the output data showed a high sensitivity of the models to both soil fertility and acidity related parameters. The simulation results of Picos indicated a strong relationship between soil pH, root formation and the number of days with water stress (Fig. 6). Simulation runs with cowpea by using the measured pH in the representative soil profile showed that the model considered water availability as the only limiting factor for crop growth, although field data revealed a positive growth and yield response of cowpea to fertilisers even under the water-limited growing conditions of 1998. A sensitivity analysis of the model revealed that an increase of the soil pH improved the water availability, leading to more reliable simulation results (Fig. 7). Adapting the Al tolerance index of the used crop files to local varieties and assessing the spatial variability of the soil pH are, therefore, considered as the key factors for improving the reliability of the models.

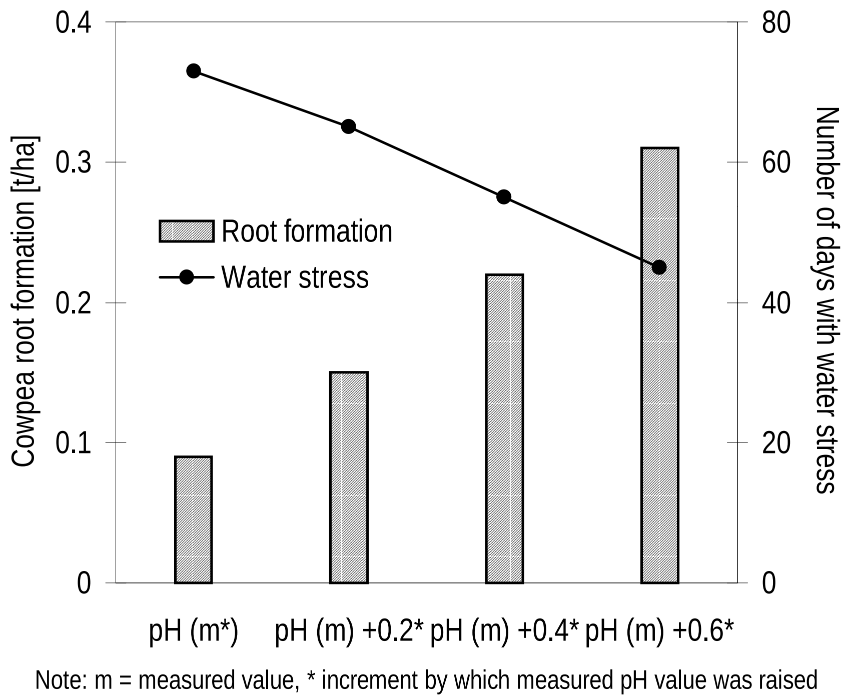

Figure 6. Simulated cowpea root formation and corresponding number of days with water stress as affected by increasing the soil pH. Field data were recorded between 1998 and 1999 at Picos PI, NE Brazil.

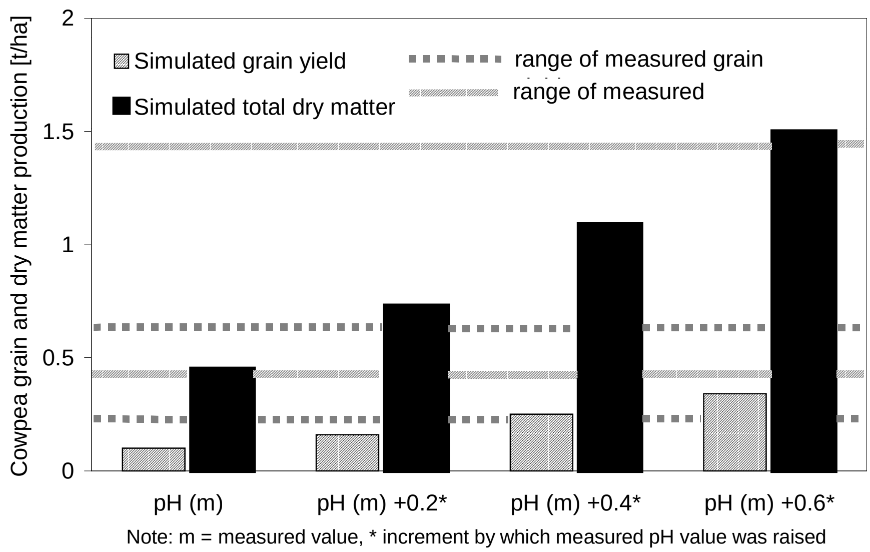

Figure 7. Simulated cowpea grain yield and total dry matter production as affected by increasing the soil pH. Field data were recorded between 1998 and 1999 at Picos PI, NE Brazil.

Conclusions

From this study, it is concluded that (i) the models have the potential to simulate growth and yield of local varieties even under the adverse site conditions of highly acid soils, (ii) the sensitivity of the models to soil pH modifications is very high, (iii) the models under-estimate the potential of local varieties to cope with adverse site conditions, particularly with acid soils, and (iv) further calibration of crop files with regard to improved crop management and soil acidity related parameters is required.

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References

Cabelguenne, M. and Debaeke, P. (1998). Experimental determination and modelling of the soil water extraction capacities of maize, sunflower, soya bean, sorghum and wheat. Plant and Soil 202(2), pp. 175-192

Cavero, J., Plant R.E., Shennan, C., Williams, J.R., Kiniry, J.R.,and Benson, V.W. (1998). Application of EPIC model to nitrogen cycling in irrigated processing tomatoes under different management systems. Agricultural Systems 56(4), pp. 391-414

Kramer, F., Allison, B.E., Leicht, A., and Kleber, M.. (1993)Calibration of the EPIC simulation model in the “Horkheim Island nature measurement field” (Germany). Mitteilungen der Deutschen Bodenkundlichen Gesellschaft No. 72(1), pp. 167-170

Nisbet, E.G. (1994). Globale Umweltveränderungen: Ursachen, Folgen, Handlungsmöglichkeiten, Klima, Energie, Politik, Heidelberg, Spektrum Akademischer. Verlag

Roloff, G., de Jong, R. and Nolin, M.C. (1998). Crop yield, soil temperature and sensivity of EPIC under central-eastern Canadian conditions. Canadian Journal of Soil Science 78(3), pp. 431-439

Walker, B. and Steffen, W.L. (1999). The nature of global change In: Walker, B. Steffen, W.L., Canadell, J. and Ingram, J. (eds.). The Terrestrial Biosphere and Global Change - Implications for natural and managed ecosystems, Cambridge University Press, Cambridge (UK) pp. 1-18

Walker, B. and Steffen, W.L. (1997). An overview of the implication of global change for natural and managed terrestrial ecosystems. Conservation Ecology [online]1(2), Available from the Internet. URL: http://www.consecol.org/vol1/iss2/art2