

EFFECT OF RICE MOISTURE CONTENT AT HARVEST ON ECONOMIC RETURN

R. Lu, T. J. Siebenmorgen, T. A. Costello, E. O. Fryar Jr.

ABSTRACT. *Economic analyses were conducted to assess the impact of rice harvest moisture content (MC) on economic return to a producer. The primary factors considered included percent milled rice, percent head rice, field yield, and drying costs. The results showed that rice harvest MC had a dramatic impact on the final gross income to a producer. The optimal harvest MC was influenced by field yield loss rate and, to a lesser degree, drying charge schedule. The relative price of broken to head rice also affected the optimal harvest MC. Significant losses in gross income could be incurred if rice is harvested at MCs lower than 15% or higher than 22%. Keywords. Rice, Moisture content, Economics, Harvest.*

Harvesting is an important operation in rice production. The time at which rice is harvested directly influences the economic return to a producer (the value of harvested rice less certain specified costs such as harvest, storage, and drying costs). The primary factors that determine this economic return are rice field yield (FY); milling quality, including percent milled rice (PMR) and percent head rice (PHR); and drying costs. Studies (e.g., Lu et al., 1992; Siebenmorgen et al., 1992) have shown that FY, PMR, and PHR are a function of average rice moisture content (MC) (unless otherwise specified, all moisture contents reported in this article are on a wet basis). FY, PMR, and PHR will decrease and drying costs will increase as rice harvest MC increases above the optimal range. Conversely, when harvesting is delayed, FY losses will be incurred as a result of lodging and shattering. Moreover, rain and/or dew occurring during the late harvest season may cause rice kernels to fissure, resulting in PHR reductions.

Weather is the single most important factor influencing rice MC throughout the harvest season and, therefore, will affect the time of harvest. Harvesting is also constrained by factors such as crop acreage, field conditions, harvesting capacity, drying method, and the availability of drying and storage facilities.

Considerable research has been done to determine optimal harvest MC for rice to obtain maximum FY, PMR, and PHR (e.g., McNeal, 1950; Kester et al., 1963; Morse et al., 1967; Nangju and De Datta, 1970; Bal and Ojha, 1975; Calderwood et al., 1980; Geng et al., 1984; Siebenmorgen et al., 1992). These studies did not consider weather as a variable nor did they address the effect of harvest timing on economic return to the producer. Comprehensive studies of the effects of rice MC at harvest, or time of harvest, on *economic return* have not been reported.

The objective of this research was to assess the impacts of rice MC at harvest and/or time of harvest on economic return to a producer. The work reported in this article is based on mathematical equations proposed by Lu et al. (1992) for predicting FY, PMR, and PHR as a function of average rice MC. A simulation model developed by Lu and Siebenmorgen (1994a, b) was used to predict rice MC throughout harvest seasons. These models have been verified to be applicable for long-grain rice grown in Arkansas.

PHYSICAL CONSIDERATIONS

Many producer-specific factors, including crop acreage, field conditions, harvesting capacity, and the availability of drying and storage facilities, dictate the amount of rice that can be harvested at a given MC by a particular producer. The analysis reported herein focuses strictly on the generic effect that MC at harvest has on economic return. These producer-specific factors are neglected for this analysis, and it is assumed that all rice can be harvested at the same MC level. It is, however, to be realized that further extension of the analysis reported herein will be needed to include these producer-specific factors for developing optimal harvesting schedules.

RICE FIELD MC

Accurate determination of rice MC throughout a harvest season was crucial to this analysis. In the model of Lu and Siebenmorgen (1994a, b), the field drying/rewetting of rice is simulated as a process of simultaneous heat and mass transfer. The model predicts the effects of dew and rain on

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The authors are **Renfu Lu**, *ASAE Member Engineer*, Agricultural Engineer, Instrumentation and Sensing Laboratory, Beltsville Agricultural Research Center, USDA-Agricultural Research Service, Beltsville, Maryland (formerly with the Biological and Agricultural Engineering Dept., University of Arkansas, Fayetteville); **Terry J. Siebenmorgen**, *ASAE Member Engineer*, Professor, **Thomas A. Costello**, *ASAE Member Engineer*, Associate Professor, Biological and Agricultural Engineering Dept.; and **Edward O. Fryar Jr.**, Associate Professor, Agricultural Economics and Rural Sociology Dept., University of Arkansas, Fayetteville. **Corresponding author:** Terry J. Siebenmorgen, Biological and Agricultural Engineering Dept., University of Arkansas, Fayetteville, AR 72701; e-mail: <TSiebenm@saturn.uark.edu>.

rice MC. The weather data required by the model include air temperature, relative humidity, total solar radiation, wind velocity, and rain precipitation. Either hourly or daily weather data can be used in the model. The model has been validated by Lu and Siebenmorgen (1994b) using field data collected over the three harvest seasons of 1988 through 1990 and was found to be adequate for predicting rice MC during the harvest seasons in Arkansas.

MILLING QUALITY

The PMR and PHR for long-grain varieties throughout a harvest season were predicted using the models developed by Lu et al. (1992), which are applicable for rice grown in Arkansas. In predicting PMR, it was assumed that weather conditions did not have direct impact on PMR during the entire harvest season (Lu et al., 1992; Siebenmorgen et al., 1992). The maximum potential PMR was considered as an input value, which is typically 70% for long-grain varieties. The PHR prediction model considered the effect of rain on PHR reductions and assumed that rain starts to influence PHR after rice MC decreases to 18%. The effects of high-humidity air and dew on PHR were neglected, which has been justified by Lu et al. (1992) and Siebenmorgen et al. (1992).

FIELD YIELD

The following equation was used to predict FY change throughout a harvest season:

$$FY = \begin{cases} \frac{c}{1 - PMR/100} & M > M_x \\ FY_{max} (1 - a \gamma N) & M \leq M_x \end{cases} \quad (1)$$

where

- FY = field yield adjusted to 12.5% MC (kg/ha)
- c = constant (kg/ha)
- M_x = moisture content at maximum FY (% w.b.)
- FY_{max} = potential field yield at M_x (kg/ha)
- N = number of days from FY_{max}
- γ = field yield reduction rate (d^{-1})
- a = FY loss parameter

In equation 1, the factor a was introduced to account for the effects of varietal differences and crop and environmental conditions on FY reductions. This factor was not included in the equation proposed by Lu et al. (1992). Depending on the lodging- and shattering-resistance characteristics of individual rice varieties, the a-value can be less than or greater than one. The FY reduction rate, γ , reported by Lu et al. (1992) was $0.00661 d^{-1}$. This value was obtained from the data of a four-year study conducted by Calderwood et al. (1980). The M_x -value was chosen to be 22% (Lu et al., 1992), and the c-value was calculated based on the maximum potential FY.

ECONOMIC CONSIDERATIONS

The total rice value is determined by the quantity of rice harvested per unit area, the quality of milled rice, including PMR and PHR, and the prices paid for head rice and broken rice:

$$R = FY \times (PHR \times P_H + (PMR - PHR) \times P_B) \quad (2)$$

where

- R = unit rice revenue (\$/ha)
- P_H = price paid for head rice (\$/kg)
- P_B = price paid for broken rice (\$/kg)

In determining the unit rice revenue, the hull and bran fractions were assumed to be of zero value.

Three major costs are incurred in harvesting and related operations—harvesting, transportation, and drying costs. In this article, the harvesting and transportation costs were considered equal under different harvesting schedules and, therefore, were not included in the analysis. Drying costs are dependent on a number of factors, such as rice MC, drying method, drying charge schedule, and facilities available. Rice is dried either in on-farm facilities or in off-farm (or commercial) facilities. Since approximately 80% of the rice produced in Arkansas is dried in commercial facilities, only commercial drying costs were considered in this article.

A comprehensive survey of the charges for commercial drying was conducted for companies or cooperatives throughout Arkansas. There are predominantly two types of drying charge schedules used by various companies in Arkansas—one is the incremental rate schedule and the other the flat rate schedule. In the incremental rate schedule, charges levied for rice drying are based on the MC of the rice received at the elevator. In the flat rate schedule, the same charge is applied regardless of rice MC. Drying costs were charged by most surveyed companies on the basis of dollars per bushel of rice, which is calculated based on the green weight of rice received at elevators. In this study, the rice bulk density was assumed constant at 578 kg/m^3 (45 lb/bu), regardless of MC, as is done in the drying cost calculations in industry. Figure 1 shows a typical incremental rate schedule applied by a drying company in Arkansas for the 1990 harvest season, in which three different MC categories were used in charging drying costs. Significant drying costs are incurred if rice is harvested above 24% MC according to the schedule shown in figure 1.

PROCEDURE

Economic analyses were performed for 'Newbonnet' long-grain rice harvested in 1988 and 1989 at Stuttgart, Arkansas, to estimate the impacts of time of harvest, with

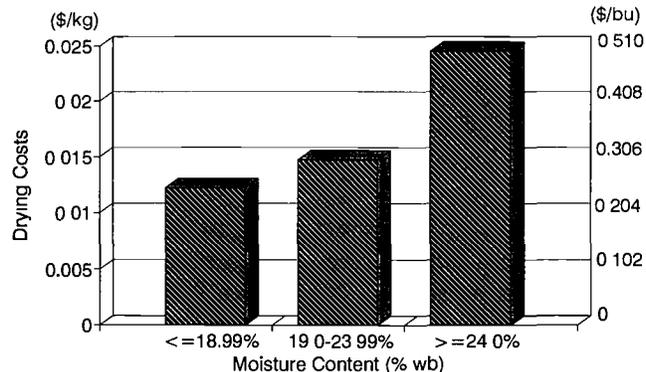


Figure 1—A typical incremental drying charge schedule applied by a drying company in Arkansas in 1990.

the associated MC determined through the simulation model described previously, on economic return to a producer. Hourly weather data, including air temperature, relative humidity, solar radiation, wind velocity, and rain amount and duration were used to simulate rice MC throughout the harvest seasons. The moisture content at 1:00 P.M. on each harvest date was used in estimating FY, PMR, and PHR for that harvest date. The FY, PMR, and PHR were estimated using the equations shown earlier. The drying costs incurred under the incremental rate schedule were calculated using the data shown in figure 1. The drying costs incurred under the flat rate schedule were calculated at \$0.01472/kg (\$0.30/bu) according to the survey results. The gross income (\$/ha), which is equal to the unit rice revenue from equation 2 minus drying costs, was calculated for each harvest date.

The maximum potential PMR and the maximum potential PHR were chosen to be 70 and 60%, respectively. The maximum potential FY was assumed to be 6500 kg/ha (5807 lb/acre), from which the c value in equation 1 was calculated to be 1950. The price paid for head rice was calculated at \$0.2523/kg (\$0.1143/lb). The price of broken rice was considered to be the fraction of that of head rice.

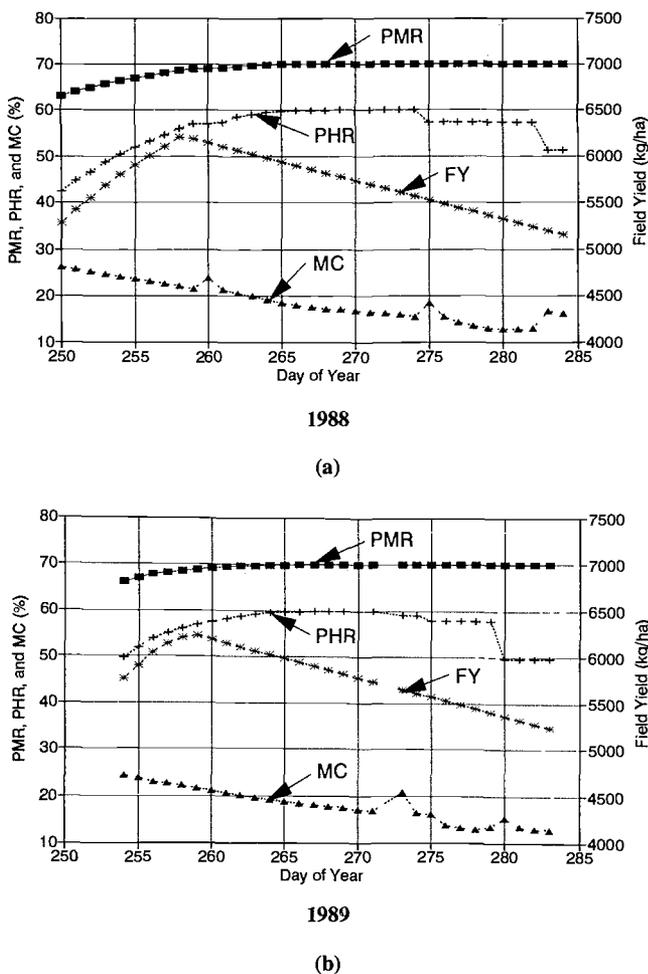


Figure 2—Predicted values of PMR, PHR, MC, and FY as a function of time of harvest for 'Newbonnet' variety in the harvest seasons of (a) 1988 and (b) 1989.

RESULTS AND DISCUSSION

Predicted values of PMR, PHR, FY ($a = 1$), and MC throughout the entire harvest seasons of 1988 and 1989 are shown in figure 2. The PMR approached maximum at approximately 18% MC and thereafter remained constant. The PHR increased considerably as rice MC decreased until about 18%. Thereafter, environmental conditions showed significant influences on PHR. Rain caused significant reductions in PHR when rice MC was lower than 15%. The FY increased progressively as rice MC decreased until 22% and thereafter decreased linearly with harvest date as the results of lodging and shattering losses.

DRYING CHARGE SCHEDULES

Figure 3 shows the effects of the two different drying charge schedules on costs (\$/ha) for drying rice harvested at different MCs. The drying costs were significantly influenced by harvest MC and drying charge schedule. Under the incremental rate schedule, drying costs increased dramatically when rice was harvested above 24% MC, and the maximum drying cost was incurred at 24% MC. However, with the flat rate schedule, the change in drying costs over the harvest MC range was not as great as in the incremental rate schedule, and the maximum drying cost was incurred when rice was harvested at 22% MC.

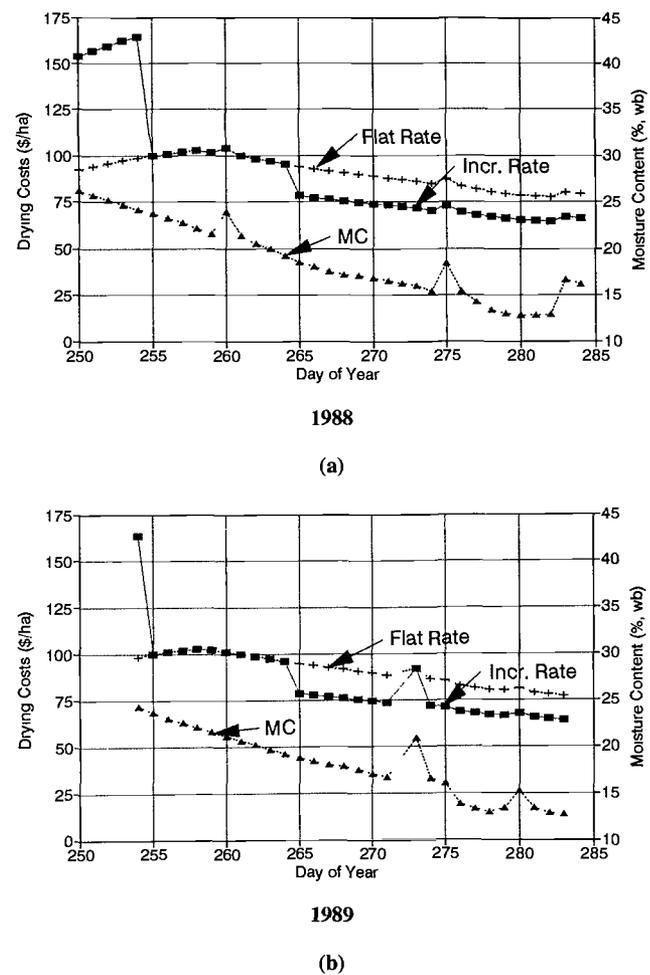


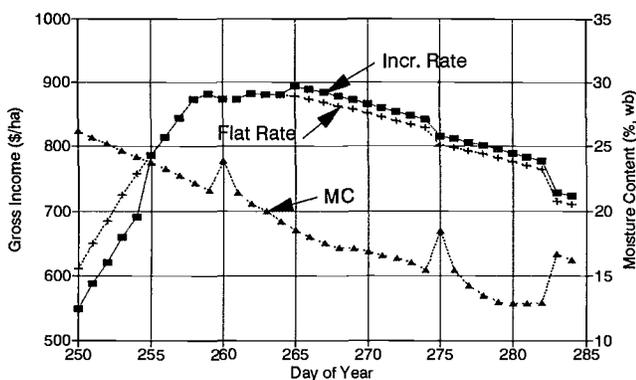
Figure 3—Effects of time of harvest on MC and associated drying costs incurred under the incremental and flat rate schedules for the harvest seasons of (a) 1988 and (b) 1989.

Figure 4 shows the effects of the two drying charge schedules on the gross income to a producer. The gross income shown in the figure was calculated on the basis that $P_B = 0.5P_H$. The overall trends in gross income change with time of harvest were similar under the two drying charge schedules. Drying charge schedules had dramatic impacts on gross income when rice was harvested above 24% MC. Significant losses in gross income were incurred with both drying charge schedules when rice was harvested above 22% MC due to lower PMRs, PHRs, FYs, and higher drying costs. Under the incremental charge schedule, the gross income was nearly constant when rice was harvested between 17 and 22%. The maximum gross income was obtained when rice was harvested slightly less than 19% MC. Under the flat rate schedule, the maximum gross income was obtained when rice was harvested between 19 and 22% MC. There was potential advantage for the producer under the flat rate schedule if rice was harvested at a high MC, as compared to the incremental rate schedule. The incremental rate schedule appeared to allow rice to be harvested at somewhat lower MCs without causing significant losses in gross income. Figure 4 also shows that there was a great risk in gross income loss when rice was harvested at MCs lower than 15% because rain would cause significant PHR reductions. Harvesting at

MCs higher than 22% could also lead to significant gross income losses due to high drying costs and reduced FY and milling yields. However, it should be mentioned that the results shown here may not be generalized. This is because drying costs and charge schedules vary considerably, depending on location and drying company. The analysis shown in figure 4 simply shows how different harvest MCs or times of harvest would affect the changes in gross income under the two drying charge schedules with the specific drying charges.

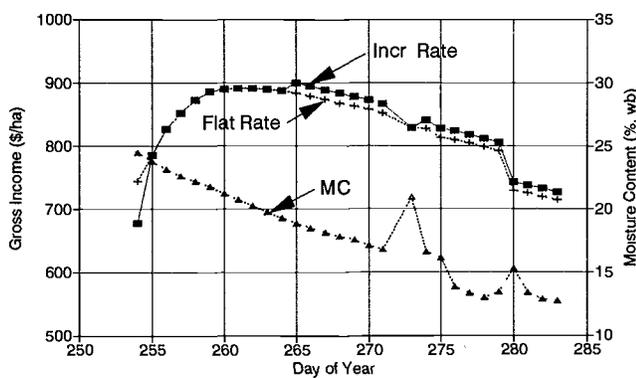
MILLED RICE PRICE

In the rice market, broken rice is usually sold at a lower price compared to head (or whole) rice. The prices for broken and head rice vary considerably, depending on the supply and demand of the rice market and other factors. The price for broken rice can be as low as one half to one third of the price for head rice or as high as that for head rice. Hence, it would be desirable to estimate how the changes in the relative price of broken rice would affect the optimal harvest MC or time of harvest. Figure 5 shows a comparison of the gross incomes received from two hypothetical prices for broken rice, i.e., $P_B = 0.5P_H$ and $P_B = P_H$, when the drying costs were calculated based on the incremental rate schedule. As expected, the prices for



1988

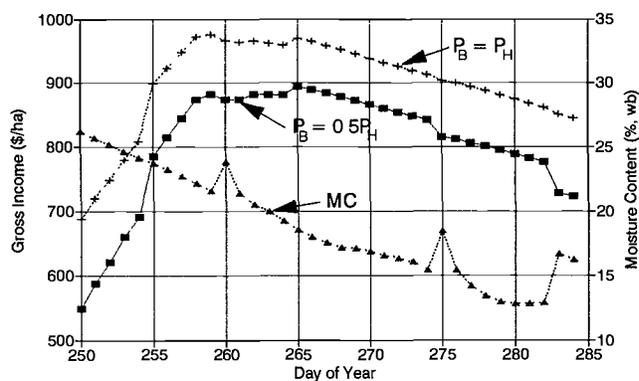
(a)



1989

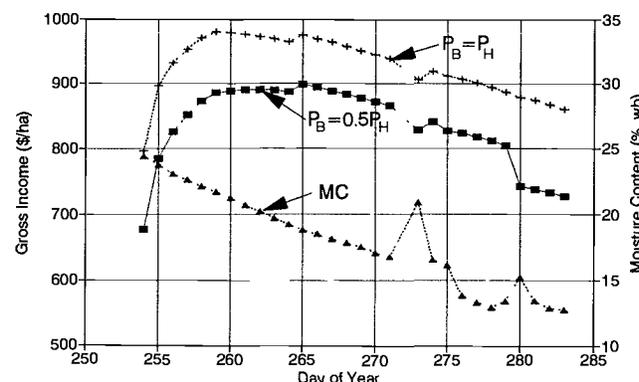
(b)

Figure 4—Effects of drying charge schedules on gross income to a producer for the harvest seasons of (a) 1988 and (b) 1989.



1988

(a)



1989

(b)

Figure 5—Effects of the relative prices for broken (P_B) and head rice (P_H) on gross income to a producer for the harvest seasons of (a) 1988 and (b) 1989.

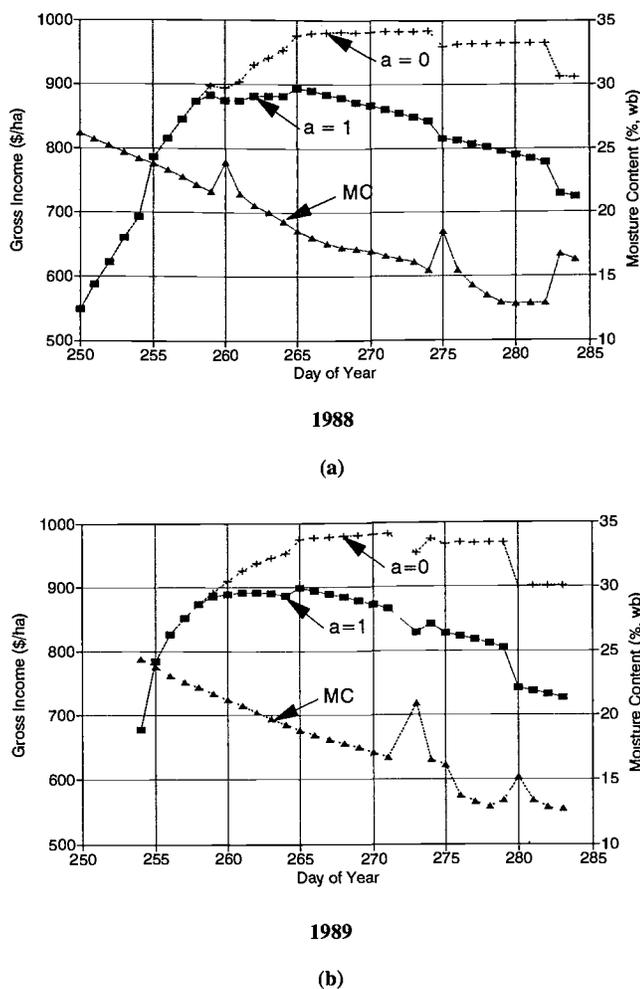


Figure 6—Effects of two field yield loss rates ($a = 0$: zero loss rate; $a = 1$: 0.00661/d loss rate) on gross income to a producer for the harvest seasons of (a) 1988 and (b) 1989.

broken rice showed significant influences on the producer's final income for the two harvest seasons of 1988 and 1989. The change in broken rice price had effect on the optimal harvest MC. The maximum gross income for the price schedules of $P_B = P_H$ and $P_B = 0.5P_H$ was obtained at 22% MC and a MC slightly lower than 19%, respectively. There was increased potential for greater losses in gross income when rice was harvested at MCs lower than 15% and the price for broken rice was lower than that for head rice. Similar results were also obtained under the flat rate drying schedule.

FY LOSSES

As discussed earlier, FY losses are influenced by many factors such as variety, crop, and environmental/weather conditions. Figure 6 shows the effects of the FY loss rate on the gross income to a producer when the drying costs were calculated using the incremental rate schedule of figure 1. The gross income was significantly influenced by the FY loss rate. The optimal harvest MC was between 15 and 19% when no losses in FY ($a = 0$) were incurred after rice MC decreased to 22%. The optimal harvest MC was slightly lower than 19% when the FY loss rate was

0.00661/d ($a = 1$). Similar results were also obtained when the flat rate for drying charges was applied. These results indicate that the optimal harvest MC or time of harvest is significantly influenced by the FY loss rate. A higher FY loss rate means that rice should be harvested at higher MCs to obtain the maximum gross income. There is need to quantify the FY loss rate or the FY loss parameter, a , for each individual rice variety so that better simulation results can be obtained.

SUMMARY AND CONCLUSIONS

Analyses were conducted to assess the impact of rice harvest MC or time of harvest on economic return to a producer. The primary factors considered included PMR, PHR, FY, and drying costs. The influences of commercial drying charge schedules, the prices for broken rice, and field yield loss rates were considered in the analyses.

The maximum drying costs, expressed in terms of dollars per unit land area, under the flat rate schedule were incurred when rice was harvested at 22% MC. The maximum drying costs for the incremental rate schedule were incurred at 24% MC. In the incremental drying charge schedule, the change in gross income was minimal when rice was harvested between 17 and 22% MC and the maximum gross income was obtained at a MC slightly lower than 19%. In the flat drying charge schedule, the maximum gross income was obtained between 19 and 22% MC. The incremental drying charge schedule appeared to allow rice to be harvested at somewhat lower MCs without causing significant losses in gross income. The price for broken rice had significant influence on the gross income, and it also had effect on the optimal harvest MC. The optimal harvest MC was influenced by the FY loss rate. Lodging- and shattering-susceptible varieties should be harvested at higher MCs to avoid significant losses in final income. Significant losses in the final income could be incurred if rice is harvested at MCs higher than 22% or lower than 15%.

The analysis reported in this article provides the basis for further harvesting simulations. Optimal harvest decisions can be developed with the consideration of constraining factors including crop acreage, harvesting capacity, drying methods, and the availability of drying and storage facilities.

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