La sécheresse en zone intertropicale

Pour une lutte intégrée

EVALUATION OF THE CLIMATIC RISK ON UPLAND RICE IN BRAZIL

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I. INTRODUCTION

The cultivation of upland rice is considered of great importance in Brazil since it is responsible for approximately 60 % of total rice produced and is planted on about 5 million ha in all states of the country. The yield is low (1.2 t ha $^{-1}$) and shows a great fluctuation from one year to another, basically due to the cultivation system used by farmers and to the occurrence of dry spells ("veranicos"), respectively. It is considered the second most risky crop of the country, in relation to the reimbursement of PROAGRO (Agricultural Insurance Programm), and drought is considered the main cause. Most of the upland rice is grown in the "cerrados" area on soils classified by LOPES (1983) as acid, with low fertlity and low water holding capacity. In general, rice is planted for one or two years after cleaning the area and replaced by pasture afterwards (EMBRAPA, 1981). The soil is generally not adequately prepared, corrected and fertilized. Besides that, many farmers plant large areas, part of those being seeded too late. Most studies on agroclimatic suitability for upland rice in Brazil at national, regional and state levels, are based on the Thornthwaite & Mather monthly water balance (IPEA, 1972 ; CAMARGO et al, 1976). This method, despite showing interesting differences among regions, does not allow an adequate interpretation of the drought stress caused by "veranico". STEINMETZ et al. (1982) evaluted the occurrence of favorable rainfall periods (probability of getting 50 mm or more in 10 days) of 20 distinct localities in Brazil. The study indicated an increase in the number of favorable periods from South to North and from Northeast to Northwest. The probability of dry spells occurrence (less than 40 mm/10 days) and chances of having sequences of 10-days periods without rainfall during January and February in the State of Sao Paulo were analysed by ALFONSI et al (1979) and by ARRUDA et al (1979), respectively. Each of these methods has some advantages in evaluating the climatic risk of the crop. However, the short period water balance is the most adequate, since it considers climate, soil and plant parameters.

The objective of this study is to evaluate the climatic risk involved in the upland rice production in distinct regions of Brazil through the simulation of a 5-day period water balance considering planting date, cycle of the crop and levels of water availability to the root system.

II. MATERIAL AND METHODS

Climatic risk analysis for upland rice is mainly based upon a climatic-plant water balance model (FOREST and KALMS, 1982), which provides an estimated ratio of the water needs satisfaction (ETr/ETm), calculated separately for each stage of growth.

Evaluation of actual evapotranspiration (ETr) needs to solve the general equation of water balance :

$$ETr = Rainfall - runoff - drainage + water\ stock\ fluctuation$$

A mathematical function (EAGLEMANN, 1971) giving variation of ETr in relation to the water climatic demand (ETm) has been adapted (FRANQUIN and FOREST, 1977) as follows :

$$\begin{aligned} ETr_{daily} = 0.7 - 0.05\ ETm_d &+ HR\ (4.9\ ETm_d - 0.6\ ETm_d^2) \\ &- HR^2\ (8.6\ ETm_d - 1.6\ ETm_d^2) \\ &- HR^3\ (4.3\ ETm_d - 0.9\ ETm_d^2) \end{aligned}$$

Estimation of the maximum evapotranspiration of rice (ETm) is obtained by : ETm = Kc x ETP, where Kc is the crop coefficient and ETP is the potential evapotranspiration. Water availability index (HR) is calculated every 5 days, by comparison of the actual humectation of the profile (due to accumulation of rainfall and water stock) and the maximum humectation which has been obtained during the periods before. Runoff is estimated only if data are available. To calculate drainage, the model takes into account an estimation of the maximum water content available to the root system of the plant (RU). Drainage is consequently calculated by comparing humectation during the period and the RU level. The main interest of the model is that agronomic situations are effectively taken in account : ETr/Etm indexes are calculated for different periods of planting, duration of cycle and levels of available water to the root system (RU). By simulation of different situations, the model gives a sensitive evaluation of the variability of ETr/ETm indexes and consequently a basic estimation of the climatic risk constraint for upland rice production. Daily rainfall data for periods greater than 20 years were used. These data were checked using the regional vector methodology (JACCON, 1980). Potential evapotranspiration data were those calculated by HARGREAVES et al (1979). Crop coefficient values were those established by KALMS (1980).

Simulations for 84 localities in Brazil were done considering several planting dates and 3 levels of RU for a short cycle variety (110 days). Results of 25 stations will be shown in this paper. The study was done by using a water balance model developed by IRAT (FOREST , 1984) and available on a microcomputer system at CNPAF/EMBRAPA.

A level of 20 mm of rainfall (5 days) was established as the minimum necessary for planting. The expected yield was calculated according an empirical equation established by FOREST (1984). Exp (yield) = (0.01). (ETm). (ETr/ETm cycle). (ETr/ETm min). Preliminar results obtained at CNPAF indicate a fairly good agreement, between the expected yield obtained by simulation of the water balance and the yield measured in the field experiments. The frequential analysis of ETr/ETm cycle and of Exp (yield) was performed for different probabilities. In particular some value of ETr/ETm and expected yield are given for a probability of 80 % meaning that they will be equal or superior 4 years on 5.

III. RESULTS AND DISCUSSION

The analysis of regression between the ETr/ETm during the cycle and minimum value of ETr/ETm, which usually coincides with the flowering period, for five locations of Brazil, representatives of distinct water regime showed a linear regression equation and a high correlation coefficient (Fig. 1). Besides, appears a great difference in relation to the water needs satisfaction of these locaties. Below value of 75 % for ETr/ETm of the cycle and 65 % for ETr/ETm min the relation between the two variables are not so tight.

The effect of planting date of a short cycle variety on five locations with distinct rainfall regimes can be seen in Fig. 2. The results show that for a 50 mm RU level, there is a great difference among the locations in relation to the best planting time, the climatic risk involved and the interannual variability of the water needs satisfaction. Establishing a limit of 80 % or more of ETr/ETm during the cycle as adequate to have a good yield (Fig. 2) indicates that : - In Porto Velho (North region) there is not a specific period to plant upland rice, since all dates tested from October to January presented values of ETr/ETm greater than 80 %. Also, the interannual variability is very low. Decision about when to plant have to consider other aspects rather than water needs satisfaction ; - In Carolina (Northeast region) most of the planting dates present values of ETr/ETm greater than 80 % except for those after mid-january. The best planting periods are those from mid-November to mid-December. However, the interannual variability is relatively high for most planting periods ; In Goiânia (Central West region) the results are much better if the crop is planted from mid-October to the end of November. After that, there is a considerable decrease in the ration of ETr/ETm up to the end of January ; - Buri (Soueast region) shows a similar pattern as Carolina, even though the risk involved in the upland rice cultivation is much higher than is Carolina. Interannual variability tends to be higher during the October planting dates. - Capinzal (South region) shows a completely different situation. The risk involved in all planting dates is high except for the very late ones. However, in this part of the country, sowing after December might have problems of low temperatures during the flowering period of the crop.

Influence of RU on ETr/ETm cycle, frequential analysis of ETr/ETm cycle and probability of expected yield being greater than 80 %, is presented in Table 1. Using a RU = 50 mm and the ETr/ETm cycle at 80 % level of probability to compare the climatic risk of the distinct locations, it can be seen that in the northern region most places (except Humaitá) present ETr/ETm values greater than 90 %. The expected yield for these places is greater than 3 t ha^{-1}. Since drainage is relatively high in this area, it might be necessary to include this factor to obtain a better estimation of the expected yield. The climatic risk in this region is very low.

Most places in the Central west region (except Ponta

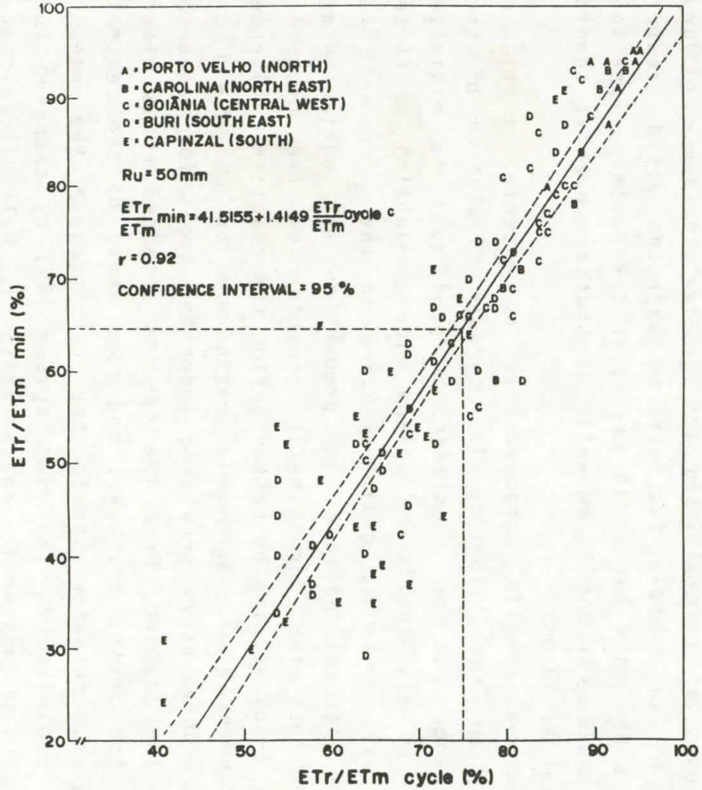

FIG. I. RELATIONSHIP BETWEEN ETR/ETM CYCLE AND ETR/ETM MINIMUM DURING THE REPRODUCTIVE STAGE OF THE CROP FOR FIVE LOCATIONS OF BRAZIL WITH DISTINCT RAINFALL REGIMES.

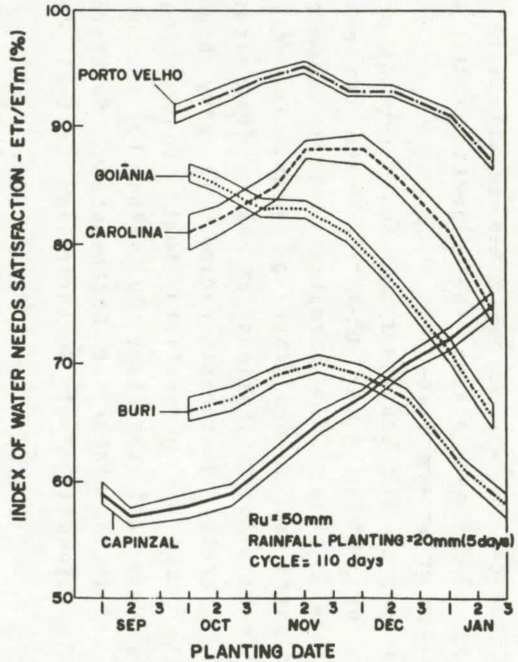

FIG. 2. INFLUENCE OF PLANTING DATES ON WATER NEEDS SATISFACTION OF UPLAND RICE ON FIVE LOCATIONS OF BRAZIL WITH DISTINCT RAINFALL REGIMES.

Porã), showed, that ETr/ETm is greater than 70 % (at 80 %, probability), and expected yield higher than 2 t ha $^{-1}$. Similar results have been obtained at Grajaú and Carolina, Maranhão State (Northeast region), and Estrela do Sul and Conceição do Rio Verde, Minas Gerais State (Southeast region). In these places the climatic risk can be considered as low or intermediate.

Most locations of the Southeast and South regions present a probability of ETr/ETm lower than 70 % and the expected yield lower than 2 t ha $^{-1}$. The climatic risk in these places can be considered as intermediate or high. The climatic risk in the remaining 2 stations of Bahia (Barreiras and Formoso do Rio Preto) Northeast region, is very high. As a result, it could be generalized that, considering the best planting date and the same RU value fo all places, the climatic risk is higher at Northeastern, Southern and Southeastern locations than at Northern and Central Western ones.

Table 1 also shows that the influence of RU on ETr/ETm and expected yield varies according to the region. For locations in Southern or Northeastern regions, the RU must be much higher than at other regions to compensate for the lower amount of rainfall and the greater incidence of dry periods. As an example, to get an expected yield greater than 2.5 t ha $^{-1}$, in 8 out of 10 years, in the Northern location the RU schould be around 30 mm while at Southern ones it should be as great as 90 mm.

Based on results obtained, it is expected that the evaluation of the climatic risk through simulation of the water balance can be considered a good tool to minimize influence of dry spells on upland rice production in three distinct ways : 1- By giving support to the government to establish regional policies of production and agricultural insurance once the agroclimatic zonation of the crop is defined ; 2- By helping to better define the relative influence of environmental and agronomic parameters on low yield of the crop, consequently providing important tools for research to solve the problem. From the results obtained it is clear that for the South, Southeast and some areas of the Central West region, research should try to increase the amount of water exploited by the root system (RU) by changing the plant, soil or agronomic characteristics. Multidisciplinary teams of scientists should define the best ways to do that;

TABLE 1. Influence of three levels of water availability to the root system (RU) on plant water needs satisfaction (ETr/ETm) during the cycle of upland rice and values of ETr/ETm and expected yield at 80% probability on distinct regions of Brazil (short cycle variety).

STATION/"MUNICÍPIO"	REGION/ STATE	GEOGRAPHICAL COORDINATES			RU = 30 mm			RU = 50 mm			RU = 90 mm		
		Lat. °S	Long. °WGr	Altitude (m)	ETr/ETm cycle	ETr/ETm ≥ (Prob. 80%)	Exp.yield ≥ (t.ha^{-}) (Prob. 80%)	ETr/ETm cycle	ETr/ETm ≥ (Prob. 80%)	Exp.yield ≥ (t.ha^{-}) (Prob. 80%)	ETr/ETm cycle	ETr/ETm ≥ (Prob. 80%)	Exp.yield ≥ (t.ha^{-}) (Prob. 80%)
	NORTH												
TAPERINHA (SANTARÉM)	PA	2	54	20	81	77	2.24	93	92	3.81	94	94	4.00
ALTO TAPAJÓS	AM	7	57	125	93	89	2.87	96	95	3.60	96	95	3.62
HUMAITÁ	AM	7	63	75	82	71	1.68	92	83	2.57	94	88	2.97
PORTO VELHO	RO	8	63	128	81	81	2.51	93	91	3.39	95	94	3.65
SERINGAL	AC	9	68		87	83	2.46	95	93	3.28	96	95	3.48
	NORTHEAST												
GRAJAÚ	MA	5	46	149	62	60	1.42	82	74	2.24	88	81	2.87
CAROLINA	MA	7	47	193	73	67	1.78	88	80	2.75	92	89	3.82
CAMPO MAIOR	PI	4	42	125	60	55	1.13	79	67	1.67	86	80	2.87
BARREIRAS	BA	12	44	435	45	39	.65	54	46	.92	64	54	1.13
FORMOSA DO RIO PRETO	BA	11	45	491	44	36	.50	54	44	.80	64	54	1.28
	CENTRAL WEST												
PORTO NACIONAL	GO	10	48	237	72	65	1.54	85	75	2.15	89	86	3.44
GOIÂNIA	GO	16	49	729	69	64	1.37	80	74	2.22	88	84	3.30
DIAMANTINO	MT	14	56	286	69	68	1.60	79	79	2.53	84	87	3.04
GAL. CARNEIRO	MS	15	53	646	72	66	1.78	86	81	2.86	91	88	3.73
PONTA PORÃ	MS	22	55	650	54	50	1.14	69	63	1.55	81	72	2.33
	SOUTHEAST												
ESTRÊLA DO SUL	MG	18	47	461	64	57	1.12	77	69	2.00	85	78	2.90
TAPIRAÍ	MG	19	46	670	59	52	1.18	73	64	1.83	82	72	2.30
CONCEIÇÃO DO RIO VERDE	MG	21	45	850	67	62	1.46	80	74	2.29	88	84	3.23
TERRA ROXA	SP	20	48	478	67	59	1.26	87	69	1.84	87	83	3.02
JAGUARIUNA	SP	22	47		62	56	1.31	73	66	1.80	82	76	2.49
	SOUTH												
PONTA GROSSA	PR				64	54	1.13	75	65	1.62	83	79	2.46
GUARAPUAVA	PR	25	51	1108	64	59	1.03	75	68	1.51	83	75	1.72
SÃO MATEUS DO SUL	PR	25	50	760	56	52	.89	66	58	1.23	74	65	1.69
XANXERÊ	SC	26	52	841	65	56	1.24	76	69	1.91	85	78	2.84
CAPINZAL	SC	27	51	447	56	49	.86	67	58	1.24	77	70	2.02

3- By orienting farmers about the climatic risk involved by planting at apropriate times. An experience on this aspect has been initiated this year at CNPAF/EMBRAPA. It was reported by a national rural TV program that the farmer could minimize the "veranico" effect on upland rice by planting at the most apporpriate time using varieties with an adequate cycle. CNPAF sent a simple kind of direct reading pluviometer to those farmers interested in collecting daily rainfall. The farmers are supposed to send the daily rainfall data to CNPAF once a year. They were asked to look for official or private meteorological stations close to their farm. Using the rainfall data collected at the farm level or obtained somewhere nearby (minimum of 10 years) and some informations on the soil characteristcs and agronomic aspects, several simulations of the water balance will be done to indicate the most appropriate period to plant and some other agronomic techniques that could be used to minimize the veranico effect. Extension service personnel have also been involved in this project. From the 5,100 letters received, pluviometers were sent to about 1,020 farmers in 23 states of the country covering about 570 "municipios".

IV. REFERENCES

(1) ALFONSI RR., PINTO HS., ARRUDA HV. de (1979). *Frequência de veranicos em regiões rizícolas do estado de São Paulo.* In : Anais I Reunião de técnicos em rizicultura do estado de São Paulo. Campinas, SP. 430 p.

(2) ARRUDA HV. de, PINTO HS, ALFONSI RR. (1979). *Probabilidade de estiagens nos meses de janeiro e fevereiro na região de Campinas (SP).* In : Anais I Reunião de técnicos em rizicultura do estado de São Paulo, Campinas, SP. 430 p.

(3) CAMARGO AP., ALFONSI RR., PINTO HS., CHIARINI JV. (1976). *Zoneamento da aptidão climática para culturas comerciais em áreas de cerrado.* In : IV Simpòsio sobre o cerrado. Bases para utilização agropecuária. Coordenador : Mãrio G. FERRI. Editora da Universidade de São Paulo. Livraria Itatiaia Editoria Ltda, Belo Horizonte, Minas Gerais.

(4) EAGLEMAN AM. (1971). *An experimentally derived model*

for actual evapotranspiration. Agri. Meterorolgy, 8 (4-5).

(5) EMPRESA BRASILEIRA DE PESQUISA AGROPECUARIA. DEPARTEMENTO TECHNICO-CIENTIFICO, BRASILIA, DF. (1981). *Programa Nacional de Pesquisa de Arroz.* Brasília, EMBRAPA-DID, 69 p.

(6) FRANQUIN P., FOREST F. (1977). *Des programmes pour l'évaluation et l'analyse fréquentielle des termes du bilan hydrique.* Agronomie Tropicale XXXII-1.

(7) FOREST F. (1984). *Simulation du bilan hydrique des cultures pluviales.* IRAT-DRD, 63 p.

(8) FOREST F., KALMS JM. (1982). *Influence du régime d'alimentation en eau sur la production du riz pluvial. Simulation du bilan hydrique.* Paper presented at the Upland Rice Workshop, Bouaké, Ivory Coast.

(9) HARGREAVES GH., HANCOCK JK., HILL RW. (1979). *Potential evapotranspiration and precipitation deficits for Tropical America.* Centro International de Agricultura Tropical-CIAT, Cali, Colombia.

(10) IPEA. (1972). *Variacões climáticas e fluctuações da oferta agrícola no Centro-Sul do Brasil.* Vol. I, Relatório de yesquisa. Vol. II, Zoneamento Ecològico. Instituto de Planejamento Econômico e Social, Brasìlia. 419 p., 35 maps.

(11) JACCON G. (1980). *Etudes des précipitations annuelles de l'Etat de la Paraiba. Homogénéisation et analyse régionale.* Repport ORSTOM-SUDENE.

(12) KALMS JM. (1980). *L'évapotranspiration réelle maxima (ETm) du riz pluvial en région centre Côte d'Ivoire.* Institut des Savanes, Département des cultures vivrières, Division d'Agronomie.

(13) LOPES AS (1983). *Solos sob "cerrado", caracterìsiticas, propriedades e manejo.* Piracicaba, Instituto da Potassa & Fosfato, 162 p.

(14) STEINMETZ S., REYNIERS FN., LIU WTH. (1982). *Favorable rainfall periods in upland rice regions of Brazil.* Paper presented at the Upland Rice Workshop, Bouaké, Ivory Coast.

RESUME

La culture du riz pluvial a une grande importance économique et sociale au Brésil où elle contribue à environ 60 % de la production moyenne des 9 millions de tonnes de paddy et 80 % des 6,6 millions d'hectares. La majeure partie est dans les Etats du Centre Ouest, Maranhão, Minas Gerais, São Paulo et Paraná, mais elle est présente dans pratiquement tous les Etats et Territoires couvrant une étendue de latitude de 5°N à 28°S.

Sa productivité moyenne est très basse (- 1.2 t/ha) et présente une importante variabilité interannuelle. Les principales raisons sont les périodes de sécheresse prolongées et les particularités du système de culture habituel. La majorité du riz pluvial est produit en zone de savane (Cerrados) sur des sols pauvres, à faible capacité de réserve en eau. Il est cultivé après défrichement une ou deux années pour préparer l'installation d'un pâturage. Ceci entraîne une correction du sol insuffisante, une préparation du sol inadéquate et une fertilisation faible.

Les solutions à apporter à ces problèmes sont d'ordre économique : établissement de politiques régionales de production, et d'assurances agricoles, d'ordre technique : par un diagnostic des causes de la basse productivité et d'ordre éducatif : pour conseiller les producteurs. Elles nécessitent toutes une évaluation du risque climatique en fonction des situations agronomiques.

Le CNPAF-EMBRAPA en coopération avec l'IRAT-GERDAT a développé un programme d'évaluation du risque climatique du riz pluvial en fonction des régions du Brésil et des dates de semis, du cycle de la variété et de la réserve en eau utile maximum, qui sont les trois paramètres essentiels des situations agronomiques qui conditionnent l'utilisation des pluies.

Le risque climatique est caractérisé par le taux de satisfaction des besoins en eau expression du rapport entre l'évapotranspiration réelle (ETr) et l'évapotranspiration maxima (ETm).

Partant de données pluviométriques journalières sur une période de vingt ans ce taux est calculé par pentade en utilisant un modèle de bilan hydrique développé par l'IRAT et disponible sur un logiciel micro-informatisé. Les valeurs par pentades sont regroupées pour l'ensemble du cycle et pour les principales phases de développement.

Pour classer les régions sont établies des classes de taux de satisfaction tenant compte des valeurs des paramètres des situations agronomiques.

Le régime pluviométrique est également évalué par la distribution fréquentielle, et l'intensité des pluies, et par la fréquence et la durée des périodes sèches.

Les producteurs qui souhaitent une aide du laboratoire envoient les données climatiques de stations météorologiques proches de leur propriété et une fois par an celles qu'ils ont recueillies quotidiennement dans un pluviomètre fourni gracieusement par le CNPAF.

Les principaux résultats obtenus actuellement font ressortir les notions nouvelles suivantes.

Il existe des différences très accentuées dans les régimes pluviométriques des régions. Laissant apparaître une diminution de quantité de pluies pendant la saison de culture du Nord au Sud du Brésil.

Pour la meilleure date de semis et dans les mêmes conditions de RU le risque climatique est plus accentué dans les régions Sud et Sud-Est que dans les régions Centre-Ouest et Nord.

L'augmentation de la RU réduit le risque climatique de façon variable suivant les régions. Dans la région Sud ces valeurs doivent être plus élevées pour compenser la quantité plus réduite de pluies.

La date de semis influence le risque climatique en fonction des régions. Ainsi pour un cultivar de cent-dix jours de cycle, un taux de satisfaction de 80 % sera atteint par un semis entre début octobre et janvier à Porto Velho (Nord-Ouest). Ce taux ne sera atteint à Goiânia que pour un semis entre mi octobre et fin novembre. A Capinzal (régions Sud) ce taux n'est jamais atteint.

Après une offre télévisée, 5 000 demandes de pluviomètres ont été reçues au Centre et 1 000 ont été satisfaites. Des données pluviométriques journalières de périodes de cinq à quinze ans pour environ cinquante localités ont été reçues. Après analyse des données chaque producteur a reçu les informations préliminaires sur les époques de semis les plus appropriées pour l'aspect utilisation des pluies.