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GROWING SEASON ANALYSES FOR RAINFED WETLAND FIELDS

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GROWING SEASON ANALYSES FOR RAINFED WETLAND FIELDS[1]

ABSTRACT

Cropping systems for rainfed wetland areas must fit field water conditions sufficiently to ensure that the same types of cropping pattern can be used from year to year and that their performance will be stable. This study describes a field-water balance simulation that can be conditioned to a range of hydrological characteristics associated with profile texture and landscape position of wetland fields. This PADIWATER model is used to evaluate the average date of occurrence of critical growing season events, which are expressed in probabilities that the soil will be dry, moist, wet, or flooded. These events allow determination of the duration of growing season components suitable for premonsoon dryland (upland) crops, wetland rice, and postmonsoon dryland crops, so that the agronomic feasibility of major rice-based cropping pattern types can be evaluated.

The effects of the aquic nature of a field and different spillway heights on the duration of growing season components are identified. This demonstrates how field water conditions during the growing season are modified by important land qualities. The growing season analysis is used for crop scheduling and for the identification of soil management methods that modify field water conditions to get better cropping pattern performance.

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GROWING SEASON ANALYSES FOR RAINFED WETLAND FIELDS

Rice-based cropping systems differentiate into three major groups: dryland, rainfed wetland, and irrigated wetland. Dryland rice culture does not accumulate water on the field surface and is on land that, except for limited periods, does not hold moisture in the rooting zone in excess of field capacity. Wetland rice culture encourages water accumulation on the soil and is on land that keeps the rooting zone saturated for a substantial part of the rice growing season. Rainfed wetland rice culture and irrigated wetland rice culture are similar, particularly where irrigation is not used throughout the year.

The cropping pattern suited to a site depends on the prevailing climate and land characteristics. In rainfed wetland fields the year can be divided into four parts:

1. Dry period, the season when the soil-water contribution to crop growth approaches zero.

2. Premonsoon moist period, which starts when the topsoil holds enough water for crop established and ends when the topsoil becomes saturated and dryland crop growth is affected by lack of oxygen in the root zone.

3. Wet period, which in wetland fields, is characterized by long periods of standing water or saturation of the topsoil (aquic-moisture regime, USDA 1975). It ends when the profile drains. Only rice can be grown during the wet period. Farmers modify the duration of the wet period by opening levees toward the end of the rainy season to drain wetland fields that have surface drainage potential.

4. Postmonsoon period, when moisture content in the root zone is reduced from above field capacity to the point where all extractable water has been used by crops. The duration of this period determines the possibility for dryland crop production after rice.

In this paper the variation in the wetland rice growing season caused by different seepage and percolation rates and spillway heights is analyzed. Dates of onset and termination of critical growing season periods are evaluated for soils with different seepage and percolation rates and different spillway heights. The extent to which farmers can modify the duration of growing season components by surface drainage is also evaluated. These analyses are made by using a wetland-field, water-balance model for shallow flooded rainfed areas. The model is designed to operate with records of daily rainfall and estimates of evaporative demand based on monthly mean pan evaporation data.

SEEPAGE AND PERCOLATION INDEX AS A FIELD CHARACTERISTIC

The duration of growing season components is modified by land-related factors (Wickham 1978, Morris and Zandstra 1979). These factors are the rate of water loss through the profile (percolation), the rate of water loss through the bunds (seepage) (Wickham and Sen 1978), and the subsoil water contribution (Doorenbos and Pruitt 1975).

Percolation and groundwater contribution are determined by the soil texture of the profile, soil compaction, and depth of the water table. For typical and similarly managed rainfed wetland fields, profile texture and depth of water table appear to cause most of the variation.

Seepage loss from a field is the lateral movement of water through levees. Within a rice growing area, seepage out of the field is compensated by seepage into the field. The length of the field through which water is gained or lost, as well as the height differences between the field and higher- and lower-lying fields surrounding it, determines net effect of seepage on field water status. Rainy season measurements of seepage and percolation using the subsidence technique of Giron and Wickham (1976) showed great variation in daily values even in periods during which seepage and percolation was not affected by field operations. On a clay loam soil, average net seepage and percolation ranged from 0.6 to 8 mm/day in a toposequence of wetland fields at IRRI (Table 1). Bolton and Zandstra (1980) found average net seepage and percolation rates of 0.5 mm/day for fields in a plain and 0.8 mm/day for fields on a plateau landscape position, where actual daily values varied from -12 to +12 mm/day.

Table 1. Seepage and percolation in relation to topographic position. IRRI experimental farm.

Seepage and percolation	Field type					
	Top paddy 24.84 MAS[a]		Middle paddy 23.50 MAS		Lowest paddy 22.39 MAS	
	Mm/day	Days	Mm/day	Days	Mm/day	Days
Net	2.98	75	1.41	106	0.63	106
Positive	6.44	50	6.70	51	8.38	51
Negative	3.91	25	3.49	55	7.74	51

[a]MAS = meters above sea level.

Seepage and percolation combined can be considered an index of the aquic nature of a field, with lower-lying, heavier-textured, more water-enriched fields being more aquic and, therefore, having lower seepage and percolation than higher-lying, lighter-textured fields subject to water depletion.

For the purpose of growing season analyses, the seepage and percolation (SP) index has been related to an existing hydrological classification (IRRI 1978) of rainfed wetland rice (Table 2). This table gives the present estimate of the SP index that should be assigned to a field, given its landscape position and associated potential for ponding and drainage. It is based on observation and measurements of the duration of standing water in rainfed wetland fields and the calculated combined net seepage and percolation rates. The SP index combines the effects of differences in water enrichment, drainage potential, and soil texture that are normally associated with a wetland toposequence.

Although wetland SP indexes vary from 0 to >6 the distribution of rice land strongly favors fields with SP indexes below 3. The typical wetland rainfed fields will have SP = 1-3, whereas the somewhat lower-lying irrigated fields tend to be heavier textured and will typically have an average net SP = 0-2.

THE PADIWATER MODEL

PADIWATER is a simulation model that evaluates, on a daily basis, the water in or on the top 300 mm of the soil. The water content of the top 50 mm soil determines water loss through evaporation. Water movement between the 0-50 mm and 50-250 mm layers occurs as saturated flow, which is evaluated by simple subtraction or addition of water above field capacity, or by unsaturated flow, which is evaluated on the basis of unsaturated flux.

The water balance of a leveled and bunded field for a given day $\underline{i}$ is represented by:

$$\underline{W_i} = \underline{W_{i-1}} + \underline{R_i} - \underline{ES_i} - \underline{SP_i} - \underline{OF_i} + \underline{GW_i}$$

(all components are measured in mm) where:

Table 2. General association of hydrology class to landscape position, ponding and drainage potential, and seepage and percolation index used for the PADIWATER model.

Hydrology	Water table	Landscape position	Ponding potential	Drainage potential	S&P index
Pluvic	Deep water table	Knolls and summits	Very low, nonpaddy	High surface, high internal	>6
Perfluxic	Deep water table; highly fluctuating perched water table	Upper side slopes of knolls and summits	Low	High surface, moderate internal	4-6
Orthofluxic	Deep water table; less fluctuating perched water table	Lower side slopes and steep waterways	Moderate	High surface, imperfect internal	2-4
Orthocumulic	Water table or perched water table, close to the surface during wet and intermediate months	Lowest paddies on the side slopes, high plains	High	Moderate surface, low internal	1-2
Percumulic	Water table is almost consistently above ground surface during wet months	Waterways in high plains; low plains	Very high	Low surface; very low internal	0-1
Orthodelugic	Water table rises more than 30 but less than 50 cm above ground level for more than 2 weeks	Waterways and back swamps in low plains subject to inundation	Shallow flooded	No surface drainage; no internal	0[a]
Perdelugic	Water table rises beyond 50 cm but less than 100 cm above ground level	Similar to Orthodelugic	Deeply flooded	No surface drainage; no internal	[a]

[a]PADIWATER model does not apply to conditions in which water levels are controlled by basin flooding induced by lateral water movement. [b]S&P = seepage and percolation.

W_i is the soil water in or standing on the top 300 mm of the soil on day i,

W_{i-1} is the soil water in or standing on the top 300 mm of the soil on day $i-1$,

R_i is rainfall on day i,

ES_i is evaporation from the soil or standing water surface on day i,

SP_i is seepage and percolation on day i,

OF_i is overflow from the field when W_i exceeds spillway height on day i, and

GW_i is groundwater contribution to the top 30 cm of the soil on day i.

The components of the water balance, as treated in PADIWATER, are:

1. Evaporation of soil water (ES), calculated from the water content (WL) of the top 50 mm of the soil layer and pan evaporation as follows:

$$ES_i = Ep \qquad \text{for } Wl_i \geq Wls$$

$$ES_i = Ep\,(Wl_i^2/Wls^2) \quad \text{for } Wl_i < Wls$$

where:

Wl_i is the water content of the top 50 mm of the soil on day i,

Wls is the water content of the top 50 mm of the soil at saturation, and

Ep is the average value for class A pan evaporation for that month.

The water balance of the top 50 mm of the soil layer (Wl_i) for any given day i is:

$$Wl_i = Wl_{i-1} + R_i + F_i + UP_i$$

where:

F_i is the unsaturated flux between the 0-50 and 50-250 mm soil layer, and

UP_i is the free water held in the 0-300 mm layer which cannot be accommodated in the 50-250 mm layer.

In this water balance, Wl_i cannot exceed Wls and equals Wls whenever the top 300 mm of the soil is at saturation ($W_i = Ws$) or when there is standing water ($W_i > Ws$).

Upward flux of water from the 50-300 mm layer contributes to Wl when the topsoil dries. Flux was calculated from the matrix suction of these two layers, and their hydraulic conductivities and thickness were determined after Hillel (1977). In PADIWATER, flux is calculated to the nearest mm by iteration: the direction and magnitude of the initial flux is calculated. Then water is transferred between these layers in proportion to the initial flux and calculations are repeated. This process continues until daily flux is less than 1 mm. The newly estimated water content of the two layers is then returned to the water balance.

During initial wetting of a dry soil, downward flux from the wetting front is calculated similarly. In this case the boundary of the two layers is flexible and is determined by the depth of the wetting front, as calculated from the volumetric water content at field capacity.

2. Rainfall, considered effective because wetland fields are bunded. The contribution of the initial small rains to the water balance is, however, modified to reflect field and greenhouse observations of high evaporation losses. For rainfall below 15 mm on soil with Wl less than 10 mm, rainfall evaporation loss (Er) is considered as:

$$Er = 0.167\ Ep \sqrt{R_i}$$

only for $R_i \leq 15$ and $Wl_i < 10$.

When the conditions for inclusion of Er are satisfied, the total evaporation ($Er + ES_i$) cannot exceed Ep for that day. Treated this way, the maximum loss of initial rainfall is 80% of the evaporative demand of that day, and rates of initial water accumulation in the top 5-10 cm soil follow closely that observed in the greenhouse and in the field.

3. Seepage and percolation in PADIWATER, treated as an index of the aquic nature of the field. It depends on the location of the field in the landscape and profile texture. The SP index will be low for bottomlands and heavier-textured soils and high for light-textured soils at a high position in a toposequence. A 0-6 range is considered for most wetland soils.

Upon initiation of rains after the dry season, initial percolation rates are much higher than those that prevail after the profile is recharged. Wickham and Sen (1978) found as much as 10 times increase of seepage and percolation after a paddy field was dried. Observations of the day during which standing water occurred and the duration of standing water were made during early rains in a toposequence of paddy fields. These were used to relate the potential initial seepage and percolation losses to the extent to which the profile was recharged. In PADIWATER, the SP index is modified to a potential seepage and percolation in mm (SP_p):

$$SP_p = (SP + 1) - SSP/2, \text{ bound by}$$

$$SP_p \geq SP \qquad (1)$$

so that daily seepage and percolation is:

$$\underline{SP_i} + 0.5\ \underline{SPa} + 1.5\ \underline{SPa}\ (\underline{Wf}/\underline{H}) \text{ for } \underline{Wi} > \underline{Ws} \quad (2)$$

$$\underline{SP_i} = 0.5\ \underline{SPa}\ (\underline{Wi}-\underline{Wo})/(\underline{Ws}-\underline{Wo}) \text{ for } \underline{Ws} > \underline{Wi} > \underline{Wo} \quad (3)$$

$$\underline{SP_i} = 0 \quad \text{for } \underline{Wi} < \underline{Wo} \quad (4)$$

where:

SSP is the accumulated seepage and percolation,

Wf is standing water (Wi-Ws, for Wi ≤ Ws),

H is spillway height, and

Wo is water content (300-mm layer) below which no percolation occurs.

The SP_p index at the start of the rainy season is, therefore, high. For a medium-textured soil in an average draining position (SP = 3), initial water loss potential (SP_p) is 40 mm/day (equation 1). But after a total of 50 mm water has been lost from the 30-cm topsoil, SP_p is reduced to 15 mm/day and it reaches its minimum value (SP_p = SP) after 74 mm of accumulated seepage and percolation (SSP in equation 2). SSP is reset when the soil has dried (Wi < 90) and the water table is below 90 cm. The value at which SSP is reset reflects the amount of water held in the subsoil estimated from the height of the water table above 150-cm depth.

If the water table is at 150 cm and W_i is less than 90 mm, SSP is reset at 0.

Actual water loss by seepage and percolation on any given day (SP_i) is also influenced by the amount of water in and on the 300-mm soil layer. When the soil is just saturated (Wf = 0), SP_i is half the SP_p. For a field with water at spillway height, SP_i is twice the SP_p (equation 2). Below saturation, water loss is proportional to the free water in the top 300-mm layer (equation 3), although to reduce the frequency of unsaturated flux calculations, Wo was set somewhat below field capacity.

4. Overflow, the loss from the water balance of any water accumulation above spillway height. In effect, it sets the upper bound of Wi at the amount of water in and on the 300-mm topsoil when standing water depth is at spillway height.

5. Groundwater support, the amount of water contributed to the top 300 mm of the profile from the groundwater at a level below 30 cm. Groundwater contribution is a function of depth of the groundwater below 30 cm and the soil texture as described by Doorenbos and Pruitt (1975). Groundwater contribution is considered absent if the profile is not recharged -- SSP less than 10 (SP + 1).

The simulation of groundwater depth is limited to the withdrawal of the perched groundwater table after the field loses its standing water and there remains no free water in the top 30 cm of the profile. The drop in groundwater depth (4 cm/day) in the absence of rains and its reinstatement at 30 cm whenever Wi exceeds field capacity was used to simulate the behavior of a perched groundwater table in a rainfed wetland field. The 4 cm/day subsidence of the groundwater table was based on field piezometer measurements conducted in a plateau and plain landscape position (Bolton and Zandstra 1980).

EVALUATION OF FIELD WATER STATUS

Large year-to-year variation in rainfall patterns makes it necessary to evaluate the growing season on the basis of probabilities. The PADIWATER model was used to evaluate Philippine field water conditions for 27 years of Iloilo rainfall records and for 25 years of Cabanatuan rainfall records. For consecutive 3-day periods of the year the probabilities were estimated for a field with the following soil water conditions:

Flooded (F): soil has standing water,

Wet (S) : topsoil contains free water,

Moist (M) : topsoil is between field capacity and wilting point, and

Dry (D) : topsoil is below wilting point.

Of these conditions, S, M, and D are mutually exclusive and sum to 1, whereas F is a subset of S. An example of the results of the water balance analyses (Fig. 1) for Iloilo and Cabanatuan shows how the probability that the soil will be dry reduces at the onset of the rains. Water accumulates and initially increases the probability, but shortly after that, results in a high frequency of wet and flooded conditions. At the end of the rains the process is reversed. Cabanatuan field water conditions showed similar premonsoon dry and moist probabilities to those in Iloilo. The wet and flooding condition lasted longer in Iloilo, but flooding probabilities were greater in Cabanatuan at the peak of the rainy season. Cabanatuan showed an earlier onset of drought and higher probabilities of drought.

The effects of changes in the SP index and spillway heights on the average number of days in which the topsoil was in any of these four moisture conditions (Table 3) shows that both influence the water regime. Increased spillway height changed the flooded days more than any other factor. Changes in spillway heights above 50 mm showed less effects than the change from 5 to 50 mm. This agrees with Bhuiyan et al (1979) who reported substantial reductions in drought stress days at increased spillway heights. The effects of changes in spillway height on the field water conditions was less for fields with high SP indexes than for fields with low SP.

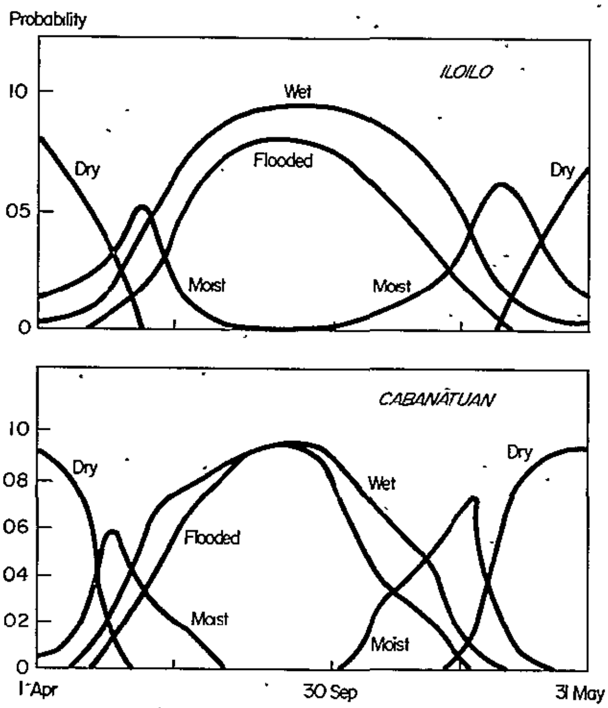

Fig. 1. Probabilities that the topsoil will be dry, moist, wet, or under standing water for Iloilo and Cabanatuan, Philippines (SP = 2, H = 100).

The water condition obtained at the spillway height of 5 mm simulates the condition in which farmers drain fields by opening the bunds. Only for fields with SP indexes greater than 4 did drainage prevent flooding conditions at Cabanatuan during the peak of the wet season. For these fields, saturation of the top 50 mm of the profile still occurred frequently, indicating that dryland crops would still suffer from excess moisture.

The effects of seepage and percolation on the field water condition are substantial. The estimated number of days when the field was flooded was reduced by 15-20 days/mm increase in the SP index (Table 3). The reduction in the number of days was less pronounced -- from 3 to 7 days. An increased SP index increased the estimated number of days in which the field was moist. This predisposes the field to the production of dryland crops before and after the peak of the rainy season.

In addition to changes in duration of flooding, and wet, moist, and dry conditions, SP index also changed the average time at which the onset of flooding occurs and the average extension of the moist into the dry season (Fig. 2A, B). The average date for the onset of flooding (P = 0.5) differed little between SP = 0 and SP = 2, but was about 15 days later in fields with SP = 4 than in those with SP = 0. For fields with a SP index greater than 4, the average onset of flooding was greatly delayed. The premonsoon moist period did not shift as a result of increased SP index but the postmonsoon moist period started and ended substantially later in fields with a low SP index. This is because low-lying, heavy-textured soils drain later. The estimated duration of the moist period was, however, reduced for fields with low SP indexes.

Table 3. The estimated average number of days in which fields are flooded, wet, moist, or dry as influenced by seepage and percolation index and spillway heights. Cabanatuan, Philippines.

Soil water condition	Spillway height (mm) 200	100	50	5
	Seepage and percolation index = 0			
Flooded	206.0	176.9	151.1	66.9
Wet	222.2	197.0	181.9	154.6
Moist	59.2	68.6	77.0	97.9
Dry	83.6	99.4	106.1	112.5
	Seepage and percolation index = 2			
Flooded	164.9	139.4	115.2	20.2
Wet	191.4	176.6	165.9	147.9
Moist	72.9	80.9	87.1	101.6
Dry	100.7	107.5	112.0	115.5
	Seepage and percolation index = 4			
Flooded	129.1	105.1	81.1	0
Wet	165.0	149.9	142.0	121.0
Moist	88.0	97.1	104.5	122.2
Dry	112.0	118.0	118.5	121.8
	Seepage and percolation index = 6			
Flooded	93.1	72.1	50.9	0
Wet	134.6	125.2	117.4	89.5
Moist	107.6	114.6	121.4	146.5
Dry	122.8	125.2	126.2	129.0

GROWING SEASON ANALYSES

These results from the PADIWATER simulation were used to estimate the average date on which seven important growing season events occurred. The occurrence of each event was defined in terms of the probability of the simulated topsoil water condition (W1 for the top 50 mm, W for the top 300 mm) in the specified ranges of the flooded (F), wet (S), moist (M), and dry (D) conditions. The definition employs the subscript 1 for the first half of the growing season and 2 for the last half:

1. Start of the premonsoon growing period occurs when the probability of drought becomes less than 0.30 or: (P[W1>D1]<0.30.

2. End of the premonsoon growing season period occurs when P[W1>F1]>0.30 or P[W>S1]>0.70.

3. Start of the wetland rice growing period when P[W1>S1]>0.70 and P[W>F1]>0.50.

4. End of the wetland rice planting period when P[W1>S2]<0.70 or P[W>F2]<0.50.

5. Start of the postmonsoon dryland crop growing period when P[W1>S2]<0.50 and P[W>F2] <0.30.

6. End of wetland rice growing period, when P[W1>S2]<0.20 or P[W1>M2]<0.50.

7. End of postmonsoon dryland crop period when P[W>D2]>0.60.

The choice of these criteria was based on experiences in the production of premonsoon crops, wetland rice, and postmonsoon crops in rainfed wetland fields at cropping systems research sites.

The premonsoon growing period was specified to have a high probability that the topsoil will be moist or wet, but not flooded. This is because flooding of more than 8 days substantially reduces dryland crop production even if it occurs during their reproductive growth stage (Herrera and Zandstra, 1979); a limit of 30% probability was used. Because surface drainage of fields may prevent standing water but can still leave a saturated profile, an additional condition was used, which confined this dryland crop growing period to the time before topsoil saturation reached a probability of 70%. This definition of the premonsoon growing season is entirely soil water-based and ignores atmospheric humidity, which is an important factor for the production of grains with acceptable market quality.

The start of the wetland rice growing season was set on the date on which fields were flooded, for more than 50% of the years, and the topsoil held free water for more than 70% of the years. This allows land preparation and the start of transplanting. Rice transplanting was considered possible until field water conditions fell below the same boundaries.

The postmonsoon dryland crop growing period should start when flooding for longer than 3 days is not probable. This prevents severe stand losses (particularly in grain legumes) associated with standing water or soil saturation and the accompanying damping-off diseases. The probability of a saturated topsoil was set below 50% for the same reason. The dates on which these conditions are met will generally allow the start of land preparation for the dryland crop or zero tillage planting by dibbling or row drilling techniques.

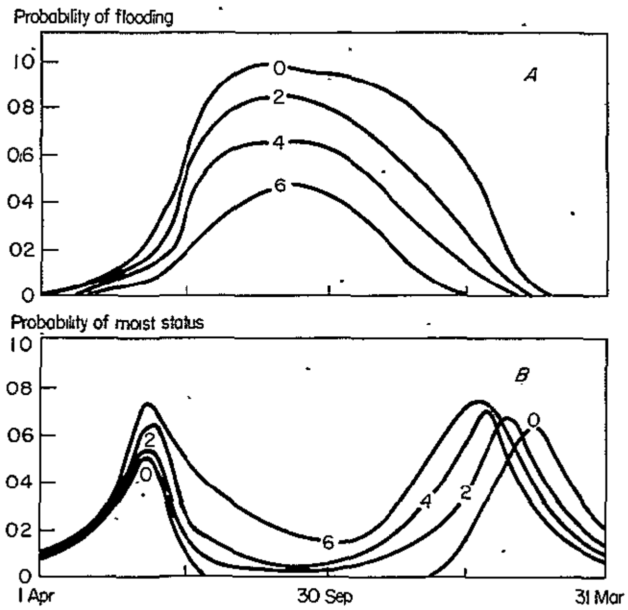

Fig. 2. Effect of seepage and percolation index on the probability that the field will be flooded (Fig. A) and moist (Fig. B). Iloilo, Philippines (H = 100).

The end of the wetland rice growing period was set on the date when the probability that the soil will be saturated dropped below 20% or the probability that it will be between field capacity and wilting point dropped below 50% in the topsoil layer, whichever occurred earliest. At that time the probability that the topsoil will be dry will be less than 30%. Field trials indicate that extending the rice growing period beyond this date generally leads to such severe yield loss that alternative land use should be considered (Morris and Zandstra 1979, Bolton and Zandstra 1980).

The postmonsoon dryland cropping period was allowed to extend well beyond that for rice. The end of this period was set on the date when, at a probability exceeding 60%, the crop could extract no more water from the top 30 cm of the soil. The high probability was used to compensate for the ability of these crops to extract water from deeper soil horizons. The cutoff date is approximate and its appropriateness depends on crop type and management (mulching, interrow tillage) used. Extending dryland crop growth beyond this date, however, would lead to little added dry matter production for most crops, because of low soil moisture contents and high evaporative demands during the dry season.

The dates on which these events occurred were evaluated for Cabanatuan, Iloilo, Iba (Zambales), Laoag, and Zamboanga. For Cabanatuan the water balance was evaluated with spillway heights of 5 (farmer drains field), 50, 100, and 200 mm, and SP indexes of 0, 2, 4, and 6. For Iloilo and Iba only spillway heights of 100 mm and 5 mm were used, with the same percolation indexes. For Laoag and Zamboanga only the SP index of 2 was used. The variation in SP index and spillway heights were included to evaluate their effects on the soil water status of wetland fields. The 5 mm spillway height was included to evaluate what moisture regime could be achieved by surface draining of fields for dryland crop production. This practice can be used in fields with high SP indexes, which often occur high in paddy landscapes with medium- to light-textured soils. Some of these fields can rarely be used to grow a transplanted rice crop, but are suitable for dryland crop production when surface drainage is used.

Start of the premonsoon period

The date on which the premonsoon dryland crop production period starts was not much influenced by changes in field characteristics. Using Cabanatuan as an example, the delay in the growing season onset as a result of a change in SP index from 0 to 6 was 4 days in drained fields -- spillway height (H) of 5 mm (Fig. 3). This delay is caused by rapid percolation losses in years with heavy early rainfall in fields with high seepage and percolation. In these fields water accumulation above saturation was slow, which led to intermittent drying of the topsoil so that the probability of drought remained high for a longer period.

The end of the premonsoon dryland crop period

Farmers drain wetland fields planted to premonsoon dryland crops. Where fields are drained (H = 5 mm) the probability of flooding exceeded 30% only in fields with SP = 0. In all drained fields, saturation (at P>0.70) was the factor that determined the end of the premonsoon period. The wettest field (SP = 0) became unsuitable for dryland crops 48 days before the field with SP = 6 (Fig. 3). The lengthening of the premonsoon period was also substantial (12 days) between SP = 0 and SP = 2.

Even in fields with SP = 6, dryland crop production becomes difficult because of the high frequency of saturation, during part of the growing season, even of the top 5 cm of the soil. Farmers, therefore, construct bunds around such level fields and shift the field water regime in favor of wetland rice culture. At higher seepage and percolation rates, or in sloping fields, soil saturation may be sufficiently infrequent to consider year-round cultivation of dryland crops. These crops still have to be tolerant of high rainfall and humidity.

The start of the wetland rice period

Start of the wetland rice period requires that the topsoil is saturated more than 70% of the time and that there is standing water more than 50% of the time. Lowering the spillway from 200 to 50 mm delayed the onset date about 4, 16, 24, and 30 days for fields with SP indexes of 0, 2, 4, and 6, respectively (Fig. 4). For a typical rainfed wetland

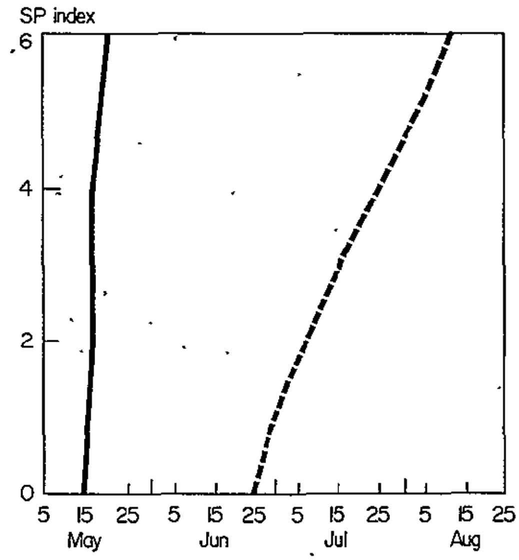

Fig. 3. Onset and termination dates of the premonsoon-dryland crop period as influenced by seepage and percolation (SP) index. Cabanatuan, Philippines (H = 5).

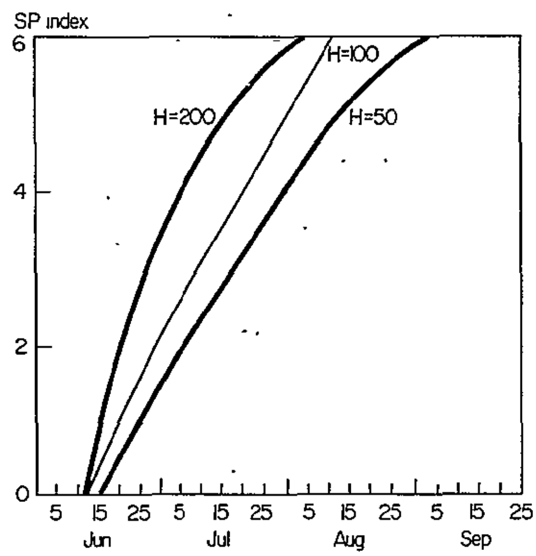

Fig. 4. Effect of field characteristics on the onset of the rainfed wetland-rice growing period. Cabanatuan, Philippines. H is spillway height in mm, SP = seepage and percolation.

field the time at which the field can be puddled can be delayed 10 to 15 days by using low, instead of high, bunds.

An increased SP index delayed the onset date about 10 days per unit increase in SP index for fields with a spillway height of 100 mm. Higher spillways reduced this delay, particularly in the lower SP index range, and lower spillways increased the delay. Drainage of the field (H = 5 mm) resulted in a simulated water regime that satisfied the flooding criterion only in fields with SP = 0, on 8 August.

The average time savings that result from dry-seeding instead of wet-seeding or transplanting rice can be evaluated by comparing the start of the wetland rice period to the start of the premonsoon dryland crop period. The specification of the wetland criterion is that it coincide with the possibility of wetland cultivation, so that the offset between the two periods is a conservative estimate of the time benefits gained by dry-seeding rice. For Cabanatuan the differences were 83, 69, 45, and 30 days for SP indexes of 6, 4, 2, and 0 at H = 100 mm. At Iba (Zambales), differences were 39, 24, 21, and 15 days for the same SP range and spillway height. For Iloilo and Laoag the time gains were 41 and 45 days for a typical field with SP = 2 and H = 100 mm. These differences are much greater than the 10 days extra field time required for dry-seeded rice -- an added growth duration of 25 days less a savings of 8 days in land preparation and 7 days in time required for planting.

The end of the rice planting period

The end of the rice planting period is important in areas where a premonsoon dryland crop or a dry-seeded rice crop is followed by a second rice crop. The criterion used determines if wetland rice stablishment is still possible, not if the crop has a chance of survival. Fields with spillway heights of 50, 100, and 200 mm showed an average delay of 6, 9, and 14 days, respectively, per unit decrease in the SP index (Fig. 5). Assuming a difference in SP of 3, the end of the rice transplanting period can differ by as much as a month between the upper and lower components of a wetland rice toposequence given the rainfall pattern in Cabanatuan.

The start of the postmonsoon dryland crop growing period

To grow crops such as mungbean, cowpea, and sorghum after rice, farmers would drain their paddies. This date was, therefore, estimated at H = 5 mm. For Cabanatuan data, fields remained saturated more than 50% of the time until 4 October at SP = 6 and until 15 November at SP = 0. This shift was linear with reduction in SP index and averaged 7 days per unit.

At Iba, Zambales, where rains stop abruptly, the start of the postmonsoon period ranged from 19 October to 6 November, a range of only 27 days as compared to 40 days for Cabanatuan. At Iloilo, the postmonsoon dryland period started about a month later -- ranging from 3 November to 6 December.

The end of the rice growing period

The end of the rice growing period was set when drought stress was expected to be so severe that

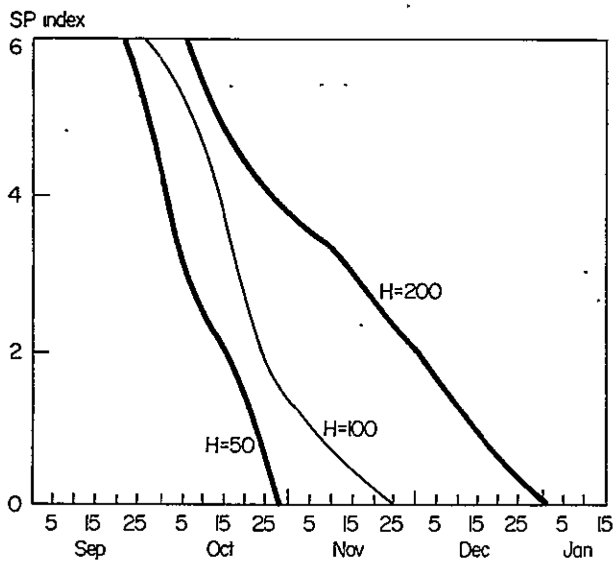

Fig. 5. Effect of field characteristics on the end of the period in which rainfed rice can be transplanted. Cabanatuan, Philippines. H = spilway height in mm, SP = seepage and percolation.

rice yield potentials would be below 2.5 t/ha if the rice growing period extended longer. This was judged to occur when the topsoil is saturated less than 20% of the time or moist less than 50% of the time. In all cases low frequency of saturation became the operative criterion. Spillway heights did not greatly influence this date. Assuming no unforeseen intermittent field drainage, the average shift was 4 and 9 days for height increases from 50 to 100 and 100 to 200 mm, respectively.

The effect of changes in the seepage and percolation averaged only 4.5 days per unit increase in the SP index for Cabanatuan, Iloilo, and Iba (Fig. 6). The effect of increased SP index did not appear to be modified by the rate of rainfall termination, which is more sudden in Cabanatuan and Iba than in Iloilo. The estimated shift of 12-14 days in the end of the rice growing season of a typical paddy toposequence can make a great difference in the yield of a second rice crop. Bolton and Zandstra (1980) found average daily yield reductions to be between 30 and 50 kg/ha.

The end of the postmonsoon dryland crop growing period

The end of the postmonsoon dryland crop growing period was evaluated at H = 5 mm because farmers will drain their fields during dryland crop production. Seepage and percolation resulted in minor (2-5 days) delay per unit decrease in seepage and percolation at Iba, Cabanatuan, and Iloilo. The end of the postmonsoon dryland cropping period ranged from 5-10 January at Iba and was about 20 February at Iloilo and mid-January at Cabanatuan.

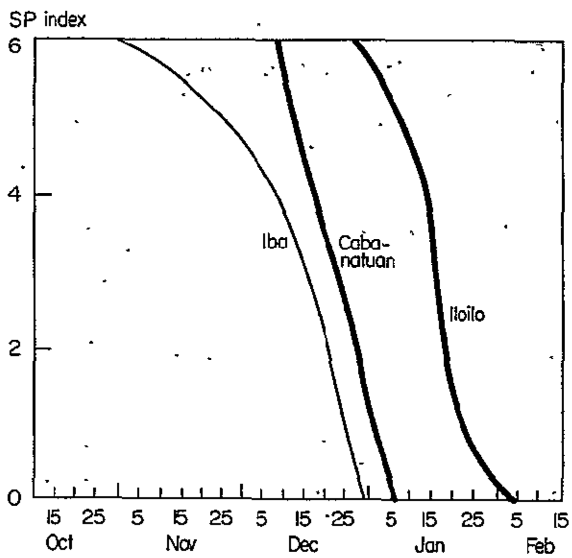

Fig. 6. End of the rice growing period for fields with seepage and percolation (SP) indexes from 0 to 6 at 3 sites in the Philippines.

DURATION OF GROWING SEASON COMPONENTS AND THE FEASIBILITY OF CROPPING PATTERNS

The onset and termination dates allow the calculation of the duration of the premonsoon-dryland, wetland-rice, and postmonsoon-dryland growing periods. By adding the duration of the premonsoon-dryland to the wetland-rice growing period, the total rice growing season obtained by dry-seeding the first rice crop can be determined. An evaluation can then be made of the agronomic feasibility of the major cropping pattern types: dryland crop (DC) - rice - DC, rice - rice - DC, rice - DC, DC - rice, and rice or DC only. This section shows by examples how the wetland growing season analysis is used to judge the suitability of these cropping patterns for different land types.

The growing season analysis was conducted for Iloilo, Cabanatuan, Iba (Zambales), Laoag, and Zamboanga using a typical 100-mm spillway height for evaluation of wetland criteria and a 5-mm height for the start and end of premonsoon and postmonsoon dryland cropping periods (Table 4). A SP index of 2 was used to represent the better than average drainage class of wetland rainfed fields.

Premonsoon dryland crop periods were too short in all sites except in Zamboanga to consider dryland crop production (Table 5). Analyses at higher SP indexes available for Cabanatuan, Iloilo, and Iba showed that fields with SP = 4 can accommodate dryland crops until 5 August at Iloilo and 24 July at Cabanatuan. At Iba, even fields with SP = 6 showed 30 June as the end of the premonsoon growing season for dryland crops because of topsoil saturation.

The wetland rice growing period ranged from 106 days at Zamboanga to 202 days at Iloilo. The late start of this period in Zamboanga is associated with an extended period of rain in the 25-40 mm/week range -- insufficient to accumulate water in all but the most aquic fields. Wetland rice culture in this rainfall regime will, therefore, require irrigation or concentration of water from upland catchment areas into lower-lying recipient wetland tracts. The Zamboanga site, therefore, appears suited to a DC - dryland rice - DC pattern. The rice crop should coincide with the period from early September to late December because a high probability of topsoil saturation in level fields was found from 1 October to 27 November (Table 4). This cropping pattern is not used in the area, where 25% of the farmers now grow maize - maize or dryland rice - maize (Denning 1980). The pattern was, however, tested for 2 years and found promising.

Only at Iloilo is there a remote possibility of growing two transplanted wetland rice crops in sequence. McMennamy and Zandstra (1979) estimated a land preparation time of 15 days, a first-crop planting time of 12 days, and a turnaround time of 26 days between crops to complete operation on all fields, if farmers have access to power tillers and mechanical threshers. With a crop duration of 80 days, the total required for 2 transplanted rice crops would be 213 days, 11 days in excess of the estimated average wetland growing season length (Table 5). A two-rice crop system that employs wetland preparation and transplanting is, therefore, not suited for fields with SP>2. For fields in the range of SP from 0 to 3, the duration of the wetland rice growing season at Iloilo increased 14.5 days per unit increase in SP (10 days for the onset and 4.5 days for the end). In Iloilo, fields with SP < 1 will, therefore, be suitable for growing 2 wetland rice crops.

Where the premonsoon period is too short for dryland crop production, dry seeding of rice can be used to capture its production potential. With dry seeding, the rice growing season ranges from 179 to 251 days in these sites (Table 5). Assuming 10 days for dryland preparation and seeding, 26 days for turnaround time, and 105- and 80-day crops, field duration for the dry-seeded rice (DSR) - transplanted rice (TPR) crop will be 221 days, 5 days less than the duration of the total rice growing season estimated at Cabanatuan. Bhuiyan et al (1979) reported that results of DSR - TPR cropping were marginal in fields that had average net seepage and percolation of 3.3 mm/day. Assuming that this seepage and percolation was measured while water depth was half the spillway height, these fields would have a SP index of about 2.3.

Postmonsoon dryland crops require a minimum of 65 days growth plus the time required for land preparation. The estimated available period ranged from 71 to 102 days for the sites studied. Because the soil profile drains rapidly and the topsoil dries quickly after rice harvest, the planting of dryland crops after wetland rice must be carefully timed. Crop establishment can be by zero tillage, broadcast, dibbling, furrow planting or drilling (experimental), and after complete plowing and harrowing. The zero tillage methods require less time, but more precise timing. They require that the topsoil is near saturation but not flooded (for broadcast), or is moist with some free water but not flooded (for dibbling, furrow planting, or drilling) (Syarifuddin 1981, Zandstra 1980). The period between the planting of the last wetland rice and the planting of the first dryland crop is best for zero tillage planting. Except in Zamboanga, this period is 7 days or less and, therefore, well defined. Rice harvest should, therefore, be scheduled just after the end of the wetland rice planting period to insure good zero tillage establishment of the dryland crops. This places the desired date of transplanting rice 90 days earlier, which is 21, 57, 10, and 48 days after the start of the wetland rice growing season in Cabanatuan, Iloilo, Laoag, and Iba.

Given the duration of land preparation, a TPR - DC pattern that employs zero tillage shows good fit for fields with SP = 2 to 4 in Cabanatuan and Laoag, but too much growing season is lost in Iloilo

Table 4. Average dates of critical growing season events for typical wetland fields at 5 sites in the Philippines (SP index = 2 mm/day).

Criterion	Spillway height (mm)	Cabanatuan (25 yr)[a]	Iloilo (27 yr)[a]	Laoag (28 yr)[a]	Iba (26 yr)[a]	Zamboanga (26 yr)[a]
Start of premonsoon growing periord	5	16 May	14 May	31 May	19 May	18 May
End of premonsoon dryland-crop period	5	6 Jul	6 Jul	15 Jul	15 Jun	1 Oct
Start of wetland rice period	100	30 Jun	30 Jun	3 Jul	12 Jun	10 Oct
End of wetland rice planting	100	25 Oct	30 Nov	11 Oct	28 Oct	31 Oct
Start of postmonsoon dryland-crop period	5	31 Oct	3 Dec	16 Oct	4 Nov	27 Nov
End of rice growing period	100	28 Dec	18 Jan	26 Nov	21 Dec	24 Jan
End of dryland-crop growing period	5	20 Jan	19 Feb	30 Dec	14 Jan	9 Mar

[a]Rainfall record length used.

Table 5. Average duration (days) of selected growing season components for typical wetland fields at 5 sites in the Philippines (SP index = 2).

Criterion	Cabanatuan	Iloilo	Laoag	Iba	Zamboanga
Premonsoon dryland crop period (H = 5 mm)	51	53	45	27	136
Wetland rice period (H = 100 mm)	181	202	146	192	106
Total rice period (H = 100 mm)	226	249	179	216	251
Postmonsoon dryland crop period (H = 5 mm)	81	78	76	71	102
Total every year	249	281	213	240	295

and Iba. By dry-seeding rice, a total duration of 110 days at Iloilo and 75 days at Iba becomes available for a first rice crop. Given the 10-day land preparation and planting time requirement for DSR and a 26-day turnaround time, the Iloilo and Iba sites show a lack of time for a DSR crop before the TPR - DC sequence in fields with SP = 2.

Alternative approaches are to use a later-maturing rice variety with higher yield potential in a TPR - DC pattern or to modify field characteristics through soil management techniques. An increase in spillway height delays the end of the period in which rice can be transplanted (Fig. 5) and similarly delays the start of the dryland crop growing season. Modifying spillway height may, therefore, be a field management method that allows adjustment of the field water regime to a desired crop sequence. Alternatively, ditches can be used in most side slope and plateau fields to place spillway heights below the soil surface and drain water to lower-lying fields. This will place the dryland crop planting period at or before the end of the rice growing season, which may help accommodate earlier planting of the dryland crops in a rice - DC pattern.

CONCLUSION

A growing season analysis derived from a field-water balance provides clear differentiation of the crop production potentials for different areas and different land types within an area. Differences in the aquic nature of typical rainfed wetland fields can lead to changes of 30 to 45 days in the duration of the premonsoon-dryland crop growing season, the wetland-rice growing season, and the postmonsoon-dryland crop growing season. This modifies the cropping patterns most suitable for these fields to the extent that they can range from a rice - DC pattern to a rice - rice - DC pattern for a given rainfall regime. These differences are of the same order as those encountered between different rainfall regimes in the Philippines.

In the wet-dry rainfall regimes of Central and Northern Philippines, the length of the premonsoon dryland crop growing period is limited by early saturation of the topsoil. Without irrigation or substantial ditching, this crop type should be planted only in the light-textured higher-lying fields with good internal drainage. In parts of southern Philippines, where the separation between the wet and the dry seasons is less abrupt, premonsoon-dryland crop cultivation can be extended to medium-textured fields with good surface drainage.

The increase in the total rice growing season obtainable by shifting from a transplanted to a dry-seeded first rice crop ranges from 15 to 83 days, depending on location and seepage and percolation characteristics of the field. For typical rainfed wetland fields the time ranges from 20 to 45 days.

The length of the wetland rice growing season increased 14.5 days per unit increase in SP index, 10 days for the earlier onset and 4.5 days for the later termination. For the typical range in the aquic nature of rainfed wetland fields a range of 45 days can be expected.

The correct soil water status at planting time is of critical importance in the successful establishment of dryland crops after wetland rice. For this reason, when considering a rice - DC pattern, it is often advantageous to give priority to selecting the best date for dryland crop planting. The planting date for rice can then be estimated such that rice will be harvested not less than 5 days before the best date for planting a dryland crop.

Field drainage and increases in spillway heights are effective ways to modify field water conditions to suit more accurately the demands of cropping patterns. With these modifications, the probability that field water conditions are in the required range at a certain time of the year can be substantially improved.

The extent of the aquic nature of a field, or its aquicity, reflects water conditions and cropping pattern performance. Increased capability in classifying wetland fields into hydrological types should be developed through further toposequence studies in rainfed wetland conditions.

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