# The Role of Biophysical Crop Models in Operational Agrometeorology

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## 1. Introduction

Although biophysical crop models can be found in the international literature for more than a couple of dozens of years (Stigter and Rijks, 1988), for many reasons they are not yet used everywhere in operational agrometeorology. For Cuba, of which I can speak openly from my own experience, we could mention the following. Many of the more advanced models are commercial products that are difficult to obtain. The effective exploitation of such models requires a solid theoretical background and experience of their potential users, which farming related users from developing countries do not have. Also large reliable databases are needed. Historically we have neither sufficient experience nor enough scientific information to understand these models fully and make profitably use of them.

But the situation exists and there is a danger of a deepening rift between the creators of crop models and agrometeorologists, who potentially are the more effective appliers of these powerful and novel tools. Our experience appears to tell us that it is impossible to extend the use of these technologies. When a group of experts/designers produces a scientific or operational report, we assume automatically that they are talking about traditional statistical models that therefore are only valid in the locality or region in which they were obtained. That's when they say "that will be true there... but things are different here"! As if the biophysical crop models were describing the ecology, physiology and agrometeorology of an alien unexplored extrasolar planet.

There are many scientific articles on the features of biophysical models, their perspectives and the developments foreseen for this technology, in several specialised journals related to agricultural problem fields. There are so many that it is impossible to review them doing justice to most of them. Instead we will give some actual examples of how biophysical models have become part of operational agrometeorology as carried out in the Camagüey Meteorological Centre. Not without highlighting that we are until now the only group that uses biophysical crop models to such ends in Cuba.

In our society any person can knock at my door, call me by telephone or send me a message through a mutual acquaintance, requesting meteorological specialized advise, with the certainty that he/she is going to get it. Specialists are expected to quickly come with their conclusions, advice and recommendations to any requesting authority, contributing to his/her understanding and making it possible to take pertinent measures. However, and this is most likely also true for the rest of developing countries, specialists in the C domain (of scientific support systems, see the framework developed by Stigter (2003; 2005)) cannot directly communicate to farmers in the A domain (of their livelihood), due to the inexistence of an appropriate communication network for that purpose. The easiest way to do so is to work voluntarily with them in the fields: e.g. sowing, cleaning and harvesting sugar cane crop, harvesting rice and coffee, and doing many other tasks that could include planting 55 gallon tanks with young trees in a Botanic Garden or cutting banana leaves under hurricane rains in order to prevent the felling of trees by winds. Such things are done here frequently when they appear necessary for understanding. Although it also happens in Cuba that outstanding farmers and their organisations participate in National and International Congresses on what they produce.

But the surest form of getting with the needed knowledge into the A domain is to go directly to policy and decisions makers and their consultants and to the extensionists and NGOs, that all work in the intermediate B domain (Stigter, 2003; 2005). This is one of the reasons that the use of biophysical models has become a common practice in our provincial agrometeorological service, although it is true that they are practically unknown and unused in the rest of the country. This is now planned to change in the framework of a capacity building project. The forms in which they are used are easier to explain through examples and personal anecdotes. This is the reason why, in this document, we abandon academic language completely and use a testimonial and journalistic style instead.

## 2. Impact of climate change and variability. Adaptation of agriculture and other sectors

In other places of the world scientists are making an effort to convince decisions makers about the imminence of climate change and its prospective impacts. In Cuba, common citizens make an effort to convince you in the street that climate change is affecting us, and they have all the reason to do that. But to convince experts and elected community leaders, coming from any sector of human activity, that climate change is here and current and future impacts are foreseeable and of calculable magnitude, a simple expert opinion or statistical case study will not do. Even specialists in biological, ecological and environmental sciences do not realize that an increase of 2.5° C in mean temperatures is equivalent to a reduction of 10% of annual precipitation (if this doesn't change itself) in what indexes of aridity refer. We made such evaluations in 1998-99 as part of a wider evaluation that included non-agricultural sectors also, and we obtained the National Science Award in January 2000 (INSMET, 2001).

It is even more difficult for the agrometeorological community to understand that it is necessary to demonstrate that meteorological drought is measurably responsible for low levels of agricultural production. The causes are however the same as in the previous case. We made these evaluations in 1999 as part of a wider evaluation on the monitoring, causes and forecasting of droughts, and we obtained another National Science Award for it in January 2002.

In both cases we made use of all biophysical crop models in our possession at that time. We have more now, and worked with daily meteorological data bases of 30 years and precipitation series of 55 years. Due largely to efforts like these, that have continued in depth and are being converted to integrated assessments, our policy and decision makers and Cuban society in general continue development and application of adaptation strategies to climate change and drought. These strategies are in turn evaluated with the use of biophysical crop models (Rivero et al., 2005 a and b).

In the use of biophysical crop models for the layout of adaptation strategies to climate variability and change, conceptual outlines have been developed pertaining to yield disaster risks. Additional models have been built in order to integrate the impact of climate on yields with its impact on water resources and climate related stress on animals. Such integrated models include the use of population development and technological efficiency scenarios (Rivero, 2001; Rivero et al., 2005 e).

In 2002, agricultural authorities requested me to give some lectures to Caribbean francophone students of the "Université des Antilles et de la Guyane" that were trained in Cuba. I decided to speak of the conditioning of agriculture by climate (Rivero, 2002). I even made for them a similar analysis as indicated above, now for their countries of origin, using agroclimate data published by FAO. I leaned very much on biophysical models and this work is available to INSAM members on request. Although it refers to a particular area of the planet, the methodologies used and concepts discussed are of general validity and could be adopted in any other place.

It is interesting to point out that, independently of the interest shown by these students, still more interested were the Cuban agricultural specialists that attended the lectures. And I understood then better that the teaching of agricultural sciences in my country had much emphasis on the importance of soils, without teaching to specialists knowledge on the basic role of agroclimatic conditions in the formulation of food production strategies.

## 3. Crop regionalization and land evaluation

More than 15 years ago I was asked by the authorities whether a certain region of my province had appropriate climate conditions for the cultivation of oranges and grapefruits. I called one of my specialists (graduated abroad) and entrusted him the task. Two days later, I received the following conclusive answer: "Yes. The textbook says that citric fruits may be grown in regions with precipitations between 1200 and 3000 mm and temperatures between 23 and 34° C (Kulicov and Rudnev, 1980)." And my reply was: "1200 with 34 or 1200 with 23° C? In a purple ferritic soil with very high internal drainage?

Only after reading three FAO manuals and having assimilated the concepts of models described in Kassam and Beek (1981), Oldeman and Frére (1982), Doorenbos and Kassam (1988), I felt able to give an answer to my authorities. Also using these techniques I could convince my authorities about stopping an enormous plan of growing African oil palm (*Elaeis guineensis* Jacq.) when they were practically already ploughing the fields.

## 4. Optimum sowing dates and other things

Potato is a high-risk crop in my province that requires high technology, low temperatures and a great consumption of water. The situation is made more difficult because November is the month of ploughing the fields for this crop, and if this is a rainy month, planting is delayed until January with harvest in April, considered a bad month for harvesting potato. Every time that there is a favourable October or November month, enthusiasts want to rush to the fields in order to advance the sowing date but when they come to us we say: "Don't do it"! In a dozen of years only once they didn't consider our advice, so they received the lesson they needed. Our authorities rely on us, and we rely on the crop biophysical model WOFOST 4.1 (Diepen et al., 1988).

For a long time, in our country people got used to think and act as if climate were some kind of background landscape and as if the principal conditioning factor of agriculture was soil. This is partly because our meteorological service existed during more than 85 years only in order to observe and forecast hurricane trajectories. In fact many tropical meteorological services worked only during the hurricane season (Riehl, 1954). High yielding varieties under irrigated conditions, free of weeds, pests and diseases, with all nutrients needed, may have also contributed to this condition. In one occasion I had the opportunity to peruse dozens of scientific reports from an experimental agricultural station, with the objective of deriving knowledge on the relationship between the crop in question and climate conditions. But I found neither a single map nor any other information about the climatic conditions in which the experiments had been carried out. In all of them appeared one simple sentence: "These results were obtained under the climatic conditions of this experimental station."

In the 2002 lectures to Caribbean francophone students on the conditioning of agriculture by climate, one other issue was that I wanted to illustrate this with the determination by climate of optimum dates of sowing for rainfed and irrigated crops. Although it may be evident for most of our colleagues, I should insist that in Cuba the optimum sowing dates for a crop are radically different in rainfed and in irrigated conditions. I went home and looked through all literature at hand, an immense task considering that my personal library has more than 10 000 volumes, in order to discover with horror that such information could not be compiled from my available literature. Then I said to my younger son: "I need you to calculate for me tonight the optimum sowing dates in our climate conditions for all available crops in WOFOST 4.1."

Authorities and growers today use such estimates without knowing how they were calculated. Over time we could verify that those dates coincide with the traditional knowledge of our peasants and with field experiments, but we obtained them with a biophysical model. In 1999 I attended an International Rice Congress. A well-known scientist lectured on recommendations and optimum sowing dates for irrigated rice according to the results of years of agricultural fields experiments. I presented the same curve of seasonal yields arriving to the same conclusions. But my curves had been obtained with WOFOST 4.1 (Rivero, 1999).

Talking about rainfed rice in Cuba in 1999 was risking a bad public reputation. But already in 2005 it became a necessity, in order to face the negative effects of increases in temperature, of reductions of precipitation and available irrigation water, and of higher frequencies of meteorological, agricultural and hydrological droughts. Latest results obtained by us on these matters have already been presented in national and international events (Rivero et al., 2005 c, d and e). These documents are available to those INSAM members that may be interested, without any commitment. Such results and analyses were made with WOFOST 7.1.2 (Supit et al., 1994) and Generic Ceres of DSSAT 3.0 (Tsuji et al., 1994; Hoogenboom et al., 1999).

## 5. Forecast of yields and agricultural production

Although it might seem incredible, the forecast of agricultural yields doesn't have the widespread use that it should have, given the advantages that it represents for growers and organisations related to the production, harvesting, storage and distribution of food. An important step in the development of such techniques is coupling models of global climate with crop models (Hansen, 2005; Betts, 2005; Challinor et al., 2005). In North America it has been revealed that farmers are more often interested in the yield forecasts for their competitors than in their own. This doesn't make sense for Cuban farmers because there is no market economy here, but an economy without the laws of offer and demand or competition. All produced food is bought and distributed with regulated prices, farmers themselves being insured against all type of natural disasters that have been certified by the Meteorological Service. However, our experimental yield forecasts for potato and rice have been well accepted by farmers and funding for the development of these services will continue. This activity is very young in Cuba, and its realization has been possible only through the use of biophysical models.

The statistics of agricultural production do not exist in the required form or they are irregular and non-reliable. We therefore thought that it could be useful to predict our agricultural production and that of the main food producing regions. We will arrive there, so it would allow us to better plan the purchasing and selling of food on the world market, taking advantage of fluctuations in offers and market prices.

Another of my specialists, also graduated abroad, obtained a system of linear multiple regression equations for forecasting citrus yields using production statistics. Upon carrying out a critical evaluation of that work I detected some conclusions from such equations that seemed to me incongruous or unjustifiable on the basis of theoretical knowledge of plant physiology and ecology. When carrying out an exhaustive revision of the used procedure, the cause of such problems came to light. The original production statistics were "total" ones: summed totals of oranges, lemons and grapefruits. It was impossible to know what percentage of the totals was oranges, lemons or grapefruits for any year at all of the time series.

## 6. Biomass and other alternative sources of energy

The evaluation of biomass like an alternative source of energy in climate change conditions was possible only using all types of available biophysical models. It is evident that no society could think of long-term solutions for conventional energy problems by using terrestrial biomass if climate change threatens to reduce considerably the net primary productivity of their natural and agricultural ecosystems. The integrated final assessment of this sector, including solar and wind energy, will be available at the beginning of 2006.

## 7. Conclusions

In our agrometeorological service, the use of biophysical crop models has been necessary and profitable. However, this can't be interpreted as meaning that these tools will substitute for the role of specialists and experts in our field. In order to use a model of this type and to obtain valuable conclusions it is required that they are used by specialists that have appropriate knowledge in their field and enough information on the nature and content of the model. The mere drawing of the problem to be solved and the analysis of results offered by them require specialised knowledge that only experienced agrometeorologists can contribute. Combined with poverty and underdevelopment, this considerably limits their use by farmers in developing countries. Only experienced specialists are able to decide when some model results should be rejected the way statistical hypotheses may be rejected.

But we also recommend that before rejecting the conclusions of a biophysical model you must revise your hypothesis, your input data and the nature of the problem rising from calculations. Several times I have heard one or another of my collaborators scream at my side that this or that model is not good at all. They have most often been mistaken. A good model contains experience by many specialists that preceded us as well as information derived from countless field experiments by others. But it cannot think for us.

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