# Choosing Soil Management Systems for Rice Production on Lowland Soils in South Brazil

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**Abstract:** Lowland soils are commonly found in the state of Rio Grande do Sul, Southern of Brazil, where they represent around 20% of the total area of the state. Deficient drainage is the most important natural characteristic of these soils which therefore are mainly in use for flood-irrigated rice (*Oriza sativa*). Degradation in these soils is progressively getting stronger since the intensity of agricultural activities leads to a higher soil density, and a lower water infiltration rate. There is a growing interest by farmers to grow other crops such as soybean in rotation with rice but this degradation has become an obstacle to do so. Soil analyses have showed differences in physical, chemical and biological properties as a result of management practices adopted by farmers. This paper shows how a soil management system was chosen by farmers in relation to irrigation and drainage constraints. Parameters were considered by farmers: soil type, (expected changes in) quality of soil structure, choice of machinery, farm size, management level, labor, inputs in terms of fertilizer and pesticides, opportunities for rotation with crops other than rice. The three management system currently in use (Conventional, Semi-direct and Pre-germinated), are taken as examples. The study showed that although farmers are well aware of potentially better management systems when considering soil quality, they were often (especially the small farmers) forced to reject the choice for the best system.

**Key words:** Lowland, rice, management systems, soil properties, Brazil.

## INTRODUCTION

The lowland soils in the state of Rio Grande do Sul are one example of a situation, where the problems linked to the nature of the soils are intensified by unsustainable agricultural activity. The impact of the management systems used in these lowland soils is high and is a matter of concern.

Twenty percent of the total area of Rio Grande do Sul state (approx. 5.4 million ha) is under lowland soil (Pinto et al., 2004). The natural deficient drainage caused by a dense and impervious B horizon makes these soils well suitable to irrigated rice production which is, the most important regional agricultural activity (52% of total Brazilian rice production), followed closely by soybeans (Azambuja et al., 2004). The rice production system involves puddling and keeping the area flooded for the duration of the growth of the rice crop. Degradation of the regional soils is mainly related to the high intensity of tillage applied in rice production (Pauletto et al., 2004).

Different management systems on lowland soils can affect differently the soil properties. Changes in soil characteristics can indicate the ability of soil to function effectively and may reflect the quality of the soil, such as limitations to root growth.

The study presented here is based on comparing farmers' knowledge with an analysis of soil properties collected from their fields in the Camaquã municipality, Rio Grande do Sul state, Brazil. An assessment was made of how the soil management system is chosen, based on natural soil characteristics.

## MATERIAL AND METHODS

### Location and soils

Camaquã is located in the Coastal Province of the Rio Grande do Sul state, south of Brazil, latitude between 30º48′ and 31º32′ S, longitude between 51º47′ and 52º19′W. Mean annual rainfall is 1213 mm and average temperature is 18.8ºC (Cunha et al., 2001).

Albaqualfs and Humaquepts (Soil Survey Staff, 2006) are the two soil great groups found in this region. The main differences between and within these soils is the inherent clay content found in the topsoil (Cunha et al., 2001).

**Rice production management systems**

Three rice management systems are currently used in the state. They are different with respect to intensity of soil tillage and water use: *conventional* (dry seedbed preparation and sowing, fields inundated after emergence, high tillage intensity), *pre-germinated* (seedbed preparation and sowing on inundated fields, high tillage intensity) and *semi-direct* (dry seedbed preparation and sowing, fields inundated after emergence, low tillage intensity). The majority of the small farmers (typically 2-30 ha) generally use the *pre-germinated* system. The other two management systems are generally used by the larger farmers (5-500 ha).

**Soil analysis**

Twenty-one rice fields from the two soil great groups and under the three different rice management systems were selected (9 pre-germinated, 9 semi-direct and 3 conventional). In each field, five replicate plots, 2x2 m each, were randomly laid out within an area of 3 ha. In total 105 representative plots were sampled. From within each sampling area, 20 samples were taken from 0-10 cm depth for analysis of chemical and physical characteristics. For analyses requiring undisturbed soil, three soil cores (5cm diameter x 3cm) were collected from each plot.

All sampling was done immediately after the harvest.

Bulk density (BD), water stable aggregates ($WSA_{>0.105mm}$), microporosity (MiP ≤ 0.05 mm), available water (AW), macroporosity (MaP) and mean weight diameter (MWD) were the physical properties analysed.

With respect to the soil chemical properties, only the ones most correlated with organic matter (OM): Total N (TN), Ca, Mg, Fe, Potential Acidity (PA) and Cation Exchange Capacity (CEC) were selected.

Detailed methods of analysis of the physical and chemical properties studied are given in Lima et al. (2009).

**Local knowledge**

Local soil knowledge, regarding to soil quality, was explored by a semi-structured interviews and discussion groups with 32 farmers. These interviews took place at the farmer's house or in his/her field.

**Statistical analysis**

We used Multivariate Analysis of Covariance (Mancova) for checking whether the management systems effects were still significant after removing the effects of clay content (main soils characteristic). The data were analysed using SPSS software (SPSS, 1998)

## RESULTS AND DISCUSSION

**Soil analysis**

Soils under the conventional management system were found to have the highest BD, and the lowest MiP (Table 1). Reduced MiP indicates a deterioration of soil structural quality which is difficult to reverse due to the long wet periods. Puddling is a rather extreme form of tillage with a strong impact on soil structure because it results in aggregate breakdown and reduction of pore size (Ringrose-Voase, 2000). The lowest soil BD value in the surface layer was observed in the soil under the semi-direct system. In our case the BD differences are not related to macroporosity, as only small and non-significant differences were found between systems (Table 1). Our results confirm the results of other studies done in the same region (e.g. Pedrotti et al., 2001).

**Table 1. Estimated soil physical properties marginal means and Standard deviations (from Lima et al. 2009).**

| Management Systems | BD (ton $m^{-3}$) | | MiP ($m^3$ $m^{-3}$) | | MaP ($m^3$ $m^{-3}$) | | AW (%) | | WSA (%) | | MWD (mm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Sd | Mean | Sd | Mean | Sd | Mean | Sd | Mean | Sd | Mean | Sd |
| **Semi direct** | 1.15a | 0.42 | 0.49a | 0.14 | 0.08a | 0.02 | 0.08a | 0.03 | 87.40a | 10.19 | 2.99a | 1.36 |
| **Pre-germinated** | 1.30b | 0.24 | 0.44b | 0.09 | 0.09a | 0.04 | 0.06b | 0.02 | 88.85a | 9.12 | 3.84a | 1.29 |
| **Conventional** | 1.34b | 0.14 | 0.42b | 0.06 | 0.09a | 0.02 | 0.06b | 0.02 | 84.70a | 6.07 | 2.74a | 0.71 |

Wilks's Lambda = 0.40, F (2, 101) = 9.24, p<0.001.
Same letters in columns indicate that the soil physical property does not differ between management systems, using Mancova with *post hoc* Bonferroni tests. Evaluated at covariates appeared in the model: % Clay = 44.41.
AW: Available Water, BD: Bulk Density, MaP: Macroporosity, MiP: Microporosity, MWD: Mean Weight Diameter, WSA: Water Stable Aggregates (fraction > 0.105 mm)

**Table 2. Estimated soil chemical properties marginal means and Standard deviations (from Lima et al. 2009).**

| Management Systems | OM (g $kg^{-1}$) | | TN (g $kg^{-1}$) | | Ca ($cmol_c$ $kg^{-1}$) | | Mg ($cmol_c$ $kg^{-1}$) | | Fe (mg $kg^{-1}$) | | PA ($cmol_c$ $kg^{-1}$) | | CEC ($cmol_c$ $kg^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Sd | Mean | Sd | Mean | Sd | Mean | Sd | Mean | Sd | Mean | Sd | Mean | Sd |
| **Semi direct** | 6.77a | 4.03 | 0.44a | 0.31 | 6.93a | 3.52 | 1.84a | 0.94 | 33.09a | 15.62 | 12.25a | 7.35 | 21.25a | 11.38 |
| **Pre-germinated** | 4.27b | 2.05 | 0.22b | 0.16 | 5.19b | 2.69 | 1.59a | 0.87 | 32.78a | 14.65 | 8.38b | 4.94 | 15.44b | 7.85 |
| **Conventional** | 4.02b | 0.97 | 0.19b | 0.07 | 3.93c | 1.34 | 1.85a | 0.77 | 21.93b | 4.25 | 11.80a | 5.98 | 17.92b | 7.76 |

Wilks's Lambda = 0.19, F (2, 101) = 17.41, p<0.001.
Same letters in columns indicate that the soil physical property does not differ between management systems, using Mancova with *post hoc* Bonferroni tests. Evaluated at covariates appeared in the model: % Clay = 44.41.
OM: Organic Matter, TN: Total N, CEC: Cation Exchange Capacity, PA: Potential Acidity.

Table 2 shows that all chemical properties had their highest value for the semi-direct system. OM contents in the soil were significantly higher under the semi-direct system, than in soils under the other two systems. Under the current puddling conditions, a decrease of bulk density can only be expected when the organic matter content can be increased (Pedrotti et al., 2005). However our study shows that, in some cases, this cannot be achieved in the rice production systems under investigation.

### Farmers' knowledge

Farmers unanimously considered soil colour, earthworms, OM and soil friability (BD) as significant indicators of soil quality. They could not decide on the order of importance of these four indicators because they assume that all are related. Farmers pointed out that soil quality could be changed through time because soil fertility can be manipulated. Small farmers realize that in potential rotating rice with soybean or fallowing could improve their soils' quality (increase in OM) and might raise additional income just as in the case of big farmers. In reality, however, these small farmers (and mainly those who use the pre-germinated rice management system) cannot risk their own sustenance by alternating soybean with rice because their low land is likely to flood during the growing season, which is fatal for soybeans. The risk of flooding in the small farms is also related to the water management systems of their rice-growing neighbours. Furthermore, the application of agrochemicals (such as herbicides) by the neighbours can damage their crops. Large farmers (who mainly use the conventional and in some cases semi-direct rice management systems), on the other hand, can plant soybean because they possess larger and higher-lying pieces of land, and have better infrastructure for drainage and, therefore, are less vulnerable to weather extremes and are hardly affected by their neighbours' land management.

This study shows, therefore, that socio-economic issues are key driving forces in day-to-day and long-term decisions about specific practices, such as rice-soybean rotation, the irrigation system, the use of fertilizer, the rice varieties and the machines to till the soil. This can be illustrated by the following farmer' statement:

"We already know our lands very well…we do not have surprises after all…we know that sometimes we are doing something wrong but it is not because we do not have knowledge, it is because we do not have economic resources to do the right thing" (quoted from Ederaldo Dumer).

**Soil quality issues**

An approach using statistical procedures that account for correlations was followed in order to more objectively assess soil quality by evaluating several soil properties simultaneously (Lima et al., 2008). Multivariate statistical, therefore, was used to select a minimum data set (MDS) from the large data sets from the same region. From the analyses a MDS resulted, consisting of eight significant soil quality indicators: AW, BD, MWD, OM, earthworm, Zn, Cu and Mn. Hence, from an analytical perspective the rice farmers in the region are right in choosing BD and OM as an indicator to characterize the quality of their soils, as these two are the ones that can also be determined visually in the field. On the other hand, the MDS showed that it may be advisable to include abovementioned micronutrients in a routine soils analysis to confirm soil quality assessments.

## CONCLUSIONS

The major effect of the management systems was on a soil physical property: bulk density. This result was found to be correlated to a significant reduction in the volume occupied by micropores, an indication of structural degradation;

The soils studied are suitable for irrigated rice production, and, although soil chemical and physical degradation was shown in the statistical analysis, farmers' experience revealed that so far it is not considered to be an obstacle;

Regional farmers have a holistic perceptions about the quality of their soils and they are conscious that the combination of natural soil characteristics. Yet, their economical constraints (e.g. in terms of farm size and soil type) lead them to a certain management system, which may not be the one they wish;

Our data, as they came from farmer's fields, gives a realistic view of the region and the struggles farmers have in making management decisions.

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