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SOIL FERTILITY CAPABILITY CLASSIFICATION (FCC) IN THE MEKONG DELTA, VIETNAMBASED ON THE CONVERSION OF SOIL MAP (WRB)

Vo Quang Minh*[1], Le Van Khoa[1], Thai Thanh Du[1], Pham Thanh Vu[1] & Le Quang Tri[1], Nguyen Thi Ha Mi[1], Tran Van Dung[2]

*Can Tho University, College of Environment and Natural Resources[1]

*Can Tho University, College of Agricultural[2]

Campus II, 3/2 street, Xuan Khanh ward, Ninh Kieu district, Can Tho city, Viet Nam

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ABSTRACT

The study was conducted to determine the spatial distribution of soil fertility capability types and its constraints for agricultural in the Mekong Delta, Vietnam. The study used soil map, soil chemical and physical data as the basis for developing the keys of the relationship to convert soil map classified by WRB system to soil fertility map classified by the FCC system. Soil constraints for agricultural cultivation from soil fertility classification were identified. The research results show that Mekong Delta has thirty-five (35) FCC soil fertility types. The thirteen (13)soil fertility constraints and recommendation for agricultural production were also identified, such as slightly acid (**a**$^-$), strongly acid (**a**), high P fixation and high Fe toxicity potential (**i**), low available P (**p**), strongly actual acid sulphate soils (**c**), slightly actual acid sulphate soils (**c**$^-$), shallow potential acid sulphate soil (**f**) deep potential acid sulphate soil (**f**$^-$), slight salinity (**s**$^-$), strongly salinity (**s**), ability low supply mineral (**k**), ability low nutrient retention (**e**), low organic carbon content (**o**).

KEYWORDS: constraints, FCC, WRB, soil fertility, Mekong Delta, Vietnam.

1. INTRODUCTION

The Mekong Delta is one of the biggest agricultural cultivation regions in Vietnam. The intensive farming, rice cropping, unbalanced fertilization, less use of organic fertilizer led to soil degradation [1]. In addition, constructing dykes to prevent against floods, using a lot of chemical fertilizers and pesticides which had made agricultural land, especially rice soil fertility degraded [2]. The intensive cultivation increased pressure and led to the degradation and pollution of soils [3].

The Fertility Capability Soil Classification (FCC) system was developed more than 25 years ago to interpret soil taxonomy and soil tests in a quantitative manner that is relevant to grow plants [4]; [5]. It is now widely used and included in the worldwide FAO soils database [6]. Most of the class limits were borrowed from Soil taxonomy [7] or the FAO/UNESCO soil classification system [8]. Emphasis is placed on features that are easily detectable in the field, such as texture, colour, depth of horizons, presence or absence of mottle, 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 consisting of a series of individual letters to describe the soil. These properties signify fertility limitations with the different interpretation and represented by small letters [3].

Nowadays, the GIS technology which helps to overlay, compose to manipulate several spatial data. The study is based on the relationship between the WRB classification system [9] and the FCC system [10] with some modifications [11] to classify soil fertility for agricultural soil in the Mekong Delta.

2. MATERIALS AND METHODS

Map and data collection

Collect soil chemical and physical for soil fertility properties identification.

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Soil map classified by WRB system at the scale of 1/100.000 of Mekong Delta in 2014 [12].

Fertility capability classification (FCC)
The Fertility Capability Classification (FCC) system [10], with some modifications [11] was used as a reference system.

Determination of the relationship between WRB system and FCC systems
Determine the relationship between the soil classification system with diagnostic characteristics including a horizon, properties and materials from WRB system definition [9] with the structure of the FCC system [10]; [11].

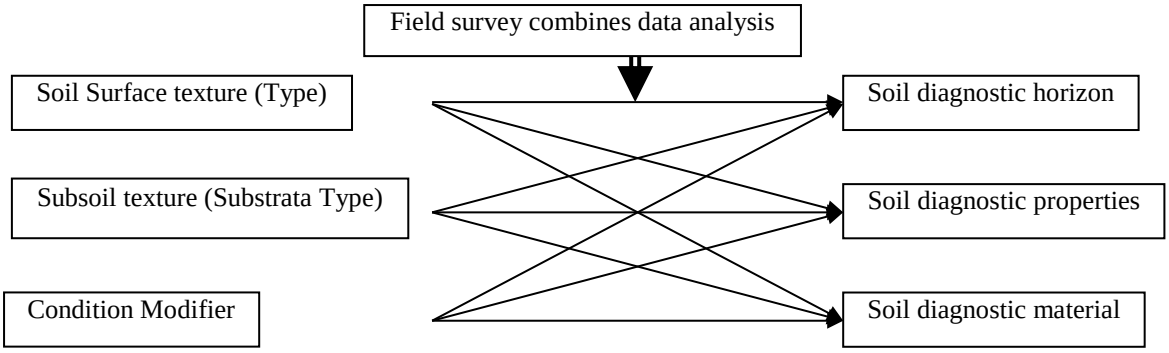

Figure 1: Relationship of major soil classes, diagnostic, diagnostic and diagnostic properties to the characteristics of the FCC classification system.

Map manipulation using a Geographic information system
The map uses a coordinate reference system WGS84/ UTM zone 48N.
The MapInfo and ArcGIS software was used to compose, present and manipulate maps to created FCC map

3. RESULTS

The relationship between soil map legend (WRB system) and soil fertility classification (FCC system)
The classification of fertility from an FCC system is based on the characteristics of the soil type, substrate type, and modifiers. Based on the occurrence of topsoil types, subsoil and complementary elements, with symbols designated for each soil fertility characteristic, soil fertility categories were named.

Based on the Mekong delta soil classification legend, 1/250,000, from WRB classification system, with major soil group and diagnostic horizons, properties and materials from WRB system, combined with soil chemical, physical properties, the relationship between modifiers and soil texture from FCC system for rice intensification in the Mekong Delta were found and presented in Table 1 and 2.

Table 1: The relationship between Major Soil Groups (from WRB system) and Modifier (from FCC system) in Mekong Delta

No.	Major Soil Groups	FCC system					
		Modifiers			Soiltexture		
		0-20cm	20-50cm	50-100cm	0-20cm	20-50cm	50-100cm
1	Albeluvisols	-	-	-	C	C	C
2	Alisols	-	-	-	C	C	C
3	Arenosols	k, e and o	k	-	S	S	S
4	Fluvisols	-	-	-	L	L	C
5	Gleysols	-	-	-	C	C	C
6	Histosols	-	-	-	O	O	O
7	Leptosols	k, e and	k	-	S	R	R

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		o					
8	Luvisols	-	-	-	C	C	C
9	Plimthosols	-	i	-	C	C	C
10	Solonchaks	s	s	s	C	C	C

Notes: ***C**: Soil Texture is Clay* ***L**: Soil Texture is Loam* ***S**: Soil Texture is Sandy*
***R**: Rock* ***O**: Organic* ***k**: Ability low supply mineral*
***e**:Ability low nutrient retention* ***o**:Low organic carbon*

Table 2: The relationship between diagnostic horizons, diagnostic properties and diagnostic materials (WRB system) and characteristics and constraint factors (FCC system) in Mekong Delta

No.	WRB system			FCC system		
	Diagnostic Horizons	Diagnostic Properties	Diagnostic Materials	Modifers 0-20cm	20-50cm	50-100cm
1	Thionic	EpiOrthiThionic	-	a and p	c	-
2	Thionic	EndoOrthiThionic	-	a^- and p	-	c^-
3	Thionic	EpiProtoThionic	Sulfidic	-	f	-
4	Thionic	EndoProtoThionic	Sulfidic	-	-	f^-
5	Salic	-	-	s	s	s
6	-	HypoSalic	-	s^-	s^-	s^-
7	-	EndoSalic	-	-	-	s
8	-	Sodic	-	s	s	s
9	Plinthic	-	-	-	i	-
10	-	Rhodic	-	-	i	-

Notes: ***a**$^-$: Slightly acid* ***a**: Strongly acid*
***i**: High P fixation* ***p**: Low P content*
***s**$^-$: Slightly salinity* ***s**: Strongly salinity*
***c**$^-$: Moderately actual acid sulphate soils* ***c**: Strongly actual acid sulphate soils*
***f**$^-$: Deep potential acid sulphate soils* ***f**: Shallow potential acid sulphate soils*
***k**: Ability low supply mineral* ***e**: Ability low nutrient retention*
***o**: Low organic carbon*

The FCC soil fertility distribution in Mekong Delta

Based on the Table 1 and Table 2 above relationship and by the conversion of WRB soil map legend into FCC soil fertility map, 35 types of soil fertility in Mekong Delta were identified. Therein, the largest area of soil fertility types is the CCC (790,734.0 ha, accounting for 20,21%) and the smallest area is Oa^-pOa^-Oc soil fertility type (2,484,8 ha, accounting for 0,06%). The detail soil fertility types and its interpretation were presented in Table 3 and its distribution in Figure 1.

Table 3: The types of soil fertility and their characteristics in the Mekong Delta

No.	FCC	Soil fertility capability interpretation	Total (ha)
1	**CCC**	texture is clay (**C**) within 100 cm from the soil surface	790,734.0
2	**LLC**	texture is loamy (**L**) between 0 and 50 cm, and a clay (**C**) between 50 and 100 cm	219,313.1
3	**CCCf$^-$**	texture is clay (**C**) within 100 cm from the soil surface, potential acid sulphate soils (**f$^-$**) in depth 50-100 cm	268,049.1
4	**LLCf$^-$**	texture is loamy (**L**) between 0 and 50 cm, and a clay (**C**) between 50 and 100 cm, potential acid sulphate soils (**f$^-$**) in depth 50-100 cm	53,212.6
5	**OOOf$^-$**	It is organic soil (**O**) within 100 cm from the soil surface, potential acid sulphate soils (**f$^-$**) in depth 50-100 cm	30,035.3
6	**CCCs$^-$**	texture is clay (**C**) within 100 cm from the soil surface, slightly salinity (**s$^-$**) in depth 50-100 cm	424,097.5
7	**CCiC**	texture is clay (**C**) within 100 cm from the soil surface, high phosphorus fixation (**i**) in depth 20-50 cm	372,508.3

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No.	FCC	Soil fertility capability interpretation	Total (ha)
8	**LLiC**	texture is loamy (**L**) between 0 and 50 cm, and a clay (**C**) between 50 and 100 cm, high phosphorus fixation (**i**) in depth 20-50 cm	189,890.0
9	**CCfC**	texture is clay (**C**) within 100 cm from the soil surface, potential acid sulphate soils (**f**) in depth 20-50 cm	12,441.1
10	**CCiCf^{-}**	texture is clay (**C**) within 100 cm from the soil surface, high phosphorus fixation (**i**) in depth 20-50 cm, and potential acid sulphate soils (**f^{-}**) in depth 50-100 cm	3,707.2
11	**LLfCs**	texture is loamy (**L**) between 0 and 50 cm, and a clay (**C**) between 50 and 100 cm, potential acid sulphate soils (**f**) in depth 20-50 cm and strongly salinity (**s**) in depth 50-100 cm	17,082.2
12	**CapCacC**	texture is clay (**C**) within 100 cm from the soil surface, soil is strongly acid (**a**) in depth 0-50 cm, low inherent P content (**p**) in depth 0-20 cm, and strongly actual acid sulphate soil (**c**) in depth 20-50 cm	139,852.9
13	**LapLacC**	texture is loamy (**L**) between 0 and 50 cm, and a clay (**C**) between 50 and 100 cm, soil is strongly acid (**a**) in depth 0-50 cm, low inherent P content (**p**) in depth 0-20 cm, and strongly actual acid sulphate soil (**c**) in depth 20-50 cm	33,515.9
14	**SkeoSkS**	texture is sand (**S**) within 100 cm from the soil surface, ability low supply mineral (**k**) in depth 0-50 cm, ability low nutrient retention (**e**) and low organic carbon (o) in depth 0-20 cm.	56,662.5
15	**SkeoRkR**	texture is sand (**S**) between 0 and 50 cm and it is rock (R) between 50 and 100 cm, ability low supply mineral (**k**) in depth 0-50 cm, ability low nutrient retention (**e**) and low organic carbon (**o**) in depth 0-20 cm.	15,827.5
16	**Cs^{-}Cs^{-}Cs^{-}**	texture is clay (**C**) within 100 cm from the soil surface, slightly salinity (**s^{-}**) in depth 0-100 cm	141,495.3
17	**Ls^{-}Ls^{-}Cs^{-}**	texture is loamy (**L**) between 0 and 50 cm, and a clay (**C**) between 50 and 100 cm, slightly salinity (**s^{-}**) in depth 0-100 cm	33,106.0
18	**CsCsCs**	texture is clay (**C**) within 100 cm from the soil surface, strongly salinity (**s**) in depth 0-100 cm	310,260.2
19	**Ls^{-}Ls^{-}Cf^{-}s^{-}**	texture is loamy (**L**) between 0 and 50 cm, and a clay (**C**) between 50 and 100 cm, slightly salinity (**s^{-}**) in depth 0-100 cm, and potential acid sulphate soils (**f^{-}**) in depth 50-100 cm	29,341.3
20	**Ls^{-}Ls^{-}fCs-**	texture is loamy (**L**) between 0 and 50 cm, and a clay (**C**) between 50 and 100 cm, slightly salinity (**s^{-}**) in depth 0-100 cm, and potential acid sulphate soils (**f**) in depth 20-50 cm	22,719.3
21	**CsCsCf-s**	texture is clay (C) within 100 cm from the soil surface, strongly salinity (**s**) in depth 0-100 cm, potential acid sulphate soils (**f^{-}**) in depth 50-100 cm	17,849.0
22	**LsLsCf^{-}s**	texture is loamy (**L**) between 0 and 50 cm, and a clay (**C**) between 50 and 100 cm, strongly salinity (**s**) in depth 0-100 cm, and potential acid sulphate soils (**f^{-}**) in depth 50-100 cm	40,104.7
23	**LsLsfCs**	texture is loamy (**L**) between 0 and 50 cm, and a clay (**C**) between 50 and 100 cm, strongly salinity (**s^{-}**) in depth 0-100 cm, and potential acid sulphate soils (**f**) in depth 20-50 cm	186,769.3
24	**Ca^{-}pCa^{-}Cc^{-}**	texture is clay (**C**) within 100 cm from the soil surface, soil is slightly acid (**a^{-}**) in depth 0-50 cm, low inherent P content (**p**) in depth 0-20 cm, and moderately actual acid sulphate soil (**c^{-}**) in depth 50-100 cm	94,796.9
25	**La^{-}pLa^{-}Cc^{-}**	texture is loamy (**L**) between 0 and 50 cm, and a clay (**C**) between 50 and 100 cm, soil is slightly acid (**a^{-}**) in depth 0-50 cm, low inherent P content (**p**) in depth 0-20 cm, and moderately actual acid sulphate soil (**c^{-}**) in depth 50-100 cm	30,094.5
26	**Oa^{-}pOa^{-}Oc^{-}**	It is organic soil (**O**) within 100 cm from the soil surface, soil is	2,484.8

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No.	FCC	Soil fertility capability interpretation	Total (ha)
		slightly acid (**a**$^{-}$) in depth 0-50 cm, low inherent P content (p) in depth 0-20 cm, and moderately actual acid sulphate soil (**c**$^{-}$) in depth 50-100 cm	
27	**Ca^{-}pCa^{-}Cc^{-}f^{-}**	texture is clay (**C**) within 100 cm from the soil surface, soil is slightly acid (**a**$^{-}$) in depth 0-50 cm, low inherent P content (**p**) in depth 0-20 cm, and moderately actual acid sulphate soil (**c**$^{-}$) and potential acid sulphate soils (**f**$^{-}$) in depth 50-100 cm	9,130.0
28	**CapCacCf^{-}**	texture is clay (**C**) within 100 cm from the soil surface, soil is strongly acid (**a**) in depth 0-50 cm, low inherent P content (**p**) in depth 0-20 cm, and strongly actual acid sulphate soil (**c**) in depth 20-50 cm and potential acid sulphate soils (**f**$^{-}$) in depth 50-100 cm	214,045.0
29	**Ca^{-}ps^{-}Ca^{-}s^{-}Cc^{-}s^{-}**	texture is clay (**C**) within 100 cm from the soil surface, soil is slightly acid (**a**$^{-}$) in depth 0-50 cm, low inherent P content (p) in depth 0-20 cm, and moderately actual acid sulphate soil (**c**$^{-}$) in depth 50-100 cm and slightly salinity (**s**$^{-}$) in depth 0-100 cm	13,199.3
30	**La^{-}ps^{-}La^{-}s^{-}Cc^{-}s^{-}**	texture is loamy (**L**) between 0 and 50 cm, and a clay (**C**) between 50 and 100 cm, soil is slightly acid (**a**$^{-}$) in depth 0-50 cm, low inherent P content (**p**) in depth 0-20 cm, moderately actual acid sulphate soil (**c**$^{-}$) in depth 50-100 cm, and slightly salinity (**s**$^{-}$) in depth 0-100 cm	2,902.2
31	**Ca^{-}psCa^{-}sCc^{-}s**	texture is clay (**C**) within 100 cm from the soil surface, soil is slightly acid (**a**$^{-}$) in depth 0-50 cm, low inherent P content (**p**) in depth 0-20 cm, and moderately actual acid sulphate soil (**c**$^{-}$) in depth 50-100 cm and strongly salinity (**s**) in depth 0-100 cm	20,680.6
32	**Caps^{-}Cacs^{-}Cs^{-}**	texture is clay (**C**) within 100 cm from the soil surface, soil is strongly acid (**a**) in depth 0-50 cm, low inherent P content (p) in depth 0-20 cm, and strongly actual acid sulphate soil (**c**) in depth 20-50 cm and slightly salinity (**s**$^{-}$) in depth 0-100 cm	50,459.2
33	**CapsCacsCs**	texture is clay (**C**) within 100 cm from the soil surface, soil is strongly acid (**a**) in depth 0-50 cm, low inherent P content (**p**) in depth 0-20 cm, and strongly actual acid sulphate soil (**c**) in depth 20-50 cm and strongly salinity (**s**) in depth 0-100 cm	31,473.6
34	**LapsLacsCs**	texture is loamy (**L**) between 0 and 50 cm, and a clay (**C**) between 50 and 100 cm, soil is strongly acid (**a**) in depth 0-50 cm, low inherent P content (**p**) in depth 0-20 cm, strongly actual acid sulphate soil (**c**) in depth 50-100 cm, and strongly salinity (**s**) in depth 0-100 cm	7,791.5
35	**CapsCacsCf^{-}s**	texture is clay (**C**) within 100 cm from the soil surface, soil is strongly acid (**a**) in depth 0-50 cm, low inherent P content (**p**) in depth 0-20 cm, and strongly actual acid sulphate soil (**c**) in depth 20-50 cm, strongly salinity (**s**) in depth 0-100 cm, and potential acid sulphate soils (**f**$^{-}$) in depth 50-100 cm.	26,496.7

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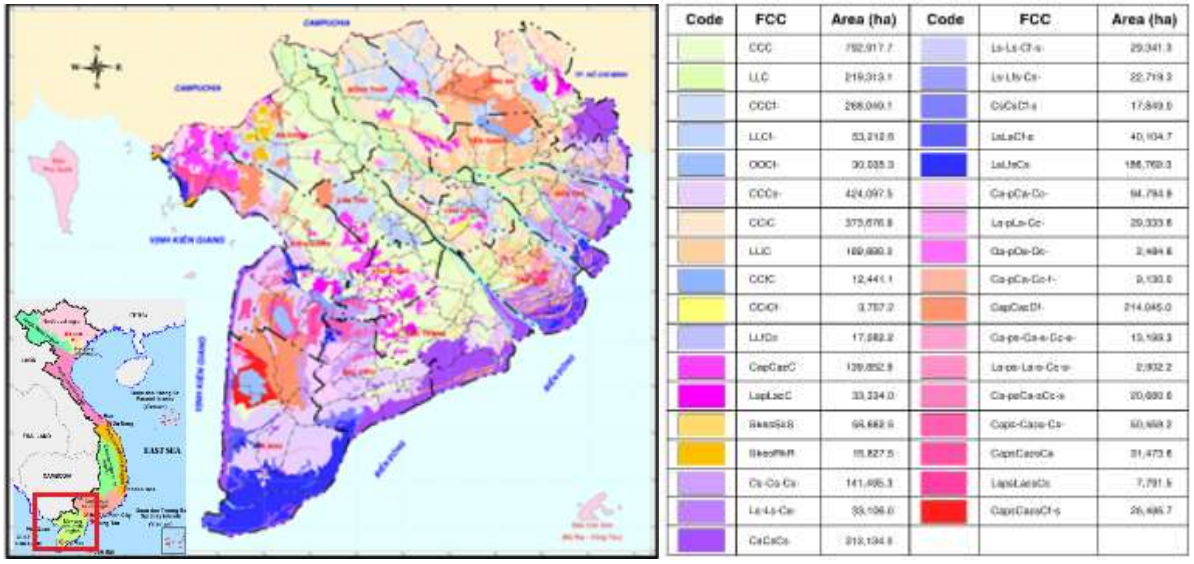

Figure 2: Soil Fertility Capability Classification (FCC) distribution in the Mekong Delta, Vietnam

Major soil fertility properties and constraints for agricultural cultivation in the Mekong delta

Besides that, the research was identified 13 types of soil constraints for agricultural cultivation, including Slightly acid (**a**$^-$), Strongly acid (**a**), High P fixation and high Fe toxicity potential (**i**), Low available P (**p**), Strongly actual acid sulphate soils (**c**), Slightly actual acid sulphate soils (**c**$^-$), Shallow potential acid sulphate soils (**f**) Deep potential acid sulphate soils (**f**$^-$), Slight salinity (**s**$^-$), Strongly salinity (**s**), Ability low supply mineral (**k**), Ability low nutrient retention (**e**), Low organic carbon content (**o**).

Table 4: The constraint of the soil fertility characteristics in Mekong Delta, Vietnam

Symbol	Soil fertility properties	Constraints
Soil fertility properties and constraintes related to soil minerals		
k	Exchangeable K < 0.2 meq/100g soil, or coarse texture (sandy) .	*Low nutrient capacity* (**k**): Soil has low mineral reserve capacity; there is a shortage of K reserves.
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 $pH_{8.2}$	*High leaching ability* (**e**): Low cation exchange capacity (CEC). Topsoil has low organic matter content, low clay content, low mineral clay content with CEC. This soil has low fertility and low nutrient retention capacity.
o	< 0.75% Organic Carbon, (applied for top soil only)	*Low organic matter* (**o**): N deficiency; respond to N; ECEC is low on sandy soil; N fertilizer should be applied at low doses but divided many time
i	> 4% free Fe; or mottle with hue redder 5YR which > 35% clay.	*High phosphorus fixation* (**i**): Due to the high content of free iron oxides (Fe_2O_3) in clay fraction causing P fixation. This constraint is also found in highly acidic soil, and associated with to aluminum toxicity. Soil with high P fixation due to Fe; lead to lacking P available; Potential toxicity of Fe, soils are difficult to puddle and will regenerate original structure rapidly.
p	Available P < 2mg/100g (Olsen), or < 1mg/100g (Bray II). (applied for top soil only).	*Low P content* (**p**): Lack of available P, crops will respond to low amount of P fertilizer
Soil fertility properties and constraints related to soil reaction		
a	Soil $pH_{H2O(1:1)}$ < 5.0 (or > 60% Al	*Al toxicity, low pH* (**a**, **a**$^-$): Aluminum toxicity will occur

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	saturation).	in aerobic layers; hese are the soils in which the main exchange complex is Al^{3+} aluminum. Constraints due to higly acidic can be caused by the oxidation of sulfide materials.
a^{-}	Soil $pH_{H2O(1:1)}$ from 5.0 to 6.0 (or 10-60% Al saturation).	
s	ECe > 4 mmhos/cm at 25^{O}C.	*Saline soil* (**s**, **s**$^{-}$); Drainage is required, but the EC of the irrigation water must be considered. .
s^{-}	ECe 2 - 4 mmhos/cm at 25^{O}C	
c	Soil $pH_{H2O(1:1)}$< 3.5; Jarosite mottle with hue = 2.5Y or yellower, chroma 6 at <50cm	*Active acid sulphate soil* (**c**, **c**$^{-}$): Al and Fe toxicity, low pH and P deficiency, derived from oxidation of sulfide materials.
c^{-}	Soil $pH_{H2O(1:1)}$< 3.5; Jarosite mottle with hue = 2.5Y or yellower, chroma 6 at >50cm	
f	Sulfidic material; pH < 3.5 after drying, without jarosite mottle with hue = 2.5Y at < 50 cm	*Potential acid sulphate soil* (**f**, **f**$^{-}$):capable of Fe and S toxicity when anaerobic and Al toxicity are aerobic; the depth at which sulfide materials occur directly affects root; Zn deficiency can be occurred; It should be noted that soil should not be oxidized.
f^{-}	Sulfidic material; pH < 3.5 after drying, without jarosite mottle with hue = 2.5Y at > 50 cm	

4. CONCLUSION

From the results of the conversion of the soil map classified by WRB (FAO, 2006) to the soil fertility map by FCC system, which was identified and evaluated the overall of soil fertility and constraints for agricultural production in the Mekong River Delta. Thirty- five (35) soil fertility types and thirteen (13) soil constraints for agricultural were identified. In which, the major soil constraints for agricultural cultivation including High P fixation and potential Fe toxicity (*i*), Potential salinity (s^{-}), Low available P (*p*), acid and Al toxicity (*a*), respectively. However, constraints of actual acid sulphate (*c*, c^{-}), potential acid sulphate (*f*, f^{-}), and low organic carbon status (*o*) have been also major constraints for agricultural cultivation in the Mekong Delta.

The soil fertility classification relied mostly on the topsoil and subsoils properties that indicated the soil fertility capability and affected to crop production.

The results were the first attempt to compare soil constraints using standardized data and methods. The principles of soil management are well known, but because of changing of climatic, soil, water situation and also the land use systems, and particularly of conservation measures, so it must be site-specific. Details of application for developing the system at different levels for classification and recommendation should be studied for a proper recommendation.

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