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Comparision of fertility capability and taxonomic classification systems to classify the soil map units in some parts of Chaharmahal-va-Bakhtiari province

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Abstract

Although fertility capability classification (FCC) has high performance in land evaluation and soil maps interpretation, so far it has been less attended in land evaluation studies. Therefore, qualitative (FCC method) and quantitative (Riquer index) land fertility capability evaluation for Wheat and Rice cultivation and comparison of Soil Taxonomy and WRB classification with FCC were chosen as this study objective. After field and laboratory studies, the soil map was prepared with the scale of 1: 50,000. Then, FCC and Riquer methods were used to determine the land fertility capability for Wheat and Rice cultivation for each of the soil map unites. Investigations showed that the FCC and Riquer methods have presented similar results and well interpreted and classified soils. The results of Riquer method indicated that the fertility capability of these lands is good except in gravelly and shallow parts, thus Wheat and Rice can be cultivated in these soils. A comparison of the current soil classification systems and the FCC results showed that the problems and inherent characteristics of studied soils were pointed well by the FCC system, whereas they have been expressed differently in Soil Taxonomy and WRB classifications. Gleyic condition, dryness and subsoil gravel are the most limitative factors to Wheat and Rice cultivation in this area.

***Keywords**:* Chaharmahal-va-Bakhtiari Province: FCC method: Riquer index: Soil Taxonomy and WRB; Gleyic condition

1. Introduction

In soil and land management, recognition of soil capabilities and their allocation to the best kind of crops has a special importance. In addition to soil suitability assessment methods for various uses and crops as presented by FAO (1979), to connect soil classification and soil fertility, Fertility Capability Classification system (FCC) were developed by Biol *et al*., (1975). This method is a practical and qualitative soil classification system for special purposes (Riquer, 1970). It aims at managing soil fertility based on important physical and chemical soil properties (Tabi *et al*., 2013). Using this method, different soil characteristics related to plant growth (physical, chemical, mineralogy and biological) are interpreted in two levels of classification characteristics due to low parameters of soil and substrates (which are directly related to plant growth). In the first level of classification, the type and subtype of each soil consists of the texture of the surface and sub-surface horizons respectively, and in the second level, descriptive symbols are determined. The first level is represented by Capital letters, and the second level, which is defined for the determination of the quantitative range of soil conditions affecting plant growth, contains 17 descriptors. The positive or negative symbol of each of these descriptors indicates their higher or lower effect on plant growth (Tabi *et al*, 2013). In other words, the FCC is an applied system for agricultural lands with similar constraints and management problems related to the nutrient storage capacity of soils, which is represented as a code for each soil. The

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interpretation of each code gives the user information for the proper classification of the soil, so researchers and agricultural development officials can identify soil fertility constraints for specific crops and agricultural development goals and programs (Sanchez *et al*., 2003).

Anusontpornperm *et al*. (2009) used the FCC methodology to interpret the soils of the northeastern region of Thailand and concluded that soils have been classified as same subgroup in the Soil Taxonomy system. According to the FCC, their fertility classification is different, especially in the soil descriptors. They stated that the FCC units have described the soils more clearly, while the American soil classification system placed soils with different descriptors in a same subgroup. Tabi *et al*. (2013) examined the productivity of Cameroon's low lands for rice cultivation. They introduced Iron and Aluminum toxicity, nutrient deficiency, high leaching potential, and low levels of nutrient deficiency, including Iron and Zinc as soil fertility constraints in rice cultivation in the studied area. In a study in which the FCC method was adopted in some semi-arid parts of India to identify the fertility capability of rainfed soils, soil moisture condition (modifier d) and low nutrient reserve (modifier k) were introduced as a reason of low soil fertility and available moisture content (Vasu *et al*., 2016). By using the FCC method for assessing fertility of rice growing soils in India, Bera *et al*. (2014) showed that soils of one taxonomic class can be classified in different FCC classes. Bera *et al*. (2014) also emphasized that the FCC method is an important tool to evaluate the problems and potentials of taxonomically varied soils, and to suggest a better landuse for crop production. Orimoloye (2016) used the FCC system to evaluate soils of some parts of Nigeria. They showed the high ability of the FCC system to indicate soil constraints and capabilities.

In addition to the methodology mentioned above, a parametric system for evaluating soil production capability has been presented by Riquer *et al*. (1970). Considering 9 factors including humidity condition, drainage, effective depth, soil texture and structure, base saturation percentage, accumulation of soluble salts, organic carbon content, cation exchange capacity, clay type and element storage, the fertility index of each soil is calculated (Riquer, 1970). Then, real fertility (according to the current state) and fertility potential (after land emendation) are measured directly from the soil's intrinsic properties. Dent (1978) used this method to determine the fertility capability of 14 series cultivated with rice and showed that if the drainage factor considered 100 for flooded lands, these lands will not have limitations to rice cultivation. Assessing land evaluation of the Bengal Basin in India using the Riquer index, Sarkar *et al*. (2012) found that the region has medium production capability. Verma and Sharma (2011) also used the Riquer index to evaluate the potential of Southwest lands in the Himalaya for tea cultivation; where results showed that the Riquer index in these soils indicated good fertility to excellent soils.

Considering the efficiency of the FCC method in interpreting soil maps and also considering that the FCC method has been less considered in studies of other researchers in Iran, identifying soil constraints and assessing the soil fertility qualitatively (FCC) and quantitatively (Riquer index), for wheat and rice cultivation in the study area, is the main objective of this study. Determining the fertility classes of these soils and interpreting the soil map of the area, as well as comparing the fertility classification (FCC methods and Riquer) and soil taxonomy (Soil Taxonomy and WRB) are the other objectives of this study.

2. Materials and Methods

2.1. Study area

The study area, with an area of 11804.7 hectares, is located in the central part of Chaharmahal-va-Bakhtiari province (Fig. 1). The landform in the study area includes alluvial plains, plateau, hills and lowlands. The groundwater level of the soils is high and the soils have a poor drainage problem.

The soil temperature regime of the study area is mesic. The moisture regime of studied area is generally xeric, but in areas with high groundwater level it is spacially aquic. After studying the basic maps of the area (topographic maps, geology, and aerial photographs), and field studies, a number of 230 soil profiles were excavated at a 700 meter intervals. After describing the representative soil profiles (Schoeneberger *et al*., 2002), 11 soil representative profiles were selected and soil samples were collected for physical and chemical analysis of these soils. After these were dried in the air, the soil samples were hammered, sieved, and their physical and chemical characteristics were then analyzed. Routine analyses were then carried out. Particle size distribution was determined by using hydrometeric method (Gee and Bauder 1986). Electrical conductivity and acidity were determined in water and soil extraction. Organic carbon content and calcium carbonate equivalent were determined by wet oxidation (Walkley and Black 1934) and the samples were treated with acid cholodric and titration by NaOH (Nelson 1982), respectively. Saturation percentage was determined by the weight of soil water in saturated condition. Buld density was calculated by silander method (Blake and Hrtge, 1986). Cation exchange capacity was determined by the replacement of exchangeable cations with ammonium acetate (Thomas, 1982). Soluble Sodium was analyzed by flame photometeric method, and soluble Calcium and Magnesium by complexometric method (Rhoades, 1982).

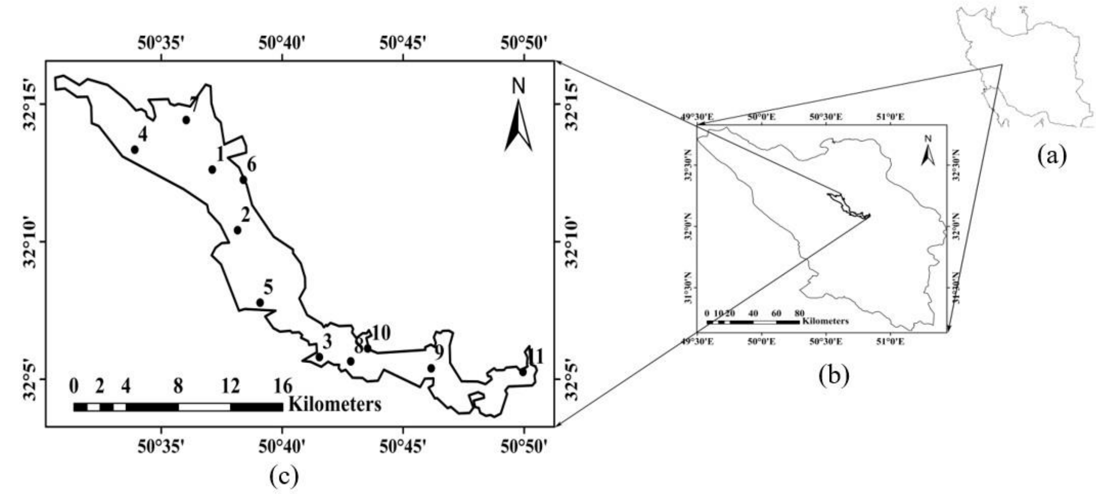

Fig. 1. Location of studied area in (a) Iran and (b) Chaharmahal-va-Bakhtiari province. Spatial distributions of representative soil profiles are shown as black points (c)

Soils were classified into a series levels according to the American soil classification system (Soil Taxonomy, 2014) and World Reference Base were classified into reference soil groups and their related prefix and suffix (WRB, 2014). Finally, a semi-detailed soil map was prepared with a scale of 1: 50,000 (Figure 2). Accordingly, the soils were divided into 5 soil map units (A, B, C, D, and E). The soil units A and B were separated based on the groundwater depth (0-100 cm and 100-200 cm, respectively). The soils in the alluvial plains were well drained and developed. The C and D soil units are located in these areas where Argillic and Calcic diagnostic subsurface horizons were observed in them. The E soil unit has been located on hill and plateau. This unit has shallow and rocky soils with low evolution. The current land use of units A, B, C, and D is irrigated cultivation (wheat), and in unit E, it is as garden.

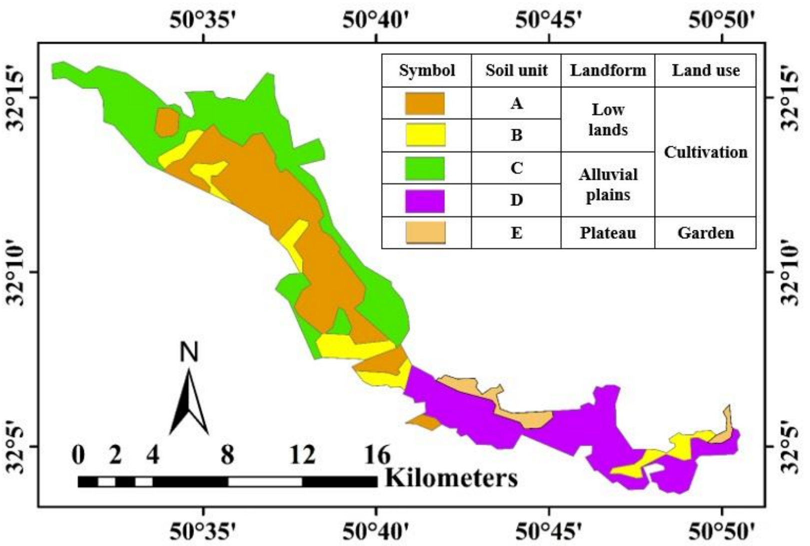

Fig. 2. The soil map of studied area (scale: 1:50000)

In order to identify the fertility limitations of soil map units and their classification, the fourth edition of the fertility capability classification was used (Sanchez *et al*., 2003). Based on the recommended tables (which are not mentioned here for the sake of brivity), soil types were determined regarding soil texture. Some modifiers then were selected to describe soil condition regarding the recommended soil and land characteristics (i.e. g, g^+, d, d^+, etc.).

Finally, the type, subtype, and descriptors of the growth of each soil unit were determined. Riquer index was used to quantitatively determine the soil fertility class of the studied area (Riquer *et al*., 1970). In this regard, a productivity index (PI) was calculated based on land and soil characteristics which affect plant yield, with:

$$PI= H * D * P * T * N \text{ or } S * O * A * M \quad (1)$$

Where, H: soil moisture, D: drainage, P: effective depth, T: soil texture and structure, N: base saturation percentage and S: soluble salts, O: organic carbon content, A: CEC of clay mineral, and M: mineral reserve.

The calculated index will gain a degree between 0 and 100. After calculating the soils fertility index, the soils producing ability were described according to five fertility classes presented in Table 1. Finally, the results of the classification of the studied soils by different classification methods (FCC, soil taxonomy and WRB) used in this study were compared for rice cultivation in low lands, because of desired soil and water conditions for cultivating rice in lowlands which are currently used to cultivate wheat instead of rice and wheat in other soil units in each of the soil map units.

Table 1. Relationship between indices and production classes in the Riquer index

ID	Index	Productivity class	Symbol
1	65-100	Excellent	I
2	35-64	Good	II
3	20-34	Moderate	III
4	8-19	Weak	IV
5	0-7	Very weak	V

3. Results and Discussion

The morphological, physical and chemical characteristics of the representative soil profiles are presented in tables 2 and 3, respectively. The results show that the texture and field capacity of all studied soils are moderate. The amount of field capacity increases and decreases respectively, with increasing clay and sand contents. Moderate soil texture, relatively with strong structure and low bulk density indicates that the soils have good porosity. The presence of underlying gravel percentage in 4, 6, 7, 10 and 11 soil profiles reduces soil water storage capacity and, consequently, water availability of the plant. Due to the amount of saturated moisture content, the studied soils have good porosity. The soils' pH is in a neutral to the slight alkaline range. The electrical conductivity of the soils is low and generally decreases with soil depth. The ratio of absorption of sodium and sodium exchangeable to these soils are low and the soils do not have alkaline and sodium problems. The low amount of organic carbon and its reduction with the soil depth and moderate soil texture has reduced the cation exchangable capacity of the studied soils.

The classification of soil profiles in two Soil Taxonomy and WRB classification systems has been presented in Table 4. Although the American soil classification system (Soil Taxonomy) classified soil units to the same great group level, except for unit A, the WRB soil classification system only places the D and E soil units in similar soil reference groups (RSG). Considering that the groundwater level is high in the soils of units A and B, by using the Soil Taxonomy classification system, placing these soils in the great group of Argiaquolls and Endoaqualfs has well classified these soils and pointed out to the specificity and difficulty of high groundwater levels, at the time the soils of these two units are located in different reference groups in the WRB system. Despite the high groundwater level, and due to lack of observance of gleyic color pattern in soils 2 and 4, these soils have not been included in the gleysols RSG. In the case of C unit, the Soil Taxonomy system also seems to better describe soils by placing them under the same groups, relative to the WRB system. Soils 7, 8 and 9, due to the secondary clay accumulation and the formation of the Argellic horizon in 100 cm of the soil surface, are classified in the Luvisols reference group of the soil according to the WRB system. In the case of unit E, both Soil Taxonomy and WRB have been well able to point to the problem of these soils.

Table 2. The morphological and physical characteristics of the representative soil profiles

Soil unit	soil profile	Horizon	Depth (cm)	Soil color		Structure	Secondary concentration	Resistance			Coarse fragment (%)
				Dry	Moist			Dry	Moist	Wet	
A	1	Ap	0-20	-	10YR3/2	2f gr	-	-	FR	-	0
		Btg1	20-70	-	5/10Y	2f,m abk	-	-	FI	-	0
		Btg2	70-110	-	5/10Y	2m abk	-	-	VFI	-	0
	2	A	0-10	7.5YR4/2	-	1m gr	-	-	FR	-	5
		Bt1	10-40	7.5YR4/1	-	2m abk	-	-	FI	-	5
		Bt2	40-75	-	10YR6/1	2m abk	-	-	VFI	ST-PL	0
		Btk	75-110	-	7.5YR7/1	1m,c abk	1ck2	-	-	ST-PL	0
	3	Ap	0-15	-	10YR5/4	2fgr	-	-	FR	-	0
		Bt1	15-35	-	2.5Y5/3	2m abk	-	-	-	ST-PL	0
		Bt2	35-80	-	2.5Y6/3	2m abk	-	-	-	ST-PL	0
		Btkg1	80-120	-	5/10Y	1c abk	1c k2, 1c th	-	-	ST-PL	0
B	4	A	0-20	-	7.5YR4/4	2f gr	-	-	VFR	-	20
		Bt1	20-40	-	7.5YR4/4	2m abk	-	-	FR	-	35
		Bt2	40-70	-	7.5YR3/4	2c abk	-	-	FR	-	15
		Btk	70-115	-	7.5YR3/4	1c abk	2c th	-	FR	-	5
	5	Ap	0-20	-	7.5YR4/2	2f gr	-	-	VFR	-	0
		Bt1	20-35	-	7.5YR4/2	2m abk	-	-	FR	-	0
		Bt2	35-55	-	7.5YR5/2	2m abk	-	-	FI	-	0
		Btg	55-105	7/10Y	-	1c abk	-	-	-	ST-PL	0
C	6	Ap	0-40	-	7.5YR3/3	2f gr	-	-	VFR	-	10
		Btk1	40-70	-	7.5YR3/3	2m,c abk	1fk2, 1fth	-	FR	-	5
		Btk2	70-90	-	10YR3/4	2c,vc abk	1fk2, 1fth	-	SR	-	5
	7	Ap	0-15	-	7.5YR4/4	2vf gr	-	-	FR	-	10
		Bt1	15-65	-	7.5YR3/4	2f abk	-	-	FR	-	12
		Bt2	65-115	-	7.5YR4/3	3m abk	-	-	VFR	-	50
D	8	Ap	0-10	10YR5/4	-	2fgr	-	S	-	-	0
		Bt	10-30	-	7.5YR5/3.5	2m abk	-	HA	-	-	0
		Btk1	30-80	-	7.5YR5/3	3m abk	2c k2, 1f th	-	FI	-	0
		Btk2	80-130	-	7.5YR5/3	2m abk	2m k2, 1f th	-	VFI	-	0
	9	Ap	0-25	-	7.5YR4/4	2fgr	-	-	FR	-	0
		Bt1	25-55	-	7.5YR4/4	2m abk	-	-	FI	-	5
		Bt2	55-85	-	7.5YR5/4	2m abk	-	-	FI	-	5
		Bt3	85-140	-	7.5YR5/4	2m abk	-	-	FI	-	5
E	10	Ap	0-35	-	7.5YR3/4	2fgr	-	-	FR	-	15
		C1	35-70	-	7.5YR5.5/4	Structure Less	-	-	FI	-	50
		C2	70-120	-	7.5YR7/3.5	Structure Less	-	-	FI	-	60
	11	A	0-10	10YR5.5/4	-	2fgr	-	-	-	SH	20
		C1	10-60	10YR6/4	-	Structure Less	-	-	-	MH	60
		C2	60-110	10YR7/4	-	Structure Less	-	-	-	VH	75

Table 3. The chemical characteristics of the representative soil profiles

Soil unit	soil profile	Horizon	Depth (cm)	EC (dS/m)	pH	CEC	Ex.Na	SAR	p.d (g.cm-3)	O.C	CaCO3	SP	Sand	Silt	Clay	Texture
						Cmol(+).kg-1				%						
A	1	Ap	0-20	0.7	7.9	10.3	0.5	1.5	1.1	1.3	25.0	51.0	51.0	41.0	8.0	Loam
		Btg1	20-70	0.8	8.1	19.7	0.6	1.5	1.1	0.8	36.5	55.0	42.0	40.0	18.0	Loam
		Btg2	70-110	1.1	8.1	21.3	0.9	1.9	1.2	0.4	45.5	49.0	35.0	45.0	20.0	Loam
	2	A	0-10	0.6	8.3	13.4	0.4	0.7	1.1	0.8	23.0	49.0	68.0	22.0	10.0	Sandy Loam
		Bt1	10-40	0.8	8.0	27.5	0.5	0.5	1.1	2.2	29.0	62.0	46.0	39.0	15.0	Loam
		Bt2	40-75	0.6	8.3	13.2	0.4	1.1	1.1	0.9	23.5	66.0	74.0	18.0	8.0	Sandy loam
		Btk	75-110	0.6	8.1	11.5	0.5	0.9	1.1	0.5	21.5	56.0	67.0	23.0	10.0	Sandy loam
	3	Ap	0-15	1.2	7.4	9.3	0.9	06	1.3	1.2	43.5	47.0	52.0	46.0	2.0	Sandy loam
		Bt1	15-35	1.0	7.7	9.6	0.8	0.1	1.3	0.4	42.5	39.0	50.0	44.0	6.0	Sandy loam
		Bt2	35-80	0.8	7.8	14.2	0.8	2.1	1.4	0.4	46.0	38.0	42.0	45.0	13.0	Loam
		Btkg1	80.120	0.7	7.8	21.2	0.5	1.9	1.3	0.3	37.0	54.0	28.0	42.0	30.0	Clay loam
B	4	A	0-20	0.6	7.9	11.1	0.5	1.4	1.3	0.6	29.5	42.0	56.0	36.0	8.0	Sandy loam
		Bt1	20-40	0.5	7.7	15.5	0.4	3.1	1.1	0.5	16.0	49.0	44.0	40.0	16.0	loam
		Bt2	40-70	0.5	7.9	18.9	0.3	1.1	1.2	0.6	10.0	52.0	32.0	42.0	26.0	Loam
		Btk	70-115	0.4	7.7	29.1	0.5	2.2	1.2	0.8	14.0	56.0	25.0	47.0	28.0	Clay loam
	5	Ap	0-20	0.7	8.0	15.2	0.4	0.9	1.1	2.1	28.5	56.0	58.0	30.0	12.0	Sandy loam
		Bt1	20-35	0.8	7.6	18.2	0.7	1.8	1.1	2.4	27.0	62.0	44.0	44.0	12.0	Loam
		Bt2	35-55	0.4	8.3	21.0	0.3	0.7	1.1	0.6	31.5	51.0	24.0	54.0	12.0	Silty loam
		Btg	55-105	0.6	8.1	23.0	0.3	0.8	1.2	0.4	35.5	52.0	16.0	58.0	26.0	Silty loam
C	6	Ap	0-40	0.9	7.6	11.3	0.8	1.7	1.3	1.4	36.5	42.0	51.0	43.0	6.0	Sandy loam
		Btk1	40-70	0.6	7.8	13.3	0.5	2.7	1.3	0.5	17.0	44.0	40.0	50.0	10.0	Loam
		Btk2	70-90	0.4	7.8	12.1	0.4	2.4	1.3	0.3	21.0	51.0	46.0	42.0	12.0	Loam
	7	Ap	0-15	1.6	7.4	12.1	1.1	1.4	1.1	3.1	29.0	72.0	58.0	38.0	4.0	Sandy loam
		Bt1	15-65	1.3	7.6	12.1	1.0	1.5	1.1	2.9	43.0	63.0	67.0	29.0	4.0	Sandy loam
		Bt2	65-115	0.8	7.7	17.1	0.8	2.2	1.3	1.2	37.5	42.0	58.0	34.0	8.0	Sandy loam
D	8	Ap	0-10	0.5	7.9	10.5	0.4	0.6	1.3	0.4	21.5	44.0	60.0	34.0	6.0	Sandy loam
		Bt	10-30	0.4	7.9	14.3	0.3	0.6	1.2	0.5	21.5	47.0	56.0	38.0	6.0	Sandy loam
		Btk1	30-80	0.4	8.0	21.2	0.3	0.8	1.3	0.1	42.0	43.0	26.0	48.0	26.0	Loam
		Btk2	80-130	0.4	8.0	11.6	0.2	0.5	1.3	0.1	41.0	42.0	48.0	38.0	14.0	Loam
	9	Ap	0-25	0.8	7.8	9.8	0.5	0.8	1.4	0.4	34.5	37.0	26.0	66.0	8.0	Silty loam
		Bt1	25-55	0.5	7.8	12.4	0.5	1.6	1.3	0.4	32.0	43.0	37.0	51.0	12.0	Silty loam
		Bt2	55-85	0.3	7.8	16.6	0.3	1.6	1.3	0.3	28.5	45.0	34.0	45.0	21.0	Loam
		Bt3	85-140	0.4	8.1	10.1	0.3	0.8	1.3	0.1	23.5	45.0	44.0	42.0	14.0	Loam
E	10	Ap	0-35	1.6	7.7	14.5	1.0	0.4	1.3	0.4	38.5	47.0	64.0	30.0	6.0	Sandy loam
		C1	35-70	0.6	7.7	9.6	0.4	0.4	1.4	0.3	42.0	36.0	48.0	44.0	8.0	Sandy loam
		C2	70-120	0.5	7.8	8.2	0.4	0.6	1.4	0.2	47.5	31.0	66.0	28.0	6.0	Sandy loam
	11	A	0-10	1.3	7.8	10.4	1.0	1.0	1.3	0.3	33.5	45.0	51.0	45.0	4.0	Sandy loam
		C1	10-60	0.5	7.8	21.3	0.6	0.6	1.4	0.5	41.5	35.0	59.0	17.0	24.0	Clay sandy loam
		C2	60-110	0.7	8.0	8.6	0.4	0.8	1.5	0.1	43.0	31.0	66.0	26.0	8.0	Sandy loam

Table 4. The classification of soil profiles in two Soil Taxonomy and WRB classification systems

Soil unit	soil profile	WRB, 2014	Soil Taxonomy, 2014	Area	
				Hectare	%
A	1	Calcic Gleysols	Typic Argiaquolls	3571.6	30
	2	Calcic Luvisols (ochric)	Typic Argiaquolls		
	3	Calcic Gleysols	Typic Endoaqualfs		
B	4	Calcic Luvisols (ochric)	Typic Endoaqualfs	1261.9	11
	5	Calcic Gleysols	Typic Endoaqualfs		
C	6	Haplic Calcisols (ochric)	Calcic Haploxeralfs	3778.3	32
	7	Calcic Luvisols (ochric)	Calcic Haploxeralfs		
D	8	Calcic Luvisols (ochric)	Calcic Haploxeralfs	2790.6	24
	9	Calcic Luvisols (ochric)	Typic Haploxeralfs		
E	10	Skeletic Regosols (ochric)	Lithic Xerorthents	402.3	3
	11	Skeletic Regosols (ochric)	Lithic Xerorthents		

The results of the qualitative evaluation of soil fertility by the FCC method (Table 5) indicate that all soil types are of type L, i.e. topsoil layer shows loamy texture class. No texture differentiation is observed in them. Based on the soil and land conditions, modifiers including g, b, r, and d were used to describe aquic soil moisture regime within 50 cm of surface, free carbonate within 50 cm of soil surface, gravel, and xeric soil moisture regime, respectively. It should be noted that determining the FCC for a specific soil can be interpreted in relation to the use of various land uses.

In the A and B soil units, and due to high groundwater levels' conditions, the description "g" is considered for them. The descriptor "d" in C, D, and E soil units represents the dryness of the air in the growing season, which may reduce the growth period of the plant. The descriptor "r^{+}" in the B and E soil units shows that these units have less gravel than the C soil unit (descriptor "r^{++}"). This high percentage of underling gravel may cause nutritional problems and water shortage to the plant.

Table 5. Results of the evaluation of soil fertility qualitatively by the FCC method

Soil unit	Soil profile	Riquer method			FCC method	
		Riquer index	Reduction factor indicator	Productivity class	Class	Limitation
A	1	36.0	High ground water surface and low organic carbon	Well	Lgb	Gley condition
	2	32.0	High ground water surface and low organic carbon	Medium	Lgb	Gley condition
	3	36.0	High ground water surface	Well	Lgb	Gley condition
B	4	38.4	High ground water surface and low organic carbon and coarse fragment	Well	$Lgr^{+}b$	Gley condition and coarse fragment
	5	72.0	High ground water surface and low organic carbon	Excellent	Lgb	Gley condition
C	6	100.0	None	Excellent	Ldb	Drought
	7	60.0	coarse fragment	Well	$Ldr^{+}b$	Drought and coarse fragment
D	8	85.0	Low organic carbon	Excellent	Ldb	Drought
	9	85.0	Low organic carbon	Excellent	Ldb	Drought
E	10	15.0	coarse fragment and shallow depth	Weak	Ldrb	Drought and coarse fragment
	11	15.0	coarse fragment and shallow depth	Weak	$Ldr^{++}b$	Drought and coarse fragment

Due to the calcareous parent material of these soils and their high calcium carbonate content (Table 3), these soils have been calcareous for reaction, and therefore descriptive “b” has been used for all these soils. According to the table 3, the EC, Sodium absorbtion ratio and exchangable Sodium of these soils are low, therefore, identifiers related to salinity and sodium have not been mentioned. Although available nutrient elements for plants, namely, Iron (Fe), Zinc (Zn), Phosphoreous (P), and Potassium (K) have not been measured in this study, it can be suspected from high Calcium carbonate equivalent of soils that availability of Fe and Zn may be restricted for plants. Also, from the high percentage of sand and silt indicating the low weathering of these soils, the possibility of low levels of K in these soils seems unlikely. And due to low soil weathering on one hand and the high Calcium Carbonate content and pH on the other hand, the possibility of P fixation by Iron and Aluminum Oxides and consequently its absence in these soils is low. On the other hand, these physical conditions can greatly impact the potentials of these soils for different cultivations (Orimoloye, 2016).

Therfore, major proved limitations of the studied soils are concerned with physical conditions namely; poor drainage, gleyic condition, denitrification and lack of ventilation in areas with high groundwater levels, drought in areas with a xeric moisture regime, high gravel percentage and low soil depths. Clearly, the capability of soils located in areas with high groundwater level for Wheat, that are currently cultivated in these areas is restricted due to drainage condition. Therfore, Rice cultivation can be considered as good replacement cultivation. Results of FCC also indicate that 3% of the studied area is weak because of high coarse fragment and shallow soil depth (Orimoloye, 2016).

The quantitave assessment of soil fertility capability by identifying the Riquer index (Table 5) showed that, in terms of production capacity, the studied area are in weak to excellent grades. Soil units A, B, C, and D are suitable for the production of all crops in terms of production capacity (Riquer, 1970). But the soils of E are poorly produced and located in poor class due to their low soil depth and rock. The productivity class of soil unit A is good, but in soil 2 of this unit, the index of Riquer and production class have decreased in comparison to soils 1 and 3, which is due to the organic matter present in the surface horizon,. In B and C soil units, the production of these soils decreased, respectively, compared to soils 5 and 6 due to the high gravel in soils 4 and 7. Comparing the results of FCC and Riquer method demonstrates these two methods as successful in expressing the fertility capability and soil production class.

Comparing the results of the classification of soils in the Soil Taxonomy and WRB by FCC method shows that the Soil Taxonomy classified the A soils properly, and pointed out to the problem of the high groundwater level. In the case of these soils, and considering the intrinsic problem of these soils, the WRB has placed them in the same reference group (except soil No. 2), and the FCC method has also classified these soils in the same units. Therefore, we can say that all three classification systems have been successful in describing these soils. In the case of soil unit D, all three systems of soil classification have well classified it in the same units. Regarding these results, soils classified using the same Soil Taxonomy and WRB are not necessarily classified in the same FCC class, which is -inconsistent with the results of Anusontpornperm *et al*. (2009) and Bera et al. (2014).

Due to the high groundwater level in unit B, the Soil Taxonomy placed soils in the same great group, but the WRB system has classified them into two different soil reference groups as Luvisols and Gleysols. In the FCC system, these soils are located in two separate units. Since the management of these two soil reference groups (Luvisols and Gleysols) is different, results of the FCC classification system seems to be more or less the same as the results of the WRB, and these two systems perform better at describing the soils of this unit than the Soil Taxonomy. This is also true for unit C. In this unit, the Soil Taxonomy has classified the soils with different FCC class in the same great group, but the WRB has refered to the difference between the two soils at the reference group level and has classified soils better than the Soil Taxonomy.

4. Conclusion

Comparing the classification of the studied soils in the Soil Taxonomy systems with the FCC system showed that these systems have classified the soils of A and D units equally. However, for B and C units, the Soil Taxonomy system has not taken into account the difference in soils and placed them in the same great group; at the time the WRB system has classified the soils into two different reference soil groups that are consistent with the FCC system. The results of the FCC and Riquer method are consistent with each other and they both describe the characteristics of these soils and classify them well. The main limitation of these soils for Wheat and Rice cultivation is high groundwater level and soil dryness in other parts of the studied area as well as deep gravel in other parts of the studied area. According to the Riquer method, fertility capability of these soils is suitable (except for unit E with stony and shallow places), and Wheat and Rice cultivation in these soil units is justifiable.

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