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DATES FOR RAINFED RICE IN SELECTED LOCATIONS
IN THE PHILIPPINES

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ABSTRACT

Climate variability and changing climate affect crop growth and development, define crop productivity, and also determine the cropping season. An objective and knowledge-based assessment of the effects of climate variability on crop productivity provides an evaluation of climatic risk of crop production such as rainfed rice. Recent advances in the sciences and technologies have accelerated the integration of information and the generation of new knowledge using systems research tools such as process-based crop simulation models, seasonal forecasting techniques, and database management. These have provided better evaluation of the effects of anticipated seasonal climate on rice production. As changing climate change has resulted to the shifts in spatial and temporal distributions of hydrologic processes including the disruption of the rainfall patterns, cropping calendar or planting window has been altered. Thus, a strategy to adapt to climate variability and to manage climate risk is to modify or adjust the planting calendar given the seasonal climate outlook. An approach based on statistical hydrology and on crop physiology allows determination of an optimal cropping calendar based on either rainfall probabilities, or exceedance probabilities of target crop yields estimated using a physiological crop simulation model. Crop yield probabilities are determined for a specific area given the seasonal climate outlook for which the optimal planting window can be determined, and can be translated in economic terms. The innovative approach is applied for selected rainfed rice growing areas in the Philippines. The procedure can be used to determine a dynamic cropping calendar based on seasonal climate forecasts in a changing climate.

KEYWORDS AND PHRASES: planting calendar, climate variability, rainfall probabilities, yield probabilities

I. Introduction

Climate and weather play an important role in crop production since weather and climate variability affect crop growth and development, define crop productivity, and also determine the cropping season (Matthews and Stephen, 2007; Lansigan et al., 2007; Tibig and Lansigan, 2007). An objective and science-based assessment of the effects of climate variability on crop productivity provides a systematic evaluation of the vulnerability and risk of crop production due to climate variability (Lansigan, 2005). There is now a general agreement that changes in the frequency and intensity of extreme weather and climate events are occurring, and climate change is now a reality. These changes have profound effects and impacts on society and environment, in general, and on agricultural production, in particular. Frequency analysis of temperature based on consolidated weather datasets from several stations around the world show that warm nights are increasing, and cold nights decreasing (Alcamo et al., 2006). There are also local observational evidences to show that temperature between different time periods has increased significantly.

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In recent years, advances in information and communication technologies as well as in various scientific disciplines have accelerated the integration of information and the generation of new knowledge using systems research tools such as process-based crop simulation models (Matthews and Stephens, 2002; Matthews et al., 1997), geographic information system (GIS), remote sensing (RS), optimization techniques, geographic positioning system (GPS), and database management. Such advances and developments provide opportunities to better evaluate the effects of anticipated weather and climate variability on crop production. While climate change and variability have resulted in the shifts in the spatial and temporal distributions of hydrologic processes including the disruption of rainfall patterns (IPCC, 2007; Katz, 2007), cropping period or planting window has also been altered. As an adaptation strategy to manage or cope up with climate risk, and to minimize the adverse impacts of climate variability, the cropping calendar is modified or adjusted considering the seasonal climate outlook.

There are at least two approaches that can be used to determine the optimal cropping calendar for a particular crop to be grown in a specific location. One approach is based on the probabilities of rainfall events, while another approach is based on the exceedance probabilities of target crop yields estimated using an eco-physiological crop simulation model (Lansigan et al., 2007; Delos Santos et al., 2007). Previous works (e.g. Lansigan et al., 2007; Lansigan and Salvacion, 2008) have also presented the use of stochastic weather data generators (Geng et al., 1988; Semenov and Barrow, 2002; Hansen and Ines, 2005) coupled with a process-based crop simulation model, and risk analysis to determine the optimal planting window in selected rice growing areas in the Philippines. Given the seasonal climate outlook crop yield probabilities can be estimated for these areas for different planting dates from which optimal planting window can be determined. Such information can be used to provide advisories to farmers and/or extension workers (Lansigan et al., 2007).

This paper presents the approaches to determine an optimal planting calendar for a particular area using either the probability analysis of rainfall events, or the probabilities of target yields which can easily be translated to economic terms. The location-specific optimal planting periods for rice production considering the seasonal climate variability in selected rice-growing areas in the Philippines are presented. The minimum data and information requirements as well as the research challenges and gaps are also described. The procedures developed can be adopted in areas where climate information is available, or can be used as general guide in updating optimal planting window given the seasonal climate outlook.

II. Climate Variability and Cropping Calendar

A. Approaches to Determining Planting Calendar

Climate change is expected to be reflected in the shift in frequency distribution of hydrologic variables such as rainfall as well as in the disproportionate increase in the mean level and variability. The shift leads to changes in spatial and temporal distributions of hydrologic variables. These changes are now evident in local historical datasets from different locations as shown in previous figures. More intense extreme events are expected to occur more frequently. Dry periods become drier while rainy months become wetter (IPCC, 2007). Climate extremes are expected to occur more frequently with shorter recurrence intervals. The altered hydrologic regimes and rainfall patterns are also expected to have significant impacts on crop production not only on crop yields but also on the schedule and timing of crop production activities. Thus, the crop growing season will be altered, and the optimal cropping calendar will shift coinciding with the change in the rainy period.
One strategy to address climate variability in agriculture is adjusting the cropping calendar, i.e. synchronizing the growing period to coincide when there is sufficient water from rainfall for crop growth and development. Several procedures and indicators are being applied to determine the best time to plant the crops ranging from indigenous knowledge, and rule-of-thumb methods, to more science-based approaches anchored on crop eco-physiology (e.g. Yoshida, 1981). However, these procedures (i.e. rules-of-thumb) often are no longer dependable or reliable especially under the conditions of altered hydrologic regimes or extreme climate variability. Thus, approaches based on sound scientific knowledge that consider the various factors influencing crop growth and development such as frequency of occurrence and/or cumulative rainfall threshold values have to be updated in the light of climate variability. For instance, Yoshida (1981) postulated that rice growing season in an area can start when cumulative rainfall during the next 30 days counting from the driest day in the year for a particular area has reached 200 mm. Rainfall threshold level for corn is less. This postulate has been verified via crop simulation with available historical datasets for Los Baños and other locations (Lansigan et al. 2008).

Local observational evidences that climate change is now a reality. Long sequences of reliable historical datasets have shown statistically significant changes in terms of distributions such as increase in mean level, variability and extreme values (Lansigan, 2009). Inasmuch as the regularity of climate in an area which is the basis for determining the planting calendar has changed, there is a need to modify or update the cropping calendar based on available historical weather datasets, or based on seasonal climate forecasts. Advanced information on the global and regional seasonal climate predictions which are being disseminated and updated regularly, and published in the Internet (e.g. http://iri.columbia.edu) including the available historical records of weather (e.g. rainfall, and temperature) can be used to modify or determine the cropping calendar.

B. Planting window for rainfed rice

Crop growth and development can be divided into three general phases, namely: vegetative stage (VS), reproductive stage (ReS), and ripening stage (RiS). For a 110-day rice variety such as IR64, the vegetative stage is about 45 days, reproductive stage 35 days, and ripening stage, 30 days as shown in Figure 1 (IRRI, 2000). Thus, determining the cropping calendar in the anticipated seasonal climate involves synchronizing available water from rainfall and the water requirements of the crop at different stages of growth. In general, crop needs about 4-6 mm. of water daily for evapo-transpiration including losses due to seepage and percolation. For example, a 110-day rice variety would need about 270 mm., 210 mm., and 180 mm. water from rainfall during the vegetative stage, reproductive stage, and ripening stage, respectively (Yoshida, 1981). This water requirement for rice already accounts for weed control via water management. Thus, planting window for growing rice in rainfed production areas should coincide with the period during which the water requirements from rainfall can be satisfied. In irrigated areas, however, water is not a limiting factor. Thus, rice production is dependent on the availability or schedule of irrigation water. For rainfed areas, the onset of rains and the availability of adequate water from rainfall are the determining factors for planting rice crop. Moreover, rice crop grown in rainfed condition must remain relatively dry during the last 2 weeks following maturity to avoid deterioration of rice quality (Saseendran et al., 1998).

Thus, cropping calendar for rice can be determined by considering the water requirements of the crop and the climate in an area over a certain period of time. However, optimal planting time for each year has to be evaluated considering the seasonal climate outlook for the incoming growing season. Thus, this approach requires the availability of
reliable seasonal climate forecasts for a specific location to be able to provide estimates of probabilities of rainfall and/or crop yields.

C. Rainfall Probabilities for Determining Optimal Planting Window

1. Estimation of probabilities of rainfall events

Determining the optimal cropping calendar for a location involves the estimation of rainfall probabilities considering the crop water requirements at different stages of crop growth and development. These probabilities are the following:

(a) Probability of onset of rainfall period, \( P_o \), or the probability of getting at least 200 mm of rainfall, or \( P > 200 \) mm;
(b) Probability of required rainfall during crop growth, \( P_w \), i.e. the probability of meeting the daily evapo-transpiration demand of the crop at vegetative stage;
(c) Probability of rainfall during ripening stage, \( P_r \), i.e. the probability of satisfying the daily evapo-transpiration demand of the crop at ripening or flowering stage; and
(d) Probability of dry harvest, \( P_d \), i.e. the probability of meeting the daily evapo-transpiration demand of the crop at maturity.

Such probabilities of rainfall events (i.e. \( P_o, P_w, P_r, P_d \)) for specified rainfall volumes or threshold levels can be estimated from available historical and synthetic (predicted or forecasted) weather sequences using the relative frequencies of rainfall events. Rainfall probabilities in graphical form for a particular location may be plotted as in Figure 2.

Considering the stochastic nature of rainfall events and processes, the optimal planting calendar is obtained by determining the period during it is likely that the desired or specified cumulative rainfall volumes during the specific crop growth periods (herein represented by the different rainfall probabilities \( P_O = P_o \times P_w \times P_r \times P_d \)). That is, the period during which \( P_O \) is maximized is considered the optimal planting date (Saseendran et al., 1998). It is the period when the estimated water requirements for each development stage of crop growth is likely to be satisfied. This is presented in Figure 3 for selected locations.

2. Planting Calendar in selected rice growing areas

Following the procedure described above, the optimal planting window for rice production in selected locations (provinces) can be determined. The optimal planting calendar is the critical period during which the rainfall requirements at different stages of crop growth and development are satisfied or met (Yoshida, 1987). Rainfall probabilities and the optimal planting window based on these relative frequencies of occurrence of rainfall events for selected location are presented in Figure 4. While water requirements for each stage of crop growth and development are crop-specific, such planting window for rice can be used as reference guide for other crops with some adjustments. For example, corn require less water than rice, and therefore, planning date can be adjusted accordingly by determining the period during which the rainfall thresholds are satisfied.

III. Determining Optimal Planting Calendar via Crop Simulation

1. Process-based crop simulation model CERES-Rice

The optimal planting window may also be obtained based on yield probabilities evaluated using a validated eco-physiological process-based crop simulation model. One such crop model is the DSSAT CERES-Rice model (Hoogenboom et al. 2004). The crop simulation model requires as inputs crop- and variety-specific genetic coefficients, location- or site-specific soils data (e.g. soil type, texture, and drainage characteristics), sequences of
daily weather data (e.g. rainfall, temperature, solar radiation, wind speed, etc.) , and crop 
management practices such as planting date, timing and dosage of irrigation and 
fertilization, etc. Model outputs are crop yields and other relevant variables related to crop 
growth and development. The model simulates crop growth and development, and yield is 
determined by weather and climate variables as well as management inputs. Thus, the 
model may also be used to evaluate the expected crop yield for different planting periods in 
a particular area.

The DSSAT CERES-Rice model has been extensively validated in several locations 
for a standard rice variety IR-72 (Matthews et al., 1995; Matthews and Stephen, 2002; 
Lansigan et al., 2007). The model can be used to simulate crop yields under different 
production systems (e.g. Penning de Vries et al., 1987; Rabbinge et al., 1997) as well as 
crop management regimes including varying planting dates. Simulations using several years 
of weather data provide estimation of probability distribution of crop yields for specified 
planting date.

2. Simulation of rice yields

The process-based crop simulation model lends itself as a useful tool in evaluation of 
crop yields under different environmental conditions and crop management practices. For 
example, for a particular location given the historical or synthetic sequences of weather data, 
the best planting date can be determined by evaluating which planting period when 
maximum crop yields may be expected. Thus, for several years of weather data, crop yields 
can be simulated for each specified planting date. Simulated crop yields can then provide 
information for the estimation of probability distribution of crop yield and yield probabilities. 
Planting date(s) that will give high probabilities, $P_Y$, of exceeding target rice yields can be 
estimated from the distributions of simulated yields, and also considering the condition for 
good grain quality based on the probability of target yield during dry harvest period, i.e. $P_Y = 
P_T \times P_d$.

Empirically derived crop yield probabilities based on simulated yields allow one to 
estimate probabilities of exceeding target or specified yield levels under different conditions 
including varying planting dates. Figure 5 shows the rice crop yield exceedance probabilities 
for a location in Isabela province during specified planting date obtained using a crop 
simulation model.

It should be noted that probabilities of yields simulated using a process-based crop 
model can also be used to determine the best planting window for a given seasonal climate 
outlook or forecast. The best planting period is the during which the highest yield can be 
achieved. However, evaluation of the reliability of such planting window can only be 
evaluated provided several equally sequences of daily weather forecasts can be generated 
for a seasonal climate outlook. Simulated crop yields using several sequences of weather 
data as inputs into the model will provide the probability distribution of crop yields. Generation of equally likely sequences for a given seasonal climate forecast can be obtained 
by temporal downscaling of regional seasonal climate outlook using various statistical 
approaches (e.g. Hansen et al., 2005; Wetterhall et al., 2005) including the use of synthetic 
weather data generators (e.g. Geng et al., 1988; Semenov et al., 2005; Lansigan et al., 
2005).

3. Comparison of planting window based on rainfall and crop yield probabilities

The optimal planting window for rainfed crop production systems can be determined 
by synchronizing crop growing period with the rainfall distribution in an area. Cropping 
period should be such that critical growth stages of the crop should coincide with days where 
adequate rainfall can be expected. Thus, data and information from rainfall patterns and
distributions for an area are critical. Rainfall probabilities can be estimated using historical weather records, or from synthetic weather data generated which have statistically same properties as the historical sequences.

However, rainfall probabilities such as the likelihood of exceeding certain rainfall threshold levels may not be easily appreciated nor readily be used at the farm level decision-making as regards planting date. A number of constraints may be cited. Firstly, adequate and reliable historical sequences of weather data are very limited particularly in most marginal crop production areas. Secondly, there are now local observational evidences that climate has changed. Thus, climate change and variability have distorted the weather patterns which necessitate the re-evaluation of the cropping calendar being used which is based on the climate in the past. Thirdly, interpretation of or communicating to farmers information on rainfall probabilities may present some difficulties. There is a need to package these information in such a way that they are easily understandable and useful to the users.

Presumably, probabilities based on consideration of more yield factors than just rainfall would be more reliable in providing the optimal planting calendar. Thus, yield probabilities determined using process-based crop simulation model will be more intuitively superior and more reliable. Moreover, farmers can easily relate to and appreciate the information on yield probabilities provided since crop yields can be measured, and can be translated directly in economic terms. Estimation of yield probabilities required a number of data and information on crop production systems which are needed as inputs to the crop model. Some or most of these input data requirements, e.g. crop coefficients, soils and weather data, may not be readily available. Thus, this limits the use of the approach based on yield probabilities.

While the two approaches based on rainfall probabilities and yield probabilities may give similar recommendations as regards planting date, the differences in absolute magnitudes between the two probabilities can be quite substantial (Saseedran et al., 1998; Lansigan et al., 2008).

IV. Concluding Remarks

Weather and climate are important factors in crop production especially under rainfed conditions. Establishment of the crop to ensure crop growth and development usually involves synchronizing growing season to coincide with the start of the rainy period. Optimal planting period can be determined based on conditional probabilities of rainfall threshold levels for specific crop growth stages, and also probabilities of achieving target yields using an eco-physiological process-based crop simulation model. Application of the two approaches depends on the availability of the adequate data at the farm level to warrant reliable analysis. The approaches presented involve a number of issues, data and information gaps as well as research and development challenges that need to be addressed.

Access to available historical weather data records is a major research and development issue in the Philippines. This is considering the limited and scarce datasets, sparse network of gaging stations throughout the country, and often short length of reliable historical records available. Thus, the reliability of rainfall probabilities from which to base the planting calendar is an important consideration in practical applications including the up-scaling and out-scaling in other areas.

There is a need for research on downscaling of seasonal climate scenarios and forecasts using available historical datasets. Use of locally-calibrated statistical
downscaling approaches such as historical analogues, stochastic disaggregation, and weighted regression techniques are needed to produce sequences of weather data based on large scale seasonal climate outlook. While there exists some downscaling model such as the PRECIS (PAGASA, 2010) its use has been limited to researchers affiliated with institutions which have undergone the training provided by the model developer.

Local application of the approach based on yield probabilities requires the generation of crop- and variety-specific coefficients for crop simulation. Crop parameters such as variety-specific coefficients are needed to simulate crop yields using eco-physiological process-based crop simulation models. While these parameters are available for certain crops and cultivars, (e.g. rice varieties such as IR 64, IR 72, and corn variety IPB 911) , coefficients for other crops are yet to be determined. Nevertheless, initially crop parameters for other crops may be used to simulate yields to serve as reference guide in determining the cropping calendar based on yield probabilities. Use of either rainfall probabilities or yield probabilities depends on what data sets are available to determine the optimal planting calendar. In either case, there is a need to device an easy guide to translate rainfall probabilities as well as yield probabilities in terms of economic information which the local stakeholders, e.g. agricultural technicians, farmers, field workers, etc., can easily understand and used in farm-level decision making.

References


Figure 1. Crop growth and development stages of 2 rice varieties (IR64 and IR8) (IRRI, 2000).

Figure 2. Plots of weekly probabilities of onset of rainy period or getting at least 200 mm. of rainfall, P200; weekly probabilities of required rainfall during crop growth, Pw; and weekly probabilities of dry harvest, Pd.
Figure 3. Estimates of probabilities $P_Q$'s based on historical rainfall data for Los Banos, Laguna.

Figure 4. Plot of weekly probabilities of having the desired or specified cumulative rainfall volumes during specific crop growth periods, $P_Q (= P_{200} \times P_w \times P_d)$; and probabilities of target yield during the dry harvest period, $P_Y$. 
Figure 5. Rice yield exceedance probabilities for a particular area and specified planting date obtained using a crop simulation model.