Research article

The Rice Soil Fertility Capability Classification System

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Abstract The Rice Soil Fertility Capability Classification (RSFCC) is based on FCC (Fertility Capability Classification) system, with some modifications. The system deals with soil morphology, physics, and chemistry characteristics. Most of the class limits of modifiers are borrowed from soil taxonomy, others could be from field observation, which consists of 4 categories and based on three soil layers. The upper layer coincides with the top 20cm or Type (**C** for clay and **L** for Loamy). The soil below the upper layer from 20 to 50cm is referred to the Substrata Type (**C** for Clay and **L** for Loamy), and from 50 to 100cm is referred to Subsoil Type (**C** for Clay, **L** for Loamy, and **S** for Sandy). The condition modifiers, directly relevant to plant growth, include a, a^- c, c^-, e, f, f, g^+, i, n^-, s, s^-, o, p. Some modifications and additions for classification are suggested, in which new modifiers of p (low P available), o (low organic carbon), c, c^- (actual acid sulfate), f, f (potential acid sulfate) are added, the former c condition modifier (sulfidic) divided into c (actual acid sulfate) and f (potential acid sulfate). Modifiers of a, i, n, s, are suggested with modifications from FCC system. The classes within each category and assigned modifiers for each soil type/substrata type/subsoil type are different, which is followed by modifiers presented.

Keywords FCC, fertility capability classification, modifier, rice

INTRODUCTION

Soil is a component of the natural medium that acquires its morphology and properties after a long and slow evolution after reaching equilibrium with environmental conditions. The data from field tests or from yield production provided by individual farmers records or else are usually local, spotty, and sometimes not reliable and are generally difficult to extrapolate. Therefore, the evaluation is normally conducted indirectly on the basis of the soil properties. The evaluations made should be validated finally with real constraints and yield data. According to Sanchez et al (2003), the problem with soil taxonomy is that it quantifies only permanent soil parameters, most of which are located in the subsoil. Soil taxonomy ignores many dynamic parameters crucial to crop productivity, which are mostly in the topsoil where the majority of plant roots are located, both in natural and agricultural systems. To overcome this limitation, a fertility capability soil classification system (FCC) was developed to interpret soil taxonomy and soil tests in a quantitative manner that is relevant to growing plants (Buol et al., 1975). It is now widely used and is included in the FAO soils database (FAO, 1995).

Based on the developed FCC system by Sanchez et al (2003), the research suggests the framework for developing the system for rice soil fertility classification and recommendation, where soil environment is effected such as soil acidity, agrochemical uses of fertilizer, pesticide, etc, and soil nutrient degradation. The recommended system is useful for farmers or agricultural extension workers to classify their soil, due to its simplicity and easy to apply by using simple lab analytical methods or field identification, with some recommendations for proper soil fertility improvement.

THE CONSTRAINS FOR RICE CULTIVATION RELATED TO SOIL MODIFIERS OR INDICATORS IDENTIFIED

The system was developed based on the soil constraints for rice cultivation, related to suggested system condition modifiers. The attributes used in the system are the lower-case letters of the constraints that have been identified for that soil, which recommended in the system description.

Constraints related to soil mineralogy

High leaching potential (e): Soils with a low cation exchange capacity (CEC) have topsoils with low organic matter content, low clay content, clay minerals with low CEC, or all these properties. These soils have a low inherent fertility and also a low capacity to retain nutrients added as fertilizers.
High phosphorus fixation (i): This is caused primarily by a high content of free ferric oxides (Fe_2O_3) in the clay fraction, which fix phosphate ions. It is a feature also found in strongly acid soils, and hence commonly associated with aluminum toxicity. High P fixation by Fe; P deficiency; Fe toxicity potential; these soils are difficult to puddle and will regenerate to their original structure rapidly.
Low Nutrient Capital Reserves (k): Low inherent fertility because of low inherent reserves of weatherable minerals; potential K deficiency depending on base contents of irrigation water.
Low organic matter status (o): N deficient; response to N fertilization very likely; low ECEC on sandy soils; N fertilizer should be applied in frequent, small doses.
Low inherent P content (p): Plant available P deficient; response to small additions of P fertilization.

Constraints related to soil reaction

Al toxicity, low pH (a, a$^-$): Aluminum toxicity will occur in aerobic layers; these are soils in which the exchange complex is dominated by alumina. The problem is strongly acid soils, which can be caused by strong leaching from high rainfall, and mainly from oxidation of sulfidic material.
Actual acid sulfate soils (c, c$^-$): Al and Fe toxicity, low pH, and P deficiency, which originated from oxidation of sulfidic material.
Potential acid sulfate soil (f, f$^-$): Potential acid-sulfate soils, causing Fe and S toxicity when anaerobic and Al toxicity when aerobic; depth at which sulfidic material occurs determines feasibility of rice production; Zn deficiency common; prevent seepage from these areas.
Constant saturation (g$^+$): Prolonged submergence causes Zn deficiency. N loss increased if soil is intermittently flooded and drained.
Saline (s, s$^-$): Defines saline soils; drainage needed but EC of irrigation water must be considered. .
Potential Sodic (n$^-$): This soil has a slightly high content of sodium but is low in calcium and magnesium salts causing soil dispersion, puddling, poor infiltration and poor aeration, and if sodium is high in the plow layer, probability of surface crust formation will be increased

METHOD FOR RICE SOIL FERTILITY CLASSIFICATION

Based on the soil constraints for rice cultivation, a method for rice soil fertility classification related to constraints recommended, on the basis of FCC system from Sanchez et al (2003) with some modifications, which are easy to apply and classify by using the simple methods for identification in the field or laboratory.

The term "FCC" is used to indicate adaptation of the Fertility Capability Classification, as developed by Sanchez and Buol (1985), and modified by Sanchez et al (2003), to the soil and rice growing conditions, which deal with soil morphology, soil physic, and soil chemistry characteristics. Most of class limits are borrowed from Soil taxonomy (Soil Survey Staff, 1994) or the FAO/Unesco soil classification system (FAO, 1974). The system consists of two categorical levels. The first category; type/substrata/subsoil type - describes topsoil, substrata and subsoil texture at three soil depths and is expressed in capital letters. The second category; condition modifiers defined to delimit specific soil conditions affecting rice growth with quantitative limits. Each condition modifier is expressed as a lower case letter. The type/substrata type/subsoil type and condition modifiers are the soil attributes in terms of their capability for rice plant growth. Emphasis is placed on features that are easily detectable in the field, such as texture, color, depth of horizons, presence or absence of mottles, etc. Soil analytical laboratory data are only used to support the classification if available. This approach was chosen to enable people with little practical experience in pedology to easily identify soils in the field and classify them into one of the broad groups or phases.

Based on the FCC structure from Sanchez et al (2003), modifiers from system were used for rice soil. Based on the FCC structure from Sanchez et al (2003), modifiers from system were used for rice soil. We found the new structure system that can be used for classifying rice soils. Fourteen soil modifiers that affect rice growth were determined: **a**, **a**$^-$, **c**, **c**$^-$, **e**, **f**, **f**$^-$, **g**$^+$, **i**, **n**$^-$, **s**, **s**$^-$, **o**, and **p**. Among these parameters, **a**, **a**$^-$,**e** , **g**$^+$**, i** , **k**, **n**$^-$, **o**, **p**, **s**$^-$ for topsoil type, (which directly affects rice root), and **a**, **a**$^-$, **c**, **f**, **g**$^+$**, k**, **i**, **s**, **s**$^-$, **n**$^-$, for substrata type, which directly affects rice root, and **c**$^-$**,f** $^-$, **s**, **s**$^-$ for subsoil type. There were 6 modifiers added to the system from Sanchez et al (2003), such as: **p**, **o**, **c**, **c**$^-$, **f**, **f**$^-$, in which superscripts **+** or **-** indicate a greater or lesser expression of the modifiers.

The structure of the soil names in the system were changed as follows: Soil texture of topsoil layer 0 to 20cm (**C**, **L**) plus modifiers of topsoil layer (**a**, **a**$^-$, **e**, **i**, **k**, **g**$^+$, **n**$^-$, **o**, **p**, **s**$^-$) plus soil texture of substrata topsoil; 20 to 50cm (**C**, **L**) plus modifiers of substrata topsoil (**a**, **a**$^-$,**c** ,**f** ,**g**$^+$ **,k** ,**i**, **s** ,**s**$^-$,**n**$^-$), plus texture of subsoil 50 to 100cm (**C**, **L**, **S**), plus modifiers of subsoil layer (**c**$^-$**, f**$^-$, **s**, **s**$^-$). The pertinent parts of the classification, which have relevance to rice growing, are described below.

System description

Type (Textute) at less than 20cm

L : Loamy : <35% clay but not loamy sand or sand.
C : Clayed : > 35% clay;
Modifiers:
a : Soil $pH_{H2O(1:1)}$ < 5.0 (or > 60% Al saturation),
a$^-$: Soil $pH_{H2O(1:1)}$ from 5.0 to 6.0 (or 10-60% Al saturation).
e : < 4 cmolc kg^{-1} soil as ECEC, or < 7 cmolc kg^{-1} soil by sum of cations at pH 7, or < 10 cmolc kg^{-1} soil by sum of cations $+Al^{3+} +H^+$ at $pH_{8.2}$
k : Exchangeable K < 0.2 meq/100g soil, or coarse texture (sandy) .
g$^+$: Prolong submergence more than 200 days/year, soil without clearly mottles represented for Fe^{3+} from less than 20cm.
n$^-$: Soil ESP from 6 to 15%.
o : < 0.75% Organic Carbon, and applied for top soil only.
p : (Applied for surface soil only). Available P < 2mg/100g (Olsen), or < 1mg/100g (Bray II).
s$^-$: ECe 2 - 4 mmhos/cm at 25^{o}C.
(Above types and modifers should be applied in this layer only)

Substra type (Textute) at 20 to 50cm

L : Loamy, <35% clay but not loamy sand or sand;
C : Clayed, > 35% clay
Modifiers:
a$^-$: Soil $pH_{H2O(1:1)}$ from 5.0 to 6.0 (or 10-60% Al saturation).
a : Soil $pH_{H2O(1:1)}$ < 5.0 (or > 60% Al saturation)
c : Soil $pH_{H2O(1:1)}$ < 3.5; Jarosite mottle with hue = 2.5Y or yellower, chroma 6.

f : Sulfidic material; pH < 3.5 after drying, without jarosite mottle with hue = 2.5Y at < 50 cm.
i : > 4% free Fe; or mottle with hue redder 5YR which > 35% clay.
k : Exchangeable K < 0.2 meq/100g soil, or coarse texture (sandy)
g⁺ : Prolong submergence more than 200 days/year, soil without clearly mottles represented for Fe^{3+} from 20cm to 50cm.

n⁻ : Soil ESP from 6 to 15%.

s⁻ : ECe 2 - 4 mmhos/cm at 25^{O}C.

s : ECe > 4 mmhos/cm at 25^{O}C.
(Above Substrata types and modifers should be applied in this layer only)

Subsoil type (Textute) at 50 to 100cm

S : Sandy, loamy sands and sands
L : Loamy, <35% clay but not loamy sand or sand;
C : Clayed, > 35% clay
Modifiers:

c⁻ : Soil $pH_{H2O(1:1)}$ < 3.5; Jarosite mottle with hue = 2.5Y or yellower, chroma 6.

f⁻ : Sulfidic material; pH < 3.5 after drying, without jarosite mottle with hue = 2.5Y at > 50cm soil surface.

s⁻ : ECe 2 - 4 mmhos/cm at 25^{O}C.

s : ECe > 4 mmhos/cm at 25^{O}C.
(Above Subsoil types and modifers should be applied in this layer only)

Interpretation of system nomenclature

The whole idea of this system is that the soil 'name' as given by its system is meaningful for soil fertility management.

CAPITAL character*:* indicated for TYPE, SUBSTRATA TYPE, SUBSOIL TYPE according to soil depth.

Normal character: indicated for **Modifiers** and follows after above character
Example*:* Soil profile which has silt texture (**L**) at < 20cm, silt (**L**) and clay (**C**) at 20-50cm, and 50-100cm, and modifiers **a**, **p** at surface and **a**, **c**, **i** at subsurface and **f⁻**, **s⁻** at subsoil, which can be named as ***LapLaciCf⁻s⁻***.

Strategies for better utilization of soil and soil fertility conservation

The management requirements are given per interpreted soil property or group of properties. A complete listing of all possible combinations is not given because only a limited number of combinations of soil properties will be found in any area under consideration. On a large scale, however, interpretation of the soil properties in relation to farming systems, local expertise or rice varieties could be a valuable extension tool. The management requirements are based on Sanchez et al (2003), Smith (1989) and several experiments in the Mekong delta, Vietnam, on soil reclamation, etc. A description of each soil fertility or management constraint identified is given below.
Al toxicity, low pH (a, a⁻): Soluble and exchangeable acidity should be removed as much as possible by leaching before applying amendments.
Actual acid sulfate soils (c, c⁻): The free sulfuric acid dissolves clay minerals and produces large amounts of exchangeable aluminum. Iron and manganese toxicities and phosphorus deficiency are common. Physical properties are very poor. Jarosite occurs at 10 to 50 cm depth (**c**). Draining results in a dramatic 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 (Breeman and Pons, 1978). The

most profitable practice is shallow drainage to grow one crop of a medium-term rice (Vo-Tong Xuan, 1997).

High leaching potential (e): The use of mineral fertilizers is not recommended in these soils in their natural state, as nutrients are not retained by these soils due to the low capacity to retain nutrients. In addition, leaching causes big nutrient losses when lime and fertilizers are applied; therefore, heavy applications of these nutrients and of N fertilizers should be split. Organic matter application is also recommended to increase soil cation exchange capacity. The practicality of adding high activity clays to increase permanent charge could be assessed (Noble et al., 2004).

Potential acid sulfate soil (f, f⁻): When **f** soils are exposed to air and are low in calcium carbonate, FeS_2 is oxidized to ferric sulfate and free sulfuric acid, producing pH values on the order of 2 or 3. Drained acid sulfate soils are extremely infertile. Flooded rice is often grown, since under constantly reduced conditions, the pH is sufficiently high to eliminate aluminum toxicity.

High phosphorus fixation (i): These soils require high levels of P fertilizers or special P management Sources and a method of P fertilizer application should be considered. P fertilizer application should be split into several times as recommended by Đỗ Thị Thanh Ren and Nguyễn Mỹ Hoa (1998).

Low Nutrient Capital Reserves (k): Potassium fertilizers must be added. Generally, these soils have also limited capacity to retain nutrients and the potassium, calcium and magnesium added can be easily lost (Nguyễn Mỹ Hoa, 2003). The other source of nutrient capital reserves is soil organic matter, which contains all the nitrogen and much of the phosphorus and sulfur capital of soils. Potassium fertilizers or organic amendments with a significant content of K will need to be applied. Crops should be closely monitored for K deficiency symptoms (P. M. Moody et al, 2008).

Prolong submergence (g^+): Prolonged submergence causes Zn deficiency, especially on all year round cultivation soil remittently flooded and drained. H_2S toxicity symptom can occur if soil high in organic matter (Ponnamperuma, 1977)

Potential Sodic (n^-): Reclamation requires the replacement of Na^+ on the exchange complex by Ca^{2+} 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.

Low organic matter status (o): Increasing the levels of organic matter in these soils would improve nutrient supply, increase CEC and water holding capacity. The management of soil organic matter involves mulching and incorporation of ‘green manure’ crops, retaining all crop residues in the field where the crop has grown, not burning crop residues, minimum or zero tillage farming systems, strip or alley cropping and application of organic materials such as animal manure, composted municipal waste, sewage sludge and locally available organic wastes obtained from off-site (P. W. Moody et al, 2008).

Low inherent P content (p): P management should be considered as a long-term investment in soil fertility, and it is more effective to prevent P deficiency than to treat P deficiency symptoms, because P is not easily lost or added to the root zone by biological and chemical processes that affect N supply. The residual effect of P fertilizer application can persist for several years, and management must emphasize the buildup and maintenance of adequate soil-available P levels to ensure that P supply does not limit crop growth and N use efficiency. Use rice cultivars that use P efficiently.

Saline (s, s⁻): 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. Continuous flooding helps to leach salts out of the root zone. Where enough irrigation water of good quality is available, salts can be leached unless there are high percentages of sodium in the soil which will result in structure collapse and pan formation (Sombroek and nachtergaele, 1994).

Limitations of the method

Land use recommendations and soil improvement/reclamations were based on field survey, farmer interview and several field, lab experiments from several authors recommended, which needs to be tested and recommended for specific location. Modifiers on soil biology as recommended by

Sanchez et al (2003) is need to be added. Besides rice cultivation, other crops such as vegetable, upland, aquaculture, etc, were integrated to rice cultivation, since the system did not classify or recommend for all systems. There are some gaps in defining and identifying the indicators or modifiers. The developed system is used for classification of rice soil fertility at specific locations only.

CONCLUSIONS AND RECOMMENDATIONS

The soil fertility classification relies mostly on the topsoil and subsoils properties that indicate the soil fertility capability and affect rice production. The classification allows no specialists to classify the soil on which they are standing, in the field, even without the aid of a laboratory. The key to the success of the system will be its usefulness to agriculturalists or soil scientists working in the field.

The results are the first attempt to compare soil constraints using standardized data and methods. In order to develop sustainable systems, there must be reliable information on the constraints and potential of the soil and land resources. The principles of soil management are well known, but because climatic, soil and water conditions vary so widely, the design of land use systems, and particularly of conservation measures, must be site-specific. Details of the system for different levels of classification and recommendation should be studied for proper recommendation.

If a soil cannot be adequately classified, or depending on the scale of study, then it is possible to create a new phase or modifiers, because the system has been left "open-ended" to accommodate such modifications in the future, which can be classify the soil for better management and for getting more crop productions. There are some relations between modifiers definition with soil diagnostic horizons, properties, materials from FAO-WRB (World Reference Based) system, so it needs to study on those relationships for conversion from soil map to soil fertility map.

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