Comparison of Tillage Systems for Paddy Rice in the Mekong Delta of Vietnam

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Abstract: In the Mekong delta of Vietnam, wetland rice is the main crop. The traditional rice cropping system with one crop per year changed to a system with two or three crops per year, and mechanised tillage replaced traditional tillage by water buffaloes. Currently, three tillage systems can be distinguished: dry tillage (ploughing and/or rotovating of the unsaturated field), wet tillage (puddling) or a mix of the two systems. The heavy monsoon rainfall causes many problems and strongly reduces the trafficable and workable periods. Tillage requires a high energy input and time pressure is high due to the short periods between crops. Whenever possible, farmers prefer dry tillage in view of soil structural quality, resistance of the crop to lodging (anchoring) and the experience that the typical soil profile is kept in better condition, resulting in higher yields. Experiments were carried on typical heavy clay soils (near Cantho, Cantho province) comparing the three tillage systems in terms of: quality of the seedbed (aggregate size, smoothness), the structure of the arable layer, bearing capacity of the hardpan, and energy expenditure and timeliness of the tillage operations.

It was found that (dry) ploughing with a disk plough had a low energy consumption (about 40% of that of the rotavator) but produced a very poor seedbed. Additional disk harrowing or rotary tillage was necessary. One pass with the rotary tiller produced a good seedbed. Where secondary tillage operations on dry soil are required, drying of the soil for at least 6 days is needed to achieve an acceptable quality of the seedbed.

A good alternative for the assessment of the surface condition of a rice-seedbed is collecting and quantifying the amount or number of clods larger than 80 mm at the surface.

INTRODUCTION

The Mekong delta, the largest delta of Vietnam (3,900,000 ha; Binh *et al*., 1995), provides more than 50% of the staple food for the whole of Vietnam and contributes for a major part to the export of rice. The delta was formed 10,000 years ago but its exploitation only started 300 years ago (Xuan *et al.*, 1998). It is a very flat, low laying region. The average topography is 2 metres above the mean sea level (Xuan *et al*, 1998), except for some minor hills in a restricted area in the west. Lowest areas are located in the Dong Thap province with topography of minus 0,5m below mean sea level. (Thach, 1980; Chiem, 1994). Acording to Kuyma (1976) the paddy soil in the Mekong delta consist of fine-textured material with low base status. Clay mineral composition of the material is characterised by the dominance of 1:1 type clay and illite. Relatively little 2:1 type clay (14 Å minerals) is found.

The climate of the Mekong delta is a monsoon. It is characterised by two distinct seasons: The dry season starts in December, ends in April. The wet season, with heavy rainfall (average of 20 rainy days per month), starts in May and ends in November (Tri, 1996; Chiem, 1994; Xuan *et al*, 1998). The lower Mekong river exhibits pronounced seasonal variations in flow, reflecting the rainfall patterns. The river starts to rise shortly after the onset of the monsoon rains in late May, and attains its maximum level in September or October. It then falls rapidly until December and slowly thereafter to reach its lowest level in April and in early May. Most of the irrigation is done in an uncontrolled manner and thus strongly dependent on the river water level. Based on these conditions, some very simple tillage systems were derived. Because humans and buffaloes could not till dry soil, the systems of that time were no tillage and wet tillage. As a consequence, farmers could only grow one rice crop per year with traditional varieties well adapted to the local climate. Le Qui Don (1776) wrote that the immigrants tried to clear forests and cut grasses to form the flat fields.

Trinh Hoai Duc (1820) reported that there were two kinds of exploitation of the land: *Son dien* (high land) and *thao dien* (low land). *Son dien* was basically a kind of shifting cultivation where during the drying season, farmers cut trees and grasses, and then burn them. When rain falls, they broadcast rice without soil preparation. This cultivation method is carried out for 3 or 4 years at the same plot, and then it shifts to other plots. Rice cultivation in *thao dien* was quite different. It depends on land conditions. If the field is not very muddy, farmers use buffaloes to plough the soil when the rain started falling, then transplant rice. With very wet field conditions, they just use the cutting tools (*phan*) to cut grasses. The grasses were raked into windrows, and then rice is transplanted in the plots between the rows. Because most of the soils in the Mekong Delta are lowland soil (*Thao dien*), wet tillage is prominent and transplanting is the main method for rice cultivation. High land (*Son dien*) gradually was planted with garden crops (fruit trees).

The main purposes of tillage at that time were to control (and to incorporate) weeds, to level the field and to create the mud layer for transplanting. With the absence of herbicides in the past, transplanting was the most effective way to control weeds in rice.

During a later period of the exploitation, when irrigation systems had been improved, new high yield varieties, herbicides, insecticides, fertilisers and tractors were introduced to the Mekong Delta. The cultivation method changed from transplanting to broadcasting, from one crop to two or three crops per year, tractors (1970: 15000, 1995: 39000) substituted buffaloes (1976: 250000, 2000: 65000). Traditional tillage was partly replaced by new systems, dry tillage, wet tillage and “mixed” tillage.

In *dry tillage systems* all soil preparation is done when the fields are not inundated. In most of the cases, big ($\geq 38kW$) tractors with tillage implements perform the work, using a disc plough for primary tillage, followed by seedbed preparation with a disc harrow or a rotary tiller. Then the fields are inundated to create a mud layer for rice establishment. *Wet tillage systems* are systems where main tillage operations and seedbed preparations are done on inundated fields. In those cases, small ($\leq 38kW$) tractors (equipped with rotary tillers or rollers and puddle wheels) or animals (pulling a local mouldboard plough, comb harrow, wooden roller) are used. In *mixed tillage systems* the main tillage operations (mostly by big tractors) are done when the fields are not inundated, but seedbed preparations are done after the fields are inundated.

When asked to compare the three tillage systems, farmers claimed that dry tillage would contribute to higher yields than wet tillage. They were, however, not unambiguous with an explanation. It is possible that it is caused by a more efficient way of using water (approx. 5000 l of water are needed to produce 1 kg rice (Tuong *et al.*, 1996; Bhuiyan,1992). Lal (1985) also concluded that poorly drained soils respond better to dry than wet tillage. The field surface level is also a very important factor for rice cultivation. On a level field with a smooth surface, water requirement is lower because of a uniform water distribution. In agronomic terms this improves crop establishment and enhances uniformity of crop growth (Bell *et al*., 1998). It also improves weed control and allows more efficient mechanisation. Traditionally, land leveling in the Mekong Delta of Vietnam has been done by manual labor on flooded fields, but nowadays this operation is mechanised. Research in the Mekong Delta of Cambodia carried out by Bell *et al*. (1998) showed that leveling the field significantly increases rice crop yield.

Because of the fine texture of the soil, there will be traffic problems when the soil is wet and high energy requirements for tillage when the soil is dry. Research of these topics has never been carried out for this area. A study by Cantho and Wageningen University compared the three tillage systems in terms of: quality of the seedbed (aggregate size, smoothness), the structure of the arable layer, bearing capacity of the hardpan, and energy expenditure and timeliness of the tillage operations. Some important findings on energy requirements and quality of the resulting seedbed are reported here.

METHODS

The field experiments were carried out at Songhau Farm, 30 km west of Cantho City. The soil on the farm is typical for the region: approx. 47% clay and 53% silt (USDA: Typic Tropaqueps). The retention curve is shown in Table 1, reflecting the typical texture, and showing the effect of puddling.

Table 1. Water retention curve (moisture content in % by weight)

pF	Puddled	Unpuddled
1.0	80.0	57.7
1.5	72.0	52.1
2.0	62.6	47.4
2.5	54.4	41.5
3.0	47.5	39.5
3.5	39.9	36.4
6.1	n.a.	3.4

Tillage on fields previously under rice was done with MTZ 50 tractors (50HP) powering standard tillage implements as disc ploughs, disc harrows and rotary tillers. The experiment was carried out in a completely randomized design. Fuel consumption was measured by flowmeter mounted on the tractor. The surface roughness was determined with a locally constructed needle-reliefmeter (see e.g. Kuipers, 1957 for a description). Roughness is expressed as 100 * log S, where S is the standard deviation of 200 points measured with the reliefmeter. Percentage of clods bigger than 80mm was determined by using sieves with 80 mm diameter openings, analysing the surface layer of the tilled field. Soil density and moisture content was measured by core sampling with stainless steel cylinders of 100 cm^3 and oven drying at 105°C. For the 'dry' tillage, the operations were carried out during a series of consecutive days in periods with dry weather. This yielded soil moisture contents ranging from very dry to contents around pF 1.0.

RESULTS

Primary tillage

Figure 1 shows the results for primary tillage in terms of fuel consumption and surface roughness.

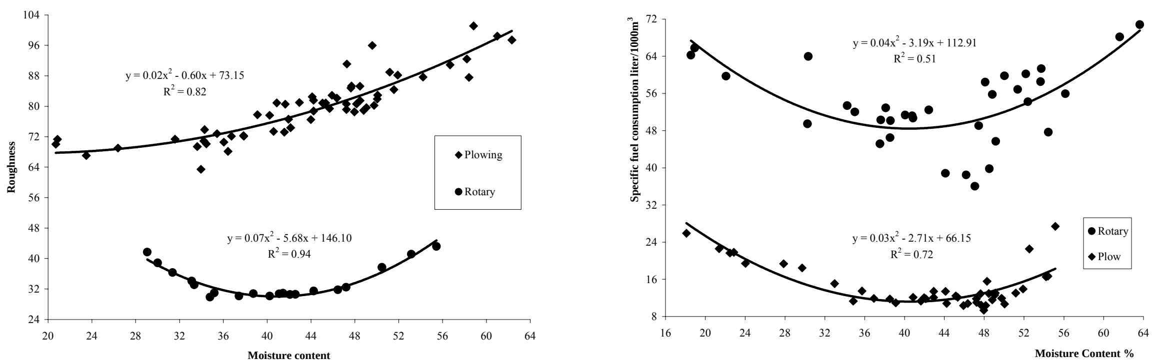

Figure 1. Primary tillage parameters for ploughing and rotary tillage: fuel consumption (left) and surface roughness (right) as a function of soil moisture content.

Ploughing was most suitable in the moisture range from 26%-42% because it showed the best crumbling effect, with a weight percentage of clods bigger than 80mm reaching a minimum. Fuel consumption for ploughing was much lower than for rotary tillage and also showed a minimum in the same range. At moisture contents both higher than 46%, or lower than 26%, ploughing resulted in high fuel consumption and very big soil clods. Therefore, with high weight percentage and very rough surface, ploughing could not create a suitable seedbed for rice. It requires additional tillage operation(s) to meet the seedbed requirements for rice seeding.

Soil conditions for rotary tillage, were optimal in the moisture range 33%-45% in view of the crumbling effect, the lowest fuel consumption, and the lowest surface roughness. Rotary tillage at moisture contents higher than 45% or lower than 33%, resulted in high values of all parameters. The blades of the rotary tiller were susceptible to wear and damage with very hard and dry soil.

Rotary tillage had a very high fuel consumption in comparison with ploughing but it produced a better seedbed for rice by one pass of operation only,

Secondary tillage

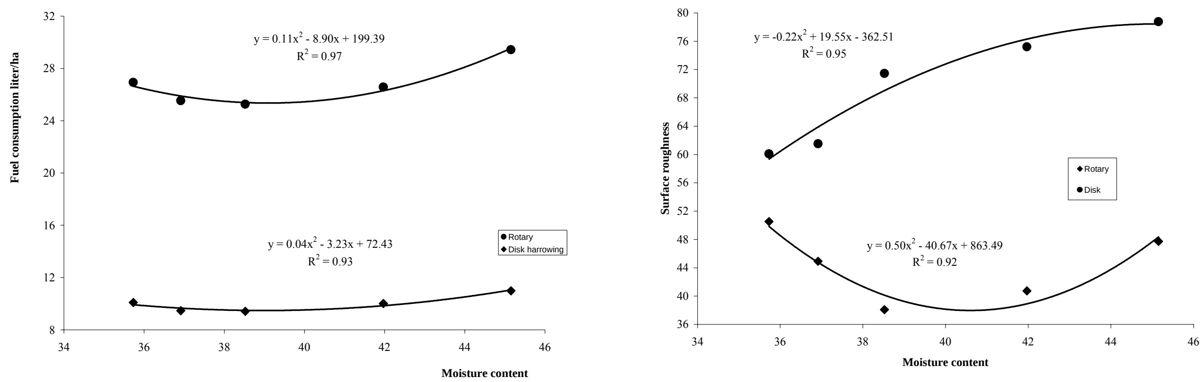

Figure 2. Secondary tillage parameters for ploughing and rotary tillage: fuel consumption (left) and surface roughness (right) as a function of soil moisture content.

Figure 2 presents the fuel consumption, and the resulting surface roughness for secondary tillage. The data show that disk harrowing had lower consumption than rotary tillage, but disc harrowing resulted in higher surface roughness and percentage of clods bigger than 80mm, so the seedbed created by disc harrowing had a lower quality than that made by rotary tillage.

Under the given conditions, disc harrowing apparently creates a seedbed which is not suitable for rice seeding. On the other hand, one pass of the rotary tiller after ploughing can create a suitable seedbed. It appears that when the tilled soil is soak with water, the pre-emerged rice seed can be broadcast without any tillage additional operation.

Rotary tillage after sun dried ploughed soil

The finding showed that after leaving the ploughed soil be sun-dried several days the fuel consumption reduced significantly (see Figure 3). It seems that rotary tillage the sun dried ploughed soil could be better after 6th sun dried day because it save fuel consumption while the others parameter like percentage of clods bigger than 80mm and surface roughness seem to meet the requirements.

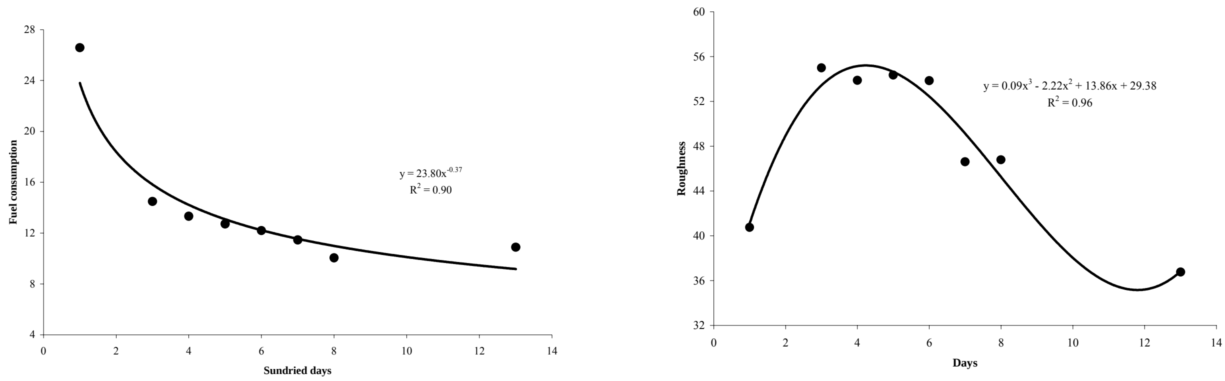

Figure 3. Effect of the length of sun-drying of ploughed soil on secondary tillage (disc harrowing and rotary tillage) parameters: fuel consumption (left) and surface roughness (right

Surface roughness and cloddiness

In view of the importance of a smooth and even seedbed, the seedbed surface was analysed by determining the surface shape with a needle relief metre and by measuring the mean weight diameter of very large aggregates and clods. A very close relationship was found between the percentage of clods larger than 80 mm, as shown in Figure 4.

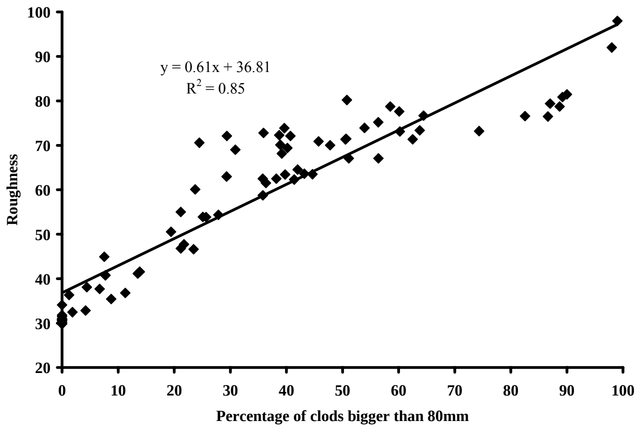

Figure 4. Relationship between roughness and clods > 80 mm.

The relationship found for all types of tillage showed an r^2 of 0.85 of the regression. When only the secondary tillage operations were analysed, the relationship was even stronger with r^2 of 0.95. Perhaps not surprisingly, but this indicates that a quick assessment of surface roughness can be achieved by collecting clods that (visually) are about fist-size. This can easily be done by untrained people.

CONCLUSIONS

It was found that (dry) ploughing with a disk plough had a low energy consumption (about 40% of the rotavator) but produced a very poor seedbed. Additional disk harrowing or rotary tillage was necessary. One pass with the rotary tiller produced a good seedbed. Where secondary tillage operations on dry soil are required, drying of the soil for at least 6 days is needed, both in view of achieving an acceptable quality of the seedbed, and having the lowest energy consumption.

For a quick assessment of the seedbed quality, collecting and counting and weighing the clods larger than 80 mm is a good alternative to measuring the surface with a reliefmeter.

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