Limitation and Recommendation for Rice Cultivation on the Problem Soils in the Southern Region of Vietnam

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**ABSTRACT**

**Background:** Soil degradation is the factor causing crops yield decline in the Southern region of Vietnam. Since the recommendations for limitation of soil constraints will consult the proper problem soil management.

**Methods:** The soil limitation identified based on soil chemistry, physics and morphology properties, suggested by Sanchez et al. (1998 and 2003). Soil data of 28 field experiments were analysed.

**Results:** There were 25 rice soil fertility classes, among those, CC (clay in top and subsoil) and CCs (clay in top and subsoil, saline affected) types occupied in large areas. The major soil limitation for rice cultivation including soils low in % organic carbon (o); high in P fixation and high Fe toxicity potential (i); potential salinity (s); low available P (p); low pH and high Al (a); actual acid sulphate soils (c, c) potential acid sulphate soils (f, f). The leaching soil toxicity, application of N, P, K fertilizers and organic matter were recommended.

**Key words:** Limitation, Problem soil, Recommendation, Rice, Southern region of Vietnam.

**INTRODUCTION**

The soil taxonomy, provide a broad picture of soil status, but failed to relate with soil and crop productivity as it lays emphasis on sub-soil properties because of their permanent nature (Sanchez et al., 1982). However, its utilization can be enhanced if the taxonomic units are grouped into management units which can easily indicate the potential and constraints of an area in terms of its fertility (Jaggedh Prasad 2000) and under such situations FCC guide the planners. It is now widely used and included in the worldwide FAO soils database (FAO, 1995). Most of the class limits were borrowed from Soil taxonomy (Soil Survey Staff, 1994) or the FAO/UNESCO soil classification system (FAO, 1974). Emphasis is placed on features that are easily detectable in the field, such as texture, colour, depth of horizons, presence or absence of mottles, etc. Soil analytical laboratory data are only used to support the classification if available. The strength of this system is its ease of use, which allows the soil to be classified at several locations simply and quickly. To facilitate the easy transfer of information about soil properties and constraints, the system consists of a series of individual letters to describe the soil. These properties signify fertility limitations with different interpretations and represented by small letters.

In the Southern region of Vietnam (Mekong delta), rice is frequently cultivation under irrigation (multiple crops) is usually irrigated with highly productivity leading to unsustainable exploitation of water and soils, inefficient use of chemical inputs and menace of disease and insect, pest problems but productivity is not sustainable owing to deteriorating resource base. Though present study an integrated system for soil fertility evaluation were carried out for soil fertility classification and recommendation for proper use of rice soil in the Mekong delta, which can assist the land use planner or agricultural extension officers to identify the constraints and recommend site-specific agro-managements.

**MATERIALS AND METHODS**

The Fertility Capability Classification (FCC) system from Sanchez et al. (2003), with some modifications from Minh (2007) was used as a reference system. Three hundred top and sub soil samples were collected from rice supporting soils of Mekong delta (Fig 1) 1996 to 2007, processed and analysed for sand, silt and clay, pH, ECe, Al3+, Fe3+, K+, Na+, Ca2+, Mg2+, CEC, organic matter, P available (Table 1) and soil profile were described as per the FAO guideline (1974).

Fourteen (14) modifiers of soil fertility status affecting the rice growth in the Mekong delta were determined as recommended by Minh (2007): a, a' (Al toxicity, low pH), c, c' (actual acid sulfate soils), e (high leaching potential), k (low nutrient capital reserves), f, f (potential acid sulfate soil), g' (constant saturation), i (high phosphorus fixation), n (potential Sodic), s, s' (saline), o (low organic matter status) and p (low inherent P content), which affected to rice root zone. In which, modifiers p, o, c, c', f, f' were added by Minh.
RESULTS AND DISCUSSION

Soil fertility classification for rice cultivation

The Fertility Capability Classification, developed by Sanchez et al. (1982, 2003) and modified by Minh (2007) was applied to describe the fertility of rice-growing soils in the Mekong delta, based on soil morphology, soil physics and soil chemistry. There were 25 soil fertility types, which were converted from soil map at 1/250,000 scale, to be identified by its corresponding letter and the corresponding limits (Fig 2). The interpretation of soil fertility capability name is shown in Table 2.

The soil limitations for crops cultivation

The attribute used in the system is the lower-case letters of the constraints that have been identified for that soil and indicated in the soil fertility type. Based on the field observations, soil analysis of chemical, physical, rice field behaviours and from several field experiments results, the major soil constraints for rice cultivation in the Mekong delta were identified and grouped as below:

Limitation related to soil mineralogy

(High leaching potential)

Soils with a low cation exchange capacity (CEC) have top soils with low organic matter content, low clay content, clay minerals with low CEC, or all these properties are mainly associated with sandy or Arenosol soils group. These soils have low inherent fertility and also a low capacity to retain added nutrients. The potential H₂S toxicity can occur if (NH₄)₂SO₄ is used as N source. These coarse-textured soils, poor inorganic carbon, often Mn deficient, application of large organic material keeps pH low even after flooding. Low nutrient capital reserves (k) are to be associated with these soils.

(i) (High phosphorus fixation)

This constraint is caused primarily by a high content of free ferric oxides (Fe₃O₄) in the clay fraction, which fixes phosphate ions in unavailable forms. It is a feature also found in strongly acid soils and hence commonly associated with the a, or a constraint, aluminium toxicity. High P fixed by Fe; P deficiency likely; Fe toxicity potential; soils difficult to puddle and will regenerate original structure rapidly. This is mainly on Plinthosol soil group or acid sulfate soil soils with OrthiThionic properties.

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Table 1: Physical and chemical methods of soil analysis.

| Parameter                          | Unit     | Methods                                      |
|-----------------------------------|----------|----------------------------------------------|
| Texture (Sand, Silt, Clay)        | %        | Hydrometer                                   |
| pH                                |          | pH meter                                     |
| Saturated Electric Conductivity (ECE) | ms/cm  | EC meter                                     |
| Exchangeable aluminum (Al⁷⁺)      | meq/100g | Titrimetric method (standard method), according to the routine methodology adapted from McLEAN, (1965) |
| Free ferric oxides (Fe⁴⁺)         | %        | Atomic Absorption                            |
| Exchangeable base cations (K⁺, Na⁺, Ca²⁺, Mg²⁺) | meq/100g | Percolation with 1N NH₄OAc pH 7 followed by Atomic Absorption Spectrophometry |
| Cation Exchange Capacity (CEC)    | meq/100g | Percolation with 1N NH₄OAc pH 7              |
| Organic Matter                    | %        | Walkely Black (1934)                         |
| P available (P₂O₅)               | mg/100g  | Olsen (1982)                                 |

Note: (According to Soil Analysis laboratory, Department of Soil Science, Cantho University, Vietnam).
**k (Low Nutrient Capital Reserves)**

Low inherent fertility because of low inherent reserves of weatherable minerals; potential K deficiency depending on base contents of irrigation water. This is mainly on Arenosol soil group.

**o (Low organic matter status)**

N deficient and hence response to N fertilization low ECEC on sandy soils; N fertilizer should be applied in splits. This is mainly on Arenosol soil group.

**p (Low inherent P content)**

Plant available P deficient and hence responds to small additions of P fertilization. This is mainly on Arenosol soil group and soils have OrthiThionic properties.

**Limitation related to soil reaction**

**a, a’ (Al toxicity, low pH)**

The exchange complex of these soils is dominated by alumina. The problem is commonly described as one of the strongly acid soils, can be caused by strong leaching from high rainfall and mainly from the oxidation of sulfidic material, which often associated with c, c modifiers. Aluminium toxicity will occur in aerobic layers, mainly on soils having OrthiThionic properties.

**c, c’ (Actual acid sulfate soils)**

Al and Fe toxicity, low pH and P deficiency, which originated from the oxidation of sulfidic material.

**f, f’ (Potential acid sulfate soil)**

Potential acid-sulfate soils resulting in Fe and S toxicity when anaerobic and Al toxicity; depth at which f modifier occurs determines the feasibility of rice production; Zn deficiency can occur; prevent seepage from the areas.

**g’ (Constant saturation)**

Prolonged submergence causes Zn deficiency. N loss increased if the soil is intermittently flooded and drained for a long time.

**s, s’ (Saline)**

Defines saline soils; drainage needed, consider conductivity of irrigation water.

**n’ (Potential Sodic)**

The soil has high content of sodium but low in calcium and magnesium salts causing soil dispersion, puddling, poor infiltration and poor aeration and if sodium is high in the plough layer, increased probability of surface crust formation. Defines sodic soils; reclaiming with drainage and gypsum applications needed; Zn deficiency can occur

**Recommendation for better soil utilization**

The management requirements are given as per interpreted soil property or group of properties. A complete listing of all possible combinations is not given because limited number of combinations of soil properties will be found in any area under consideration. At large scale, however, interpretation of the soil properties concerning farming systems, local expertise or rice varieties could be a valuable extension tool. The management requirements are based on Smith (1989), Sanchez et al. (1982, 2003), Minh (2007), field observations and several experiments in the Mekong delta on soil management, reclamation, fertility adaptation, rice varieties, etc. A description of soil fertility or management constraint identified is given below:

**a, a’ (Al toxicity, low pH)**

Soluble and exchangeable acidity should be removed as much as possible by leaching before applying amendments. Leaching with freshwater is efficient in removing free $H_2SO_4$ and efflorescences of soluble Fe and Al salts from the soil. Due to low pH and high Al contents (Guong, 1997), the amount of lime should be changing from 6 to 10 ton/ha (Xuan et al., 1982).

**c, c’ (Actual acid sulfate soils)**

Iron and aluminium or manganese toxicities and phosphorus deficiency are common. The physical soil properties are very poor. Jarosite mottles occur at 2 to 50 cm depth (c) or more than 50 cm (c). This soil should not be drained. Draining results in a drastic decrease in pH. High liming rates (greater than 10t/ha every 3 to 4 years) or long term leaching would then be required for crop production (Bremman and Pons, 1978). The most profitable practice is shallow drainage to grow one crop of medium-term rice (Xuan et al., 1982).

**e (High leaching potential)**

These soils suffer from a combination of low organic matter content and a coarse texture with relatively low cation exchange capacity. Soil management interventions for these constraints are bound to be expensive and often unprofitable as they imply a change in the clay-humus complex through considerable organic matter and/or high activity clay inputs.

**f, f’ (Potential acid sulfate soil)**

When these soils are exposed to air and are low in calcium carbonate, FeS$_2$ is oxidized to ferric sulfate and free sulfuric acid, resulting in pH of 2 or 3. Drained acid sulfate soils are infertile. Flooded rice is often grown since under reduced conditions and hence remain the pH sufficiently high to eliminate aluminium toxicity.

**i (High phosphorus fixation)**

High P-fixing soils can be identified as those with clayey top-soils having red or yellowish colours indicative of high contents of iron oxides, usually accompanied by a strong granular structure. These soils require high levels of phosphate fertilizers or special P management practices.

**k (Low Nutrient Capital Reserves)**

Potassium fertilizers must be added. Generally, these soils have poor capacity to retain added nutrients and added potassium, calcium and magnesium can be easily lost (Guong, 1997; Hoa, 2003).
Table 2: Interpretation of FCC soil fertility capability name.

| FCC   | Soil fertility capability interpretation                                                                 |
|-------|---------------------------------------------------------------------------------------------------------|
| CC    | texture is clay (C) within 50 cm from the soil surface                                                  |
| CCs   | texture is clay (C) within 50 cm from the soil surface, severe salinity in subsoil (s)                 |
| LC    | texture is loamy (L) between 0 and 20 cm and a clay (C) between 20 and 50 cm                           |
| CCc   | texture is clay (C) within 50 cm from the soil surface, Moderately actual acid sulfate soils (c)      |
| CCI   | texture is clay (C) within 50 cm from the soil surface, iron toxicity if prolonged, soil submerged (i) |
| CCAi  | texture is clay (C) within 50 cm from the soil surface, the soil is very acid (a), iron toxicity. If prolonged soil submerged (i) |
| CCv   | texture is clay (C) within 50 cm from the soil surface, cracking clays (v)                            |
| LLacp | texture is loamy (L) within 50 cm from the soil surface, the soil is very acid (a), strongly actual acid sulfate soil (c), low inherent P content (p) |
| LL    | texture is loamy (L) within 50 cm from the soil surface, the soil is very acid (a), high phosphorus fixation (i) |
| LLai  | texture is loamy (L) within 50 cm from the soil surface, the soil is very acid (a), high phosphorus fixation (i) |
| CCacps | texture is clay (C) within 50 cm from the soil surface, the soil is very acid (a), strongly actual acid sulfate soil, low inherent P content (p), slightly salinity in subsoil (s) |
| CCf   | texture is clay (C) within 50 cm from the soil surface, moderately potential acid sulfate soils (f)    |
| LLs   | texture is loamy (L) within 50 cm from the soil surface, potential salinity (s)                        |
| LLC   | texture is loamy (L) within 50 cm from the soil surface, Moderately actual acid sulfate soils (c)     |
| CCc's | texture is clay (C) within 50 cm from the soil surface, Moderately actual acid sulfate soils (c'), potential salinity (s') |
| LLt   | texture is loamy (L) within 50 cm from the soil surface, shallow potential acid sulfate soils (f), slightly salinity in subsoil (s') |
| LLc   | texture is loamy (L) within 50 cm from the soil surface, slightly salinity in subsoil (s)             |
| Lli   | texture is loamy (L) within 50 cm from the soil surface, high phosphorus fixation (i)                 |
| CCapc | texture is clay (C) within 50 cm from the soil surface, the soil is very acid (a), strongly actual acid sulfate soil (c), low inherent P content (p) |
| LIf   | texture is loamy (L) within 50 cm from the soil surface, moderately potential acid sulfate soils (f), slightly salinity in subsoil (s) |
| LIt   | texture is loamy (L) within 50 cm from the soil surface, iron toxicity if prolonged soil submerged (i) |
| CCf's | texture is clay (C) within 50 cm from the soil surface, moderately potential acid sulfate soils (f'), slightly salinity in subsoil (s') |
| LLf   | texture is loamy (L) within 50 cm from the soil surface, shallow potential acid sulfate soils (f')    |
| LLacps| texture is loamy (L) within 50 cm from the soil surface, the soil is very acid (a), strongly actual acid sulfate soil (c), low inherent P content (p), slightly salinity in subsoil (s) |
**g** (Prolong submergence)

Prolonged submergence causes Zn deficiency, especially round the year under cultivation (flooding and draining). H₂S toxicity symptom can occur if soil high in organic matter (Ponnamparuma, 1977).

**n** (Potential Sodic)

It requires the replacement of Na⁺ on the exchange complex by Ca²⁺ and leaching of Na⁺ out of the root zone. Soil permeability and internal drainage must also be improved so the displaced sodium ions can be leached out of the root zone. Commonly used mineral amendments are phosphogypsum, calcite and other acid-forming salts like iron and aluminium sulfates, lime sulphur and pyrites.

**o** (Low organic matter status)

N deficient and hence response to N fertilization; low ECEC on sandy soils; N fertilizer should be applied in split. Increasing the levels of organic matter in these soils would improve nutrient supply, increase CEC, increase water holding capacity (Moody et al., 2008).

**p** (Low inherent P content)

P management should be more effective to prevent P deficiency than to treat P deficiency symptoms and if requires a long-term management strategy because P is not easily lost or added to the root zone by biological and chemical processes that affect N supply.

**s, s** (Saline)

Na, Ca, Mg, Cl and SO₄ are the major ions involved. Presence of soluble salts requires drainage and special management for salt-sensitive rice varieties. Total reclamation of saline soils is often impractical because of the lack of high-quality water for irrigation and leaching. Wetland rice production may be an economical alternative.

**CONCLUSION**

There were 25 rice soil fertility types, in which clay soil texture in both layers and without modifiers (CC) and the same as soil with saline (s) modifier (CCs) occupied largest areas. The Fertility Capability Classification (FCC) system used for rice soils in the Southern Delta of Vietnam, was mostly on the topsoil properties, that indicated the major limitation and recommendation for rice crop cultivation on the problem soils. Some properties at sub-soil also showed relating to topsoil properties. The major soil limitation for rice cultivation in the Southern delta of Vietnam were high P fixation (i) and potential Fe toxicity (i⁺), potential salinity (s), low available P (p), acid and Al toxicity (a), respectively. However, the limitation of actual acid sulphate (c, c⁻), potential acid sulphate (f, f⁻) and low organic carbon status (o), were also major constraints for intensive rice cultivation in the Mekong delta. The main recommendation for better utilization of soils were reclamation of acid sulphate and saline soils by leaching, acid and soil toxicity and improving the status of soil nutrient by organic matter and P, K application.

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