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SENSITIVITY TESTS OF THE ENVIRONMENTAL VARIABLES IN RICEMOD

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ABSTRACT

The rice crop simulation model RICEMOD (McMennamy 1980a,b) was tested for sensitivity to the input environmental variables. The model was most sensitive to the climatic variables of day length, solar radiation, pan evaporation, and a factor relating pan evaporation to daily plant transpiration, and least sensitive to maximum and minimum temperature and rainfall. The model uses exponential equations for the soil hydraulic properties of the form:

$$Y = ae^{bx} \quad (1)$$

where a and b are variables that depend on soil texture and structure. The model was sensitive to soil volumetric water content (x) – soil matric suction function (Y) in equation 1, and especially to the exponential variable (b). It was least sensitive to soil volumetric water content (x) – soil water diffusivity function (Y) in equation 1. It was not sensitive to the subsoil water content. Variables were tested singly and in combination.

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SENSITIVITY TESTS OF THE ENVIRONMENTAL VARIABLES IN RICEMOD

RICEMOD was developed by McMennamy (1980a, b) and McMennamy and O'Toole (1983) and they described it as an initial effort to develop a relatively simple model. It is driven by the daily climatic variables of rainfall, pan evaporation, solar radiation, maximum and minimum temperature, and day length. An additional climatic factor called pan factor (PANF) relates total daily transpiration to pan evaporation and potential soil evaporation. The soil hydraulic relationships used are soil water diffusivity as an exponential function of volumetric soil water content, soil water matric suction as an exponential function of volumetric soil water content, and soil hydraulic conductivity as a power function of soil water matric suction. Subsoil moisture content (MC) is also an input variable, but is held constant over the growing season. The model has been refined by its author. We tested the version known as RICE300.

McMennamy's publications (McMennamy 1980a, b; McMennamy and O'Toole 1983) describe validation tests of the model such as comparisons of model output to independently taken field data. Response of calculated quantities to changes in input parameters should also be tested. This is known as sensitivity testing. Because climatic and soil functional relationships are the only environmental variables included in this model (no weed or insect pests were included), a systematic change in these variables was made and the model output presented.

METHOD

Two versions of the program were prepared. In 1 the climatic variables could be changed independently, and in 2 the parameters of the soil relationships could be changed independently. In any given test a percentage change of a particular variable was made while holding all others constant. For example, the amount of rainfall on any day could be changed, but not the day of the rainfall. By changing the sign of the percentage, the magnitude of the variable could be increased or decreased.

The crop growing season in the eastern part of the Philippines generally starts in April (Zandstra et al 1980), therefore 1 April 1980 was chosen as the transplanting date for 25-day-old rice seedlings in the initial simulations. In reviewing this paper, Dr. S. Yoshida (IRRI pers. comm.) pointed out that this date is generally too early for transplanting rice at IRRI. Thus, a second set of runs was made using a 25 June transplanting date. The simulation was run for about 110 days plant age. Actual plant age at harvest is determined by the program as a function of stress days (McMennamy and O'Toole 1983). Values for climatic variables are given in Figure 1 for the upland weather station at IRRI 1 April to 30 September 1980 as reported by the Agroclimatic Service Unit.

The equations for the soil hydraulic relationships are:

$$\text{Diff.} = \text{AD} \times \exp(\text{BD}(\text{Vol.} - 0.18)) \quad (1)$$

$$\text{MSuc.} = \text{AS} \times \exp(\text{BS} \times \text{Vol.}) \quad (2)$$

$$\text{Hyd. Cond.} = \text{AK} \times \text{MSuc.}^{\text{BK}} \quad (3)$$

where Diff. is soil water diffusivity, Vol. is volumetric soil water content, MSuc. is soil matric suction, Hyd. Cond. is soil hydraulic conductivity, and exp stands for the logarithm base e raised to a power given in the parentheses. Soil water diffusivity and hydraulic conductivity are measures of the ease with which water moves through the soil. Soil matric suction is a measure of the potential energy with which water is held in the soil. More precise definitions may be found in Hillel (1980). The equation constants AD, BD, AS, BS, AK, and BK are fitted parameters which depend on soil texture, structure, and in the case of AS, depth below the soil surface. The values of these parameters for an IRRI upland site are given in Table 1 and are calculated from reports by Hasegawa et al (1979), Hasegawa (1981), and Hasegawa and Yoshida (1982). Standard subsoil moisture content is also given in Table 1.

The climatic variable PANF is defined by:

$$\text{TPOTD} = \text{PANF} \times (\text{Pan evaporation} - \text{EPOTS}) \quad (4)$$

where TPOTD is daily total potential transpiration and EPOTS is daily total potential evaporation from the soil (McMennamy and O'Toole 1983). The standard value for PANF is also given in Table 1.

In general, the tests were made as follows: 1) the particular variable was changed by ±10% and ±50% (in

Table 1. Soil and climatic parameters used for equations 1-4 for a silty clay loam on the IRRI upland farm (McMennamy 1980b).

Variable	Value
AD	0.0117 $cm^2 d^{-1}$
BD	32.1 dimensionless
AS	125,500 (0-25 cm); 1,750,000 (25-50 cm); 3,000,000 (50-100 cm) cm
BS	-32.2 dimensionless
AK	0.0002632 cm d^{-1}
BK	-2.1170001 dimensionless
Subsoil moisture (MC)	0.54 dimensionless
PANF	1.15 dimensionless
Day length	11.5 to 13.2 h d^{-1}

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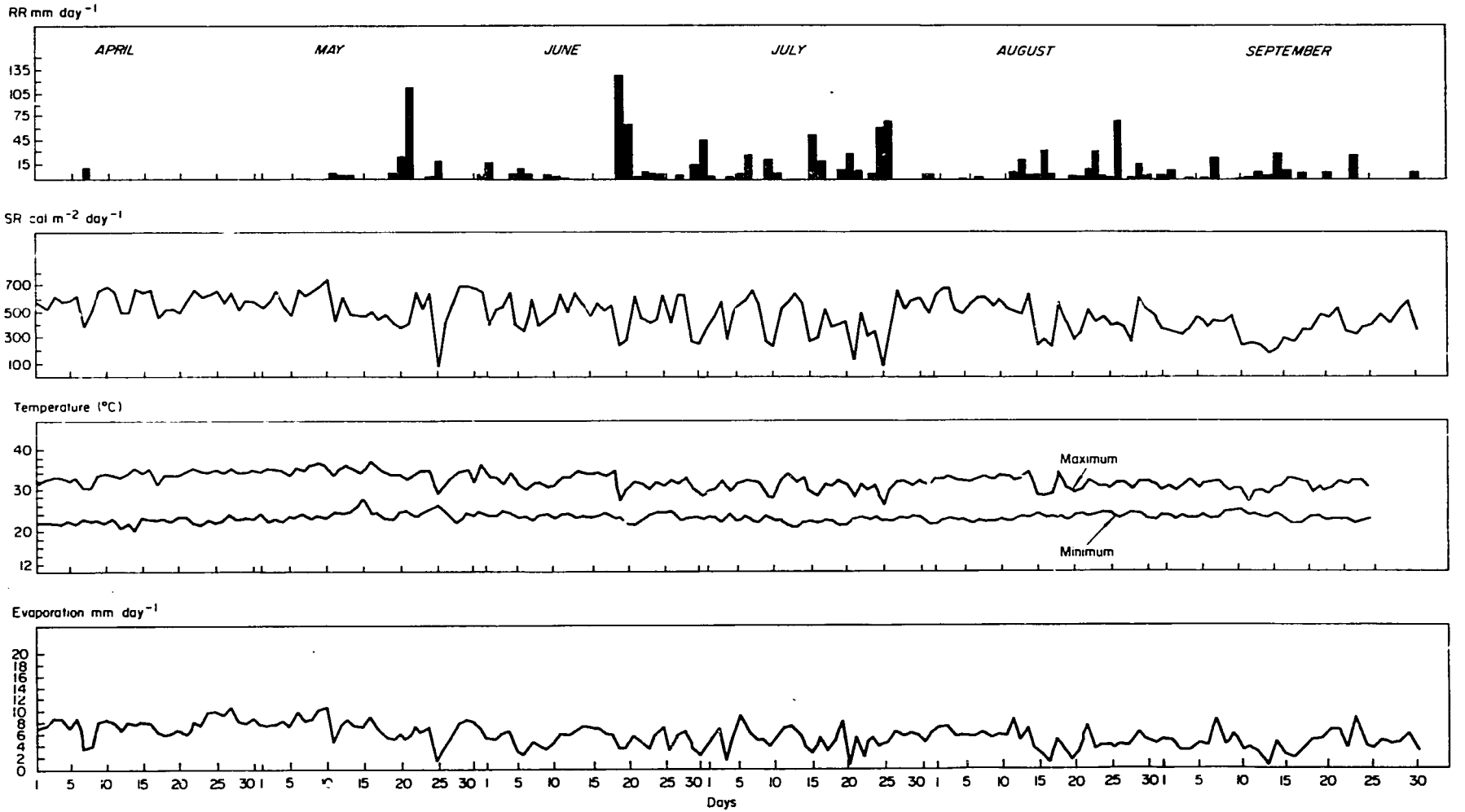

1. Daily values for rainfall (RR), solar radiation (SR), maximum and minimum temperature, and pan evaporation for Apr-Sep 1980 at the IRRI upland weather station.

some cases a 50% change was too severe and caused the computer to terminate the run and a smaller specific change was tried and reported); 2) these variables were combined to represent an increase or decrease in latitude or a wetter or drier year for climatic variables, and an increase or decrease in clay content, or an increase or decrease in aggregation for soil variables.

RESULTS AND DISCUSSION

RICEMOD calculates measurable plant and soil properties, such as leaf blade, stem (culm + leaf sheath), root, and panicle dry weight, and soil water content by layers. Only a few of these variables are used to illustrate the model sensitivity. Since the model is incompletely validated, many results will be shown as % change from the standard simulation. (The standard simulation means 0% change in any variable. Figure 1 and Table 1 give the values of the standard variables.) Table 2 gives the absolute values simulated for the different variables in the standard cases.

Climatic variables

Grain yield is of interest to most people studying rice production. RICEMOD simulates panicle weight in g m^{-2}. Percent changes in panicle weight from the standard simulation for various climatic variables are given in Table 3. Increases in rainfall had little effect on simulated yield for the crop transplanted in April, but decreases had a substantial effect. Because April is only the start of the wet season, this is to be expected as the early part of the season had little rainfall (see Fig. 1) but enough for adequate plant growth. When planting date was shifted to 25 June, even a 50% decrease in rainfall had little effect on simulated yield, and was adequate to grow an almost normal rice crop.

RICEMOD is highly sensitive to pan evaporation and seems to be well adjusted to ordinary amounts; for example, a 10% increase or decrease caused an approximately equal simulated yield reduction for the April planting. This was caused by changes in photosynthate partitioning between other plant parts and panicles. A 50% increase in pan evaporation rate further decreased panicle weight. An equal decrease in pan evaporation rate increased the simulated panicle weight. These results were expected. The June transplanted crop was not as sensitive to pan evaporation.

RICEMOD responds similarly to PANF, as given in equation 4, which is similar to the response to pan evaporation. A positive increase in PANF causes a simulated decrease in the yield and vice versa for the April planting. However, an increase for the April planting caused a more than equal percentage of decrease in the yield projections. For example, a 10% increase caused a 14% yield decrease and a 50% increase caused a 60% yield decrease. The June planting was not as sensitive. These results were expected, considering the frequent rainfalls (Fig. 1) experienced by the June crops as compared to the drier periods experienced in April.

Response to the amount of radiation was similar to pan evaporation response for the April crop. A 10% change decreased simulated panicle weight, regardless of the sign of the change, and a large increase increased projected yield. June planting resulted in an even larger change in simulated yield – from 16% for a 50% increase in radiation to −44% for a 50% decrease in radiation. Radiation levels in July and August are generally lower than in April and May (Fig. 1). Therefore the model shows a high degree of sensitivity to further decreases during a period of radiation deficiency. However, this was not the most sensitive climatic variable.

Photosynthetic day length is the most sensitive variable. It is a function of time of year and latitude and can be varied independently of radiation. Photosynthetic day length affects several of the model's equations (McMennamy 1980a, b; McMennamy and O'Toole 1983), particularly, calculations of leaf water potential, photosynthetic radiation received, and respiration.

Table 2. Simulated values of plant parts at harvest for the standard cases.

Variable	Weight or ratio	
	Apr start	Jun start
Leaf	25.1 g m^{-2}	95.6 g m^{-2}
Stem	402.8 g m^{-2}	577.0 g m^{-2}
Root	310.2 g m^{-2}	334.2 g m^{-2}
Panicle	362.0 g m^{-2}	527.9 g m^{-2}
Harvest index	0.46	0.44
Root-shoot ratio	0.39	0.28

Table 3. Effect of changing weather variables on panicle weight at harvest.

Start of simulation	% change of variable	Panicle wt (% change from standard)						
		Rainfall	Pan	Rad	Max temp	Min temp	Day length	PANF
1 Apr	+ 10	1.1	- 8.8	- 0.6	- 4.4	- 8.3	8.6	- 14.1
	- 10	- 4.4	- 7.7[a]	- 11.9	4.1	5.5	- 19.1	3.7
	+ 50	0.0	- 27.4[b]	9.7[a]	- 15.5	- 28.2	80.1[a]	- 59.9
	- 50	- 27.1	31.2[c]	- 40.9[b]	8.8	16.0	- 73.3	3.0
25 Jun[d]	+ 50	0.0	- 9.6[e]	16.0	- 10.7	- 18.3	–	- 10.8
	- 50	- 1.3	- 0.4	- 43.8[f]	6.7	14.2	- 69.2[g]	- 0.4

Plant age at harvest: [a]121 days. [b]124 days. [c]117 days. [d]Standard, 110 days. [e]112 days. [f]113 days. [g]115 days.

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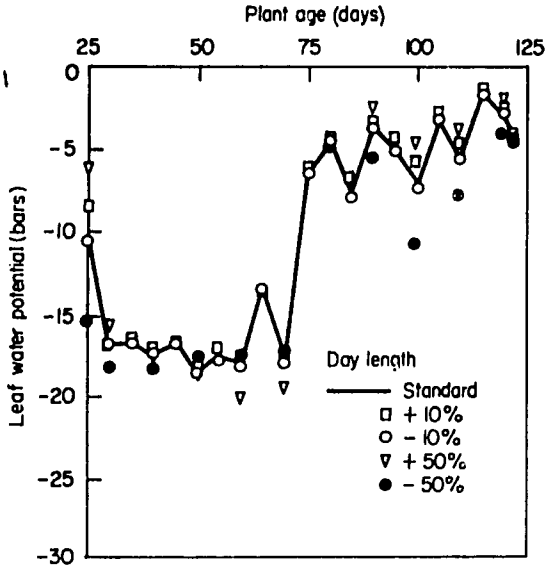
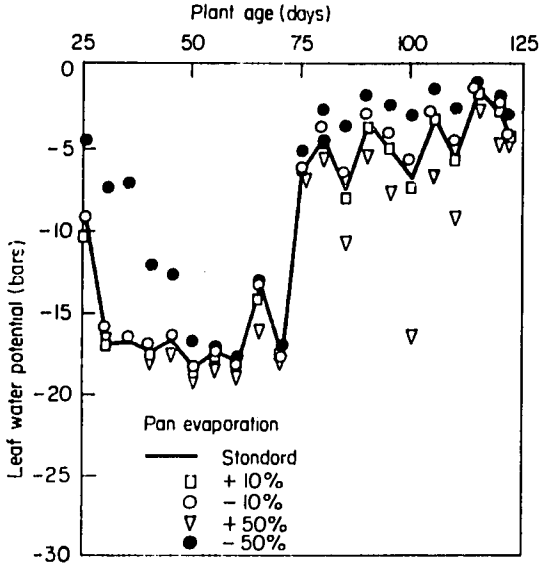
Photosynthetic day length is used to adjust for a non-12-h night length in the respiration equation (McMennamy 1980b). A ±50% change in this variable caused a larger than ±50% change in simulated panicle weight for the April planting. A 50% decrease caused a yield reduction greater than 50% for the June planting. Because photosynthetic day length is used to calculate leaf water potential, it strongly influences the calculated number of stress days and thus growth rate and growth duration. An increase in photosynthetic day length decreased leaf water potential (see later discussions) and decreased the days-to-maturity in the April planting.

RICEMOD is only moderately sensitive to changes in maximum and minimum temperature, which might be expected because temperature affects only respiration in the model (McMennamy 1980a,b). In other crop models developed for more temperate climates, temperature has greater effect because it affects photosynthesis and growth rate (Whisler et al 1979a).

Leaf water potential often is used as a physiological indicator of plant growth (O'Toole and Moya 1978, O'Toole and Cruz 1980). Leaf water potential during plant development, and especially during reproductive development, has been shown to be a good predictor of final seed yield. O'Toole and Moya (1978) found that the daily integral of leaf water potential, as well as leaf rolling score, could be used to differentiate between rice cultivars but their data and those of O'Toole and Cruz (1980) also show that midday leaf water potential also differs significantly between cultivars. Because RICEMOD (McMennamy and O'Toole 1983) does not calculate a daily integral of leaf water potential but does calculate a midday leaf water potential, the latter was used in these analyses. Figures 2 and 3 show simulated midday leaf water potential from transplanting until harvest for pan evaporation and day length. The solid line is the value for the standard case. By comparing these figures and Table 3 it can be noted that the high yielding simulations had higher (less negative) midday leaf water potential values than the standard case. Conversely, the lower yielding simulations had lower midday leaf water potential values, especially during seed filling (day 80 on).



3. Simulated midday leaf water potentials versus plant age as a function of changes in day length for an April planting.



2. Simulated midday leaf water potential versus plant age as a function of changes in pan evaporation amounts for an April planting.

Table 4. Effect of changing weather variables on harvest index.

Start of simulation	% change of variable	Harvest index (% change from standard)						
		Rainfall	Pan	Rad	Max temp	Min temp	Day length	PANF
1 Apr	+ 10	0.0	- 2.2	0	- - 2.2	- 2.2	0.0	- 8.2
	- 10	0.0	2.2[a]	- 2.2	0.0	0.0	- 4.4	- 12.2
	+ 50	0.0	- 13.0[b]	4.4[a]	- 4.4	- 4.4	8.7[a]	- 34.7
	- 50	- 26.1	2.2[c]	- 4.4[b]	2.2	2.2	- 13.0	- 12.2
25 Jun[d]	+ 50	10.8	5.4[e]	10.8	0.0	5.4	–	5.4
	- 50	18.9	16.2	- 2.7[f]	- 16.3	- 5.4	- 16.2[g]	0.0

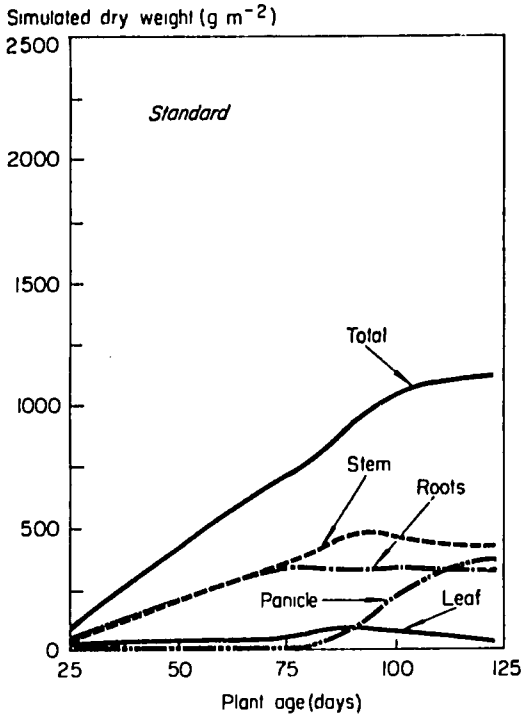
Plant age at harvest: [a]121 days. [b]124 days. [c]117 days. [d]Standard, 110 days. [e]112 days. [f]113 days. [g]115 days.

Table 5. Effect of changing weather variables on root-shoot ratio at harvest.

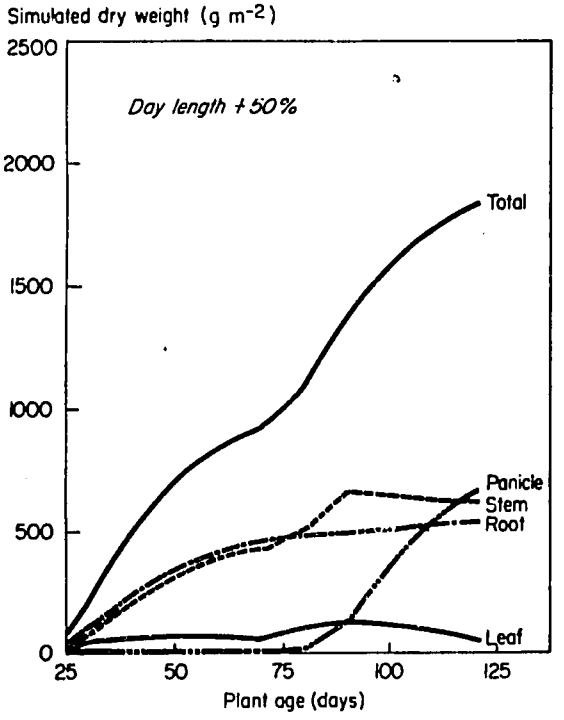
Start of simulation	% change of variable	Root-shoot ratio (% change from standard)						
		Rainfall	Pan	Rad	Max temp	Min temp	Day length	PANF
1 Apr	+ 10	0.0	7.7	5.1	2.6	2.6	7.7	- 15.4
	- 10	5.1	5.1[a]	7.7	0.0	2.6	7.7	- 7.7
	+ 50	0.0	- 2.6[b]	7.7[a]	2.6	0.0	2.6[a]	53.8
	- 50	5.1	7.7[c]	2.6[b]	2.6	5.1	2.6	- 7.7
25 Jun[d]	+ 50	0.0	0.0[e]	0.0	0.0	0.0	–	0.0
	- 50	0.0	0.0	- 3.6[f]	0.0	3.6	14.3[g]	0.0

Plant age at harvest: [a]121 days. [b]124 days [c]117 days. [d]Standard, 110 days. [e]112 days. [f]113 days. [g]115 days.

Harvest index and root-shoot ratio are other plant parameters often used as growth indices (Yoshida 1981). Tables 4 and 5 give the change from the standard simulation caused by changes in the environmental variables. Harvest index was calculated as the ratio of panicle weight to total top weight of the simulated plant, and root-shoot ratio was the ratio of root weight to total top weight at harvest. This probably gives a higher harvest index value than the standard definition of the ratio of dry grain yield to total dry weight (Yoshida 1981). These results are similar to the panicle weight results in that they are most sensitive to day length, pan evaporation, pan factor, and radiation; and least sensitive to temperature and rainfall. One can note, however, that the direction (or sign) of the change is not always the same as for panicle growth. For example, a slight decrease in pan evaporation produced a decrease in simulated panicle weight but increased harvest index and root-shoot ratio.



4. Simulated dry weights of various plant parts as a function of plant age for the standard case for an April planting.

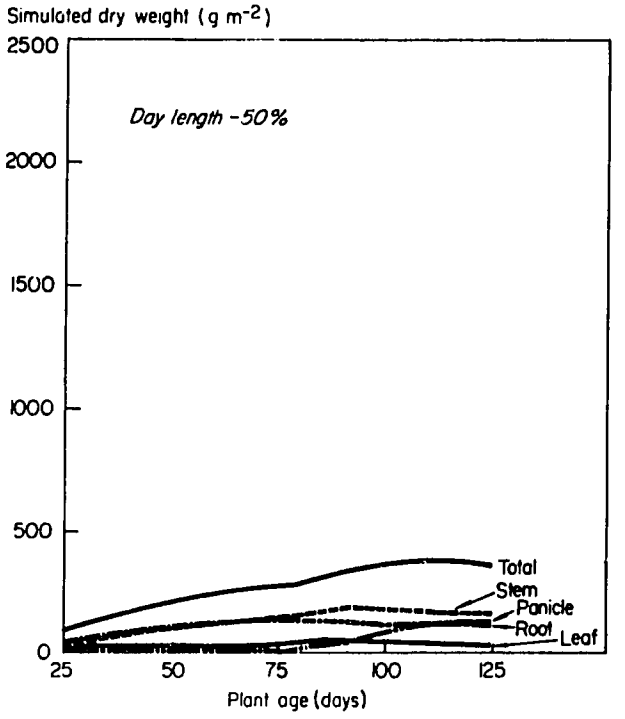


5. Simulated dry weights of various plant parts as a function of plant age for 50% increase in day length.

Photosynthate partitioning to various plant parts for the standard, long, and short day length is shown in Figures 4, 5, and 6. The graphs show the expected decline in leaf and stem weights caused by senescence, however, the model does not have an expected senescence in root weight during seed filling (Russell 1977, Fig. 2.2, Table 3.2). Increased day length increased the growth rates (curve slopes) and total weight of each plant part compared to the standard case. Decreased day length had the opposite effect. These examples are the extremes of the sensitivity tests.

Soil variables

The effect of changing the magnitude of soil hydraulic variables on simulated panicle weight, harvest index, and



6. Simulated dry weights of various plant parts as a function of plant age for a 50% decrease in daily day length.

root-shoot ratio are given in Tables 6, 7, and 8. The standard case is the same as for climatic variables. The model is not as sensitive to changes in soil hydraulic properties as it is to changes in climatic variables, especially for the June planting. For as little detail as there is in the soil section of RICEMOD, results are surprisingly similar to those found in more detailed models (Whisler et al 1979a,b).

The most significant soil parameter was the BS variable, equation 2, for the April planting. Because it is in the exponent of equation 2 it might be expected to make a relatively large change. A change of −50% caused the program to terminate after the 40th day of simulation. Apparently the calculated root resistances in the top 25 cm soil layer became too large and caused leaf water potential to become quite negative.

The model usually is least sensitive to soil water diffusivity and subsoil moisture parameters, more sensitive to soil hydraulic conductivity parameters, and most sensitive to the soil water content-matric suction parameters. The June planting shows little sensitivity to soil hydraulic components. Because of the frequent rainfall (Fig. 1), water was generally not a limiting factor for this crop. There was a noticeable change in the simulated yield only when the soil

Table 6. Effect of changing soil hydraulic variables on panicle weight at harvest.

Start of simulation	% change	Panicle wt (% change from standard)						
		AD	BD	AS	BS	AK	BK	MC
1 Apr	+10	0.0	− 2.5	−13.0	− 1.7	2.2	0.8	2.3
	−10	2.5	2.2	0.8	22.7	−12.7	− 5.0	−2.6
	+50	0.8	−15.8	−20.7[a]	5.3[b]	1.1	2.8	4.3
	−50	2.5	− 2.5[c]	1.7	−	−17.4[a]	−13.3	−3.6
	+25				3.6[c]			
	−25				−31.2[d]			
25 Jun[e]	+50	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	−50	0.0	0.0	0.0	−	0.0	0.0	0.0
	+25				0.0			
	−25				− 2.3			

Plant age at harvest: [a]123 days. [b]117 days. [c]119 days. [d]125 days. [e]Standard, 110 days.

Table 7. Effect of changing soil hydraulic variables on harvest index.

Start of simulation	% change	Harvest index (% change from standard)						
		AD	BD	AS	BS	AK	BK	MC
1 Apr	+10	0.0	0.0	−4.4	4.4	2.2	0.0	−14.3
	−10	0.0	2.2	0.0	8.7	4.4	0.0	0.0
	+50	0.0	−4.4	−4.4[a]	4.4[b]	2.2	4.4	−14.3
	−50	2.2	2.2[c]	4.4	−	2.2[a]	10.9	− 2.0
	+25				2.2[c]			
	−25				30.4[d]			
25 Jun[e]	+50	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	−50	0.0	0.0	0.0	−	0.0	0.0	0.0
	+25				0.0			
	−25				16.2			

Plant age at harvest: [a]123 days. [b]117 days. [c]119 days. [d]125 days. [e]Standard, 110 days.

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Table 8. Effect of changing soil hydraulic variables on root-shoot ratio.

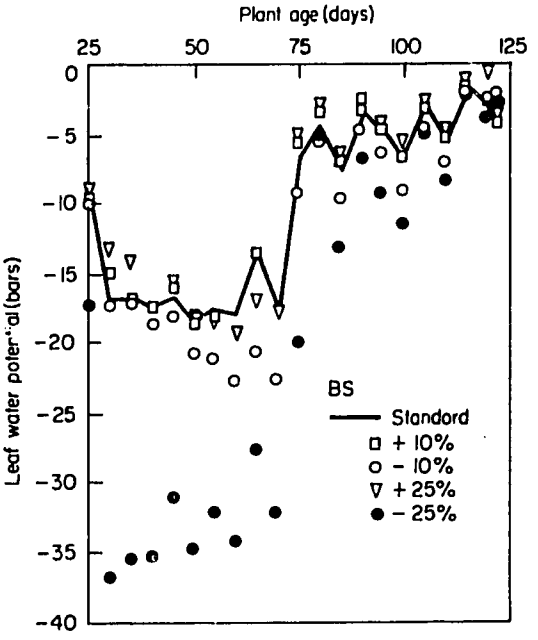
Start of simulation	% change	Root-shoot ratio (% change from standard)						
		AD	BD	AS	BS	AK	BK	MC
1 Apr	+10	0.0	5.1	12.8	- 5.1	- 2.6	0.0	-7.7
	-10	0.0	- 5.1	- 2.6	- 5.1	12.8	2.6	3.8
	+50	2.6	12.8	15.4[a]	18.0[b]	- 5.1	-7.7	-7.7
	-50	-5.1	15.4[c]	- 5.1	–	10.3[d]	-5.1	7.7
	+25				7.7[c]			
	-25				-51.3[d]			
25 Jun[e]	+50	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	-50	0.0	0.0	0.0	–	0.0	0.0	0.0
	+25				0.0			
	-25				- 3.6			

Plant age at harvest: [a]123 days. [b]117 days. [c]119 days. [d]125 days. [e]Standard, 110 days.

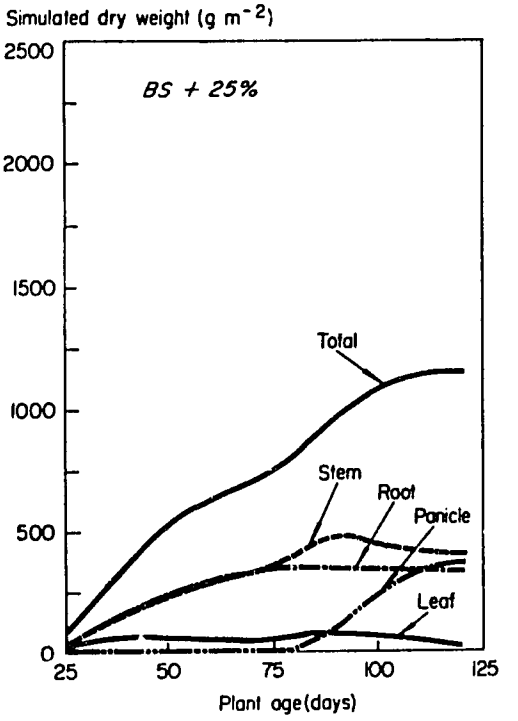
in the immediate vicinity of the roots became slowly permeable to water because of drying (as with a –25% of greater BS decrease). As with climatic variables, simulated yield changes were not perfectly matched with changes in harvest index and root-shoot ratio.

The simulated midday leaf water potentials for the April crop are shown in Figure 7 for different BS values. When compared to the standard curve for -10 and -25% change the simulated values are low for leaf water potential both early in the season and during seed filling. As in the earlier discussion, these are extreme cases.

The simulated photosynthate partitioning into various plant parts for BS changes for an April planting is shown in Figures 8 and 9. Figure 4 is the standard for comparisons. Again, a large decrease in the BS value caused a later maturation date and smaller yield, and the opposite occurred when BS was increased.



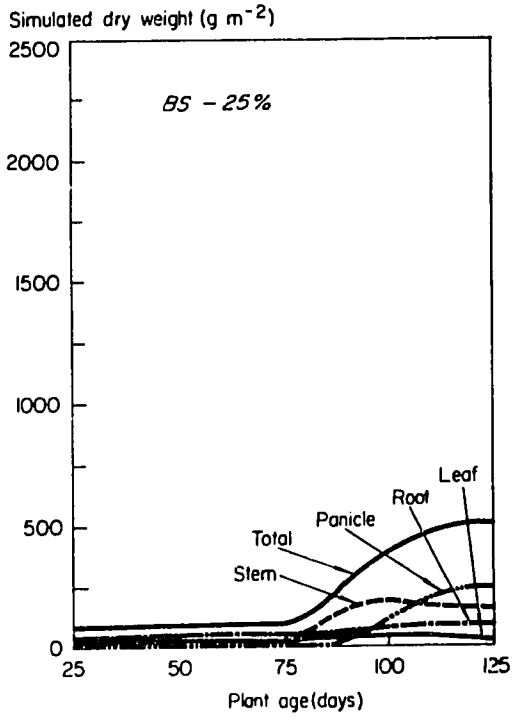
7. Simulated midday leaf water potentials versus plant age as a function of changes in the BS term in equation 2 for an April planting.



8. Simulated dry weights of various plant parts as a function of plant age for a 25% increase in BS for an April planting.

Alternative interpretation

These results are not only a sensitivity test for RICEMOD, but also help meteorologists and soil physicists answer questions such as: "What differences does it make if my instrument or procedure is off by ±10%, ±20%, etc.?" We see that an instrument which is always measuring too high an amount in minimum temperature would cause an underestimation of yield. Likewise, a procedure that gives too small a value in AK could cause the model to underestimate



9. Simulated dry weights of various plant parts as a function of plant age for a 25% decrease in BS for an April planting.

substantially. Thus, this exercise is not strictly of academic interest.

Combinations of changes

As research moves from one climatic pattern to another or from one soil to another the variables discussed change simultaneously and not individually. Several combinations were examined to see what simulation differences would be generated. A wetter, cloudier, cooler tropical climate was simulated by increasing the rainfall data by 50% and decreasing pan evaporation, radiation, and maximum temperature by 50%. The reverse was done to simulate a drier, clearer, warmer climate by keeping the same magnitudes of changes but changing the algebraic sign. A more northern latitude was simulated by increasing pan evaporation by 6%, radiation by 11%, maximum temperature by 4%, minimum temperature by 1%, and day length by 5%. A more southern latitude was simulated by decreasing pan evaporation by 14%, radiation by 13%, maximum temperature by 8%, and day length by 5% and increasing minimum temperature by 4%. These changes were based on long-term weather record comparisons of Cabanatuan, Philippines (14°N) (similar to IRRI latitude), Parwanipur, Nepal (28°N), and Singapore (1°N). Results of these studies are given in Table 9 in terms of percentage change from the standard simulations.

Interestingly, changes in rainfall increased or decreased days-to-harvest but consistently decreased simulated grain yield for both planting dates. Harvest indexes decreased but root-shoot ratios increased. Changes in latitude had less effect than rainfall, but the variable size of the changes was smaller. A move toward a more northern latitude showed a slight simulated yield increase and an increase in root-shoot ratio for an April planting. A move toward a more equatorial latitude showed a more definite simulated yield decrease and a slight decrease in harvest index and a slight increase in the root-shoot ratio for April plantings.

Table 9. Effect of interactive changes of climatic variables on crop indices as % change from standard.

	Age (days)	Panicle weight (%)	Harvest index (%)	Root-shoot ratio (%)
Standard (1 Apr)	122	0.0	0.0	0.0
Tropical, wet	117	-12.4	0.0	12.8
Tropical, dry	128	-53.9	-30.4	41.0
Higher latitude	122	1.5	0	10.3
Lower latitude	121	-14.6	- 2.2	2.6
Standard (25 Jun)	110	0.0	0.0	0.0
Tropical, wet	110	-24.0	- 2.7	3.6
Tropical, dry	114	-29.1	-10.8	25.0
Higher latitude	110	4.6	- 2.7	0.0
Lower latitude	110	-11.5	0.0	0.0

As soil aggregation is increased, total porosity, slope of the moisture characteristic curve and the saturated hydraulic conductivity may increase (Hillel 1980). The reverse happens when compaction or decreased aggregation occurs. The first condition was simulated by decreasing AD, AS, and BS by 10% and increasing AK by 50%. Signs were reversed for the second condition. As soil clay content increases, total porosity increases but AK decreases (Hillel 1980). The reverse happens when clay content decreases and sand content increases. Increased clay content was simulated by increasing AD and AS by 10% and decreasing BS by 10% and AK by 50%. The reverse was done for an increased sand content. An April planting was assumed for all these simulations. Results of the simulations are given in Table 10 as % change from the standard case.

Increased aggregation changed the simulated panicle weights and harvest index only slightly but did decrease root-shoot ratio by 5%. Decreased aggregation or increased compaction was much more noticeable in a depressed

Table 10. Effect of interactive changes of soil hydraulic parameters on crop indices as % change from standard.

	Age (days)	Panicle weight (%)	Harvest index (%)	Root-shoot ratio (%)
Standard	122	0.0	0.0	0.0
Increased aggregation	121	0.9	2.2	- 5.1
Decreased aggregation	123	-20.7	6.5	0.0
Decreased clay	121	2.8	4.4	0.0
Increased clay	124	-27.4	11.5	-10.8

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simulated yield. Harvest index was, however, increased slightly. As soil clay content decreased there was only a slight increase in simulated yield and harvest index. As clay content increased, however, there was a 27% decrease in simulated yield, an 11% decrease in root-shoot ratio, and an 11.5% increase in harvest index compared to the standard case. The latter test demonstrates the usefulness of even "simple" crop growth simulation models. These changes in soil properties affect the calculations of water flow in the soil from the bulk soil to the root and from one soil layer to another. These in turn affect the calculated root resistances and leaf water potentials, which in turn affect the calculations of photosynthesis partitioning.

In the case of increased clay, compared to the standard case, water flows less readily from bulk soil to the plant roots and from one soil layer to another, increasing root resistance, a decreased (more negative) leaf water potential, less photosynthate production due to increased stress, and less photosynthate to go into grain. It would be tedious to map out such logic and interrelationships without a computer and program to make the many calculations and store the intermediate results.

These exercises have taken RICEMOD out of the IRRI research station environment for which it was designed. However, the trials have pointed out some of the model's strength and weaknesses if it is to be extended to a wider application.

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