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FERTILITY CAPABILITY CLASSIFICATION OF PADDY SOILS IN COMPARISON WITH THE SOIL TAXONOMY IN GUILAN PROVINCE, IRAN

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ABSTRACT: The Fertility Capability Classification system (FCC) has rarely been used to classify arable lands despite a relatively long history of soil surveys in Iran. The aim of this study was to classify paddy soils using the FCC system and then, compare it with the Soil Taxonomy in the Zibakenar region of the Guilan province. Twelve soil profiles, 1 kilometer apart from each other, were selected on a SW-NE transect in the study area. Soil samples were collected from morphological horizons and physical, chemical, and mineralogical analysis were carried out. Results showed that all selected soils were classified in the same soil order, suborder, great group and even family levels based on the Soil Taxonomy system. However, these profiles were classified in several different sub-groups including: Aeric, Fluventic, Vertic and Mollic Endoaquepts. The FCC showed a greater diversity in the studied profiles. For example the Cgb, CLgb, Cg, Lgb and SLg units were found in the Aeric Endoaquepts alone. Interpretation of FCC units reflected the variation in soil fertility that is useful in nutrition management and crop production planning and was not available in the Soil Taxonomy due to the lack of distinguishing information in relation to plant growth. However, these interpretations did not show any clear relationship to the Soil Taxonomic units because cultivation had changed some soil properties especially in the upper part of the solum, where FCC places most of its emphasis. So FCC system needs further analytical data to facilitate precise classification which can rarely be achieved from the Soil Taxonomy information alone.

***Keywords*:** Soil Classification, Soil Taxonomy, Fertility Capability Classification, Rice, Guilan

INTRODUCTION

There is a considerable gap between the sub disciplines of pedology and agronomy worldwide (Sanchez and Buol, 1985). Pedologists attempt to classify soils according to more permanent properties which occur mainly in the subsoil, while agronomists look at soil quite differently, though being conscious of the fact that most soil parameters affecting crop yields are located in the topsoil. The limitation of global soil classification systems such as Soil Taxonomy, the FAO legend and World Reference Base for soil Resources, which have been developed by pedologists, is that they only quantify permanent soil attributes, which are mostly located in the subsoil. They emphasis on the topsoil dynamic attributes crucial to plant productivity, only at lower levels of classification systems, such as at family and series levels for the Soil Taxonomy.

The Fertility Capability soil Classification system (FCC) was developed as an attempt to bridge the above mentioned gap between subdiciplines of soil classification and soil fertility (Buol et al., 1975). It is a technical system for grouping soils according to the kinds of problems they present for agronomic management and is based on quantitative topsoil and subsoil parameters directly relevant to plant growth.

It focuses on specific use of natural soil classification systems which are essentially records of soil properties. Buol (1986); developed the second version which included specific interpretations of wetland rice soils. Smith et al (1989); developed the third version by adding a new condition modifier for permafrost and subdivisions of some existing ones.

Sanchez et al (2003); developed the latest version of FCC system which consisted of 17 condition modifiers defined to delimit specific soil conditions affecting plant growth with quantitative limits.

Somchai et al (2009); tried to use this system to classify soils and then compare it with the Soil Taxonomy system in order to produce more specific interpretative soil units. Torabi et al (2005); compared the results of FCC system with parametric methods in the classification of soils under rice cultivation and reported that the FCC outputs correlated well with the results of parametric methods and due to the difficulties in the calculations of parametric methods, it is easier to use the FCC system in rice paddy soil classifications. However, they did not compare FCC with the Soil Taxonomy.

Although rice cultivation is common in various types of soils, alluvial deposits with a heavy and clayey texture are more suitable compared to soils with lighter texture. Soil under rice cultivation must have enough suitability from physical, chemical and fertility aspects during all growth periods. The classification of these soils based on characteristics related to plant growth can facilitate nutritional management practices and be useful in land evaluation planning.

This study was conducted on some rice paddy soils of the Zibakenar region, north of Guilan province, with the aim of classifying soils using the FCC system and compare the results with Taxonomic units from fertility stand point. The soils were classified according to their constraints for rice growth and then, the taxonomic units of studied soils were further interpreted using their FCC classes.

MATERIALS AND METHODS

The Guilan province with a total area of nearly 1.5 million hectares is located in the southwest of the Caspian Sea (Figure 1) and about 40 percent of its area is occupied with plains and the rest is occupied by mountains. Rice, with a surface area under cultivation about 230 thousand hectares, is the major crop in this province that is grown in mountainous, plains, marshland and coastal regions. Study methods composed of field investigation and laboratory analysis. The field study included site description and soil morphological identification using pedon analysis based on standard methods (Soil Survey Manual, 2006). Laboratory analysis included the physical and chemical properties of collected soil samples using standard methods of soil analysis (Soil Survey Laboratory Methods, 2004). Soil profiles located on the rice farms along an oblique transect from southwest to northeast of the study area with the same flat landform unit from plain to sea coast. Twelve soil profiles were selected with distances of about 1 kilometer between each of them along the Khoshkebijar to Zibakenar regions (Figure 2). The soil profiles were classified according to the FCC and the USDA Soil Taxonomy classification systems.

The FCC system used in this study consisted of two categorical levels (Table 1). The first category (type/substrata type) describes topsoil and subsoil texture and the second category (condition modifiers) consist of 17 modifiers defines the specific soil conditions affecting plant growth with quantitative limits.

Type and Substrata type are expressed in capital letters and each condition modifier is expressed in lower case after them. These categorical levels are the soil attributes in terms of their capability for plant growth. Taxonomic units of soils were derived from the latest version of the USDA Soil Taxonomy Classification system (Soil Survey Staff, 2010).

Figure 1. Geographic position of Study area

Figure 2. Profiles Location on the Study Area

Table 1. Fertility Capability soil Classification system, version 4 (Sanchez et al, 2003)

Symbol	Definition
Type: texture is the average of plow layer or 0-20 cm depth, whichever is shallower.	
S	sandy topsoil: loamy sands and sands
L	loamy topsoil: <35% clay but not loamy sand or sand
C	clayey topsoil: >35% clay
O	organic soil: >12% organic C to a depth of 50 cm or more
Substrata type: used if textural change is encountered within top 50 cm	
S	sandy subsoil: texture as in type
L	loamy subsoil: texture as in type
C	clayey subsoil: texture as in type
R	rock or other hard root-restricting layer within 50 cm
R^-	as above, but layer can be ripped, plowed or blasted to increase rooting depth
Condition modifiers: in plow layer or top 20 cm, whichever is shallower, unless otherwise specified	
g	aquic soil moisture regime; mottles <2 chroma within 50 cm for surface and below all A horizons or soil saturated with water for >60 days in most years
d	ustic or xeric soil moisture regime
t	cryic and frigid (<8 ˚C mean annual)
r	gravel size coarse fragments (2-25 cm in diameter) anywhere in the top 50 cm of the soil
%	where desirable place range in % slope
c	pH<3.5 after drying
a	>60% Al saturation within 50 cm or pH<5.5 except in organic soils
no symbol	<60% Al saturation of ECEC within 50 cm and pH between 5.5and 7.2
b	free $CaCo_3$ within 50 cm (fizzing with HCl), or pH>7.3
s	>0.4 S m^{-1} of saturated extract at 25 ˚C within 1 m
n	>15% Na saturation of ECEC within 50 cm
k	<10% weatherable minerals in silt and sand fraction within 50 cm
i	dithionite-extractable free R_2O_3: clay ratio >0.2
x	within 50 cm pH>10 (in 1 M NaF)
v	>35% clay and >50% of 2:1 expanding clays, or coefficient of linear expasibility > 0.09
e	<4 $cmol_c$ kg^{-1} soil as ECEC
m	<80% total organic C saturation in the topsoil compared with a nearby undisturbed or productive site the same soil

RESULTS AND DISCUSSION

Soil morphological properties

All of soils were generally similar to each other in terms of their morphological characteristics. The soil profiles located on a flat plain landscape that continued to beach deposits. Due to alluvial nature, less age and also presence of groundwater table near the soil surface, these soils lacked a significant development and profile evolution. They were poorly drained with the thickness of the surface layer ranging from 10 to 40 cm (Table 2). A low permeable layer existed immediately below the plowed layer in the depth of 25-40 cm that was formed as a result of rice cultivation practices (puddling) and prevented vertical penetration of surface water. Redoximorphic features in the surface layers surrounded the root channels and in the sub-surface layers, they were observed on aggregate surfaces, channels and channels of rotten roots. The clay content of soils typically increased with depth especially in cambic horizon below the surface. All soils were in the early stages of their development and thus, they were grouped in the Inceptisol order of the Soil Taxonomy.

Table 2. Some morphological and chemical properties of some studied soils (8 pedons of 12)

Horizon	Depth (cm)	Color (moist)	pH_s	EC_e (dSm^{-1})	Particles %			OC %	CEC $cmol^+/kg$
					sand	silt	clay		
Pedon 1 (37° 23 09 N, 49° 46 11 E)									
Ap	0-30	10YR3/3	7.08	1.44	16	38	46	2.86	34.4
Bw	30-60	10YR3/3	7.19	1.35	2	34	64	1.52	38.0
Bg1	60-85	10YR3/2	7.38	3.18	4	37	59	0.75	44.5
Bg2	85-110	10YR3/3	7.75	1.21	2	48	50	0.60	32.5
Pedon 2 (37° 23 21 N, 49° 46 55 E)									
Ap	0-30	10YR3/4	7.22	1.00	4	42	54	2.35	38.7
Bw	30-100	10YR3/2	7.23	0.55	34	46	20	0.97	26.3
Cg	100-125	2.5YR3/2	7.54	0.70	66	25	9	0.45	10.1
Pedon 3 (37° 23 58 N, 49° 47 04 E)									
Ap	0-30	10YR3/3	7.00	1.20	14	42	44	1.45	36.4
Bw1	30-60	7.5YR3/2	7.56	0.75	20	58	22	0.94	43.3
Bw2	60-85	10YR3/4	7.61	0.71	18	50	32	0.45	26.7
Bg	85-115	10YR3/2	7.62	0.98	4	54	42	0.21	32.2
Pedon 4 (37° 23 32 N, 49° 47 42 E)									
Ap1	0-10	10YR3/3	6.88	1.77	22	42	36	2.54	34.4
Ap2	10-40	10YR3/4	7.30	1.40	20	48	32	1.85	32.0
Bw1	40-85	10YR3/4	7.33	0.81	8	50	42	0.75	40.2
Bw2	85-110	10YR3/3	7.61	1.08	8	52	40	0.33	35.8
Pedon 5 (37° 24 37 N, 49° 47 28 E)									
Ap	0-30	10YR3/3	7.21	1.19	16	42	42	1.55	34.6
Bw1	30-60	10YR3/4	7.50	0.843	16	46	38	0.76	30.8
Bw2	60-90	10YR3/3	7.40	1.04	16	37	47	0.95	42.3
Bg1	90-120	10YR3/2	7.72	1.40	20	40	40	0.20	33.3
Bg2	120-135	7.5YR3/2	7.80	1.23	14	38	48	0.20	38.9
Pedon 6 (37° 23 52 N, 49° 48 53 E)									
Ap	0-25	7.5YR3/2	7.17	0.74	24	42	34	1.78	18.8
Bw1	25-50	10YR3/3	7.57	0.95	0	40	60	1.05	38.0
Bw2	50-80	10YR3/4	7.58	1.40	0	42	58	0.75	40.1
Bg1	80-100	10YR3/2	7.45	2.60	8	38	54	0.44	35.5
Bg2	100-115	10YR3/3	7.44	2.06	10	32	58	0.21	35.0
Pedon 7 (37° 25 12 N, 49° 47 51 E)									
Ap	0-25	10YR3/4	6.93	1.80	12	48	40	2.65	36.6
Bw	25-50	10YR3/3	7.28	1.07	6	42	52	1.98	48.1
Bg1	50-80	7.5YR3/2	6.65	1.31	6	46	48	0.97	40.0
Bg2	80-115	10YR2/2	7.21	1.04	6	44	50	0.38	39.8
Pedon 8 (37° 24 49 N, 49° 48 51 E)									
Ap	0-30	7.5YR3/2	7.01	1.61	28	42	30	2.68	34.7
Bw1	30-40	10YR3/6	7.70	1.24	32	58	10	1.88	28.5
Bw2	40-70	10YR2/1	6.61	1.85	18	46	36	0.94	46.6
Bw3	70-90	10YR3/4	7.26	0.84	28	46	26	0.65	35.5
2Cg	90-120	10YR3/3	7.79	1.01	48	40	12	0.40	20.0

Chemical and mineralogical properties

Soil pH values for all horizons in the studied soils were within the range of 6.51 to 7.80. The relatively higher pH values of these paddy soils are probably due to the presence of free carbonates in different soil horizons, which were apparent by the amount of effervescent when 1 N HCl was applied in the field. Soil organic carbon measured in the surface soils (0-50 cm depth) ranged from 0.60 to 3.54 percent due to plant residual maintenance in the surface soil that is a common practice in rice cultivation.

Nitrogen in the surface soil was also relatively high due to humic material accumulation ranging from 0.66 to 3.19 g Kg^{-1} (Table 3). Available phosphorous values of the surface soil were lower than 10 mg Kg^{-1} in six pedons including profiles 2, 3, 5, 7, 10 and 12. Some researchers; however, have proved that rice response to phosphate fertilizers is negative or very low because it can absorb phosphorous even in low concentrations (Tanaka and Yoshida, 1970). All soils had high available potassium more than the critical level of 250 mg Kg^{-1} (Malakouti et al, 2008). Regarding micronutrients, Zn values were generally lower than its critical level that is 2 mg Kg^{-1} because soils were relatively calcareous and Zn deficiency was expected. Despite these conditions, Fe values were higher than its critical level that is 5 mg kg^{-1} (Malakouti et al, 2008). Mineralogical analysis of selected soils including interpretations of X-Ray diffractograms revealed that dominant clay minerals of soils were Montmorilonites, Vermiculites (Hydroxy Interlayers), Micas, Chlorites and Kaolinites (Figure 3).

Table 3. Fertility properties of studied soils measured in 0-50 cm depth

Pedon	Total N g/kg	Avail. P mg/kg	Avail. K mg/kg	Micronutrients mg/kg		
				Fe	Zn	Mn
1	2.50	44.49	402.4	10.04	1.09	7.30
2	1.13	8.41	416.2	6.16	0.60	11.68
3	1.07	9.86	308.4	9.77	0.56	6.12
4	1.50	10.15	368.6	9.92	0.84	7.92
5	1.03	6.88	378.8	6.44	0.53	3.56
6	1.43	36.79	770.2	13.85	2.01	4.14
7	2.11	9.06	410.6	10.21	1.00	9.40
8	2.13	56.90	382.4	22.84	1.77	4.22
9	1.38	10.88	574.6	7.22	0.95	2.61
10	3.19	7.10	510.4	12.82	1.16	10.24
11	1.98	25.98	718.4	12.64	1.36	3.62
12	0.66	8.55	208.8	22.25	0.36	4.10

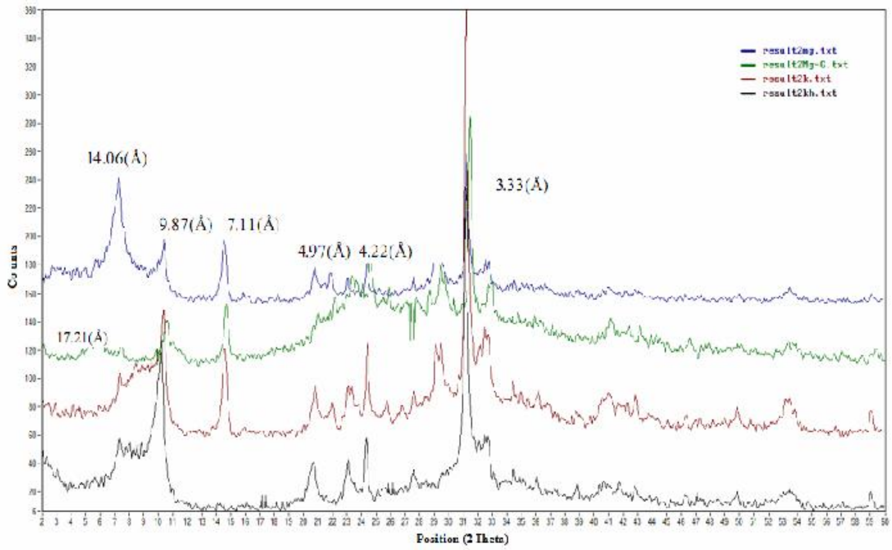

Figure 3. X-Ray Diffractograms of studied soils

Taxonomic classification

The presence of cambic horizon within 100 cm of the mineral soil surface with a lower boundary in the depth of more than 25 cm indicated that all the soils in the study area belongs to the Inceptisol soils order (Soil Survey Staff, 2010). These Inceptisols were grouped in the Aquepts suborder due to the fact that they had an aquic soil moisture regime. At the great group level, they were placed into Endoaquepts because they were under similar endosaturation conditions. The major distinction for these soils appeared at the subgroup level. Pedons 1, 4, 7, 8, 11 and12 were recognized as Aeric, pedons 2, 3 and 5 as Fluventic, pedons 6 and 9 as Vertic and pedon 10 as Mollic subgroups. All soils had the same attributes at the family level, "Fine, mixed, superactive, thermic" (Table 4).

Table 4. FCC and Taxonomic units of selected soil

Pedon	Type	Substrata type	Modifiers	FCC Class	Taxonomic Unit
1	C	-	gb	Cgb	Fine, mixed, superactive, thermic, Aeric Endoaquept
2	C	L	gv	CLgv	Fine, mixed, superactive, thermic, Fluventic Endoaquept
3	C	L	gb	CLgb	Fine, mixed, superactive, thermic, Fluventic Endoaquept
4	C	L	gb	CLgb	Fine, mixed, superactive, thermic, Aeric Endoaquept
5	C	-	gb	Cgb	Fine, mixed, superactive, thermic, Fluventic Endoaquept
6	L	C	gb	LCgb	Fine, mixed, superactive, thermic, Vertic Endoaquept
7	C	-	g	Cg	Fine, mixed, superactive, thermic, Aeric Endoaquept
8	L	-	gb	Lgb	Fine, mixed, superactive, thermic, Aeric Endoaquept
9	C	-	gbv	Cgbv	Fine, mixed, superactive, thermic, Vertic Endoaquept
10	C	-	gb	Cgb	Fine, mixed, superactive, thermic, Mollic Endoaquept
11	C	-	gb	Cgb	Fine, mixed, superactive, thermic, Aeric Endoaquept
12	S	L	g	SLg	Fine, mixed, superactive, thermic, Aeric Endoaquept

FCC units

Except for pedons 6 and 8 which were classified as "L" type and pedon 12 that was considered "S" type, all other soils belonged to "C" type because of their clayey texture in the top horizon (Table 4). A slight increase in sand content of sub-soils in pedons 2, 3 and 4 and an increase in the clay content of sub-soils in pedons 6 and 12 caused these groups to fall respectively into the "L", "C" and "L" substrata types, while the texture of other soils didn't change within the depth of 50 cm and thus had no substrata types (Table 1). The "g" modifier was used for all soils to indicate anaerobic conditions and aquic soil moisture regimes. In addition to the "g" modifier, all soils except pedons 7 and 12 also received the "b" modifier, indicating calcareous conditions and presence of $CaCO_3$ within the top 50 cm. Pedon 2 and 9 received a "v" modifier indicating vertic properties and coefficient of linear expansibility of more than 0.09 in their surface horizon (0-50 cm).

Considering additional modifiers to denote low inherent fertility, traffic pan formation, difficulty of puddling and structure degradation after rice cultivation for other crops were found unnecessary because the existing FCC parameters could, for the most part, express them. For example, it wasn't necessary to add constraints such as micronutrient deficiencies into FCC classes, since the "b" modifier denotes the calcareous nature of selected soils in which micronutrients deficiencies are a common subject. In addition, the commonly used soil tests for nitrogen are too unreliable and rapidly changing to be used as an FCC parameter (Smithson and Sanchez, 2001). Soil tests for phosphorus, although generally reliable, are also considered too labile for inclusion in the FCC.

Comparison of FCC with the soil Taxonomy

The classification of studied soils based on the Soil Taxonomy placed them into similar order, sub-order and great groups, but they were classified into different sub-groups including Aeric, Fluventic, Vertic and Mollic Endoaquepts. The Fertility Capability Classification system showed a greater capability of distinguishing and separating soils which were considered similar according to the Soil Taxonomy (Table 5). For example, Cgb, CLgb, Cg, Lgb and SLg units were only found in the Aeric Endoaquepts. In addition, the interpretation of FCC units reflected a variation in soil fertility that is useful in nutrition management and crop production planning. However, the interpretation of FCC units did not show any clear relationship to the Soil Taxonomic units, probably because of changes in some soil properties, resulted from cultivation, especially in the upper part of the solum where FCC places most of its emphasis. However, there is room for improvement. The FCC system needs further analytical data to facilitate better classification which can rarely be achieved from the Soil Taxonomy information alone.

Table 5. Taxonomic units and their equivalent classes in FCC system for studied soils

Taxonomic Unit	Aeric Endoaquept	Fluventic Endoaquept	Vertic Endoaquept	Mollic Endoaquept
FCC Unit	Cgb CLgb Cg Lgb SLg	CLgv CLgb Cgb	Cgbv LCgb	Cgb

CONCLUSIONS

The interpretation of FCC units to indicate their suitability for growing rice revealed only small differences in soil management schemes among studied soils. These differences depended on the low quantities of available micronutrients, calcareous nature and some vertic properties of the soils. The presence of "b" modifier alone represented the micronutrients deficiencies in addition to the calcareous nature of the soils and thus, eliminating the need to add any new modifier expressing these limitations.

However, these FCC units could be useful because of the difficulties in the interpretation of taxonomic units of the soils, which regarded all soils as Endoaquepts and they were similar in their properties at the family level. The FCC was especially useful for fertility evaluation of paddy soils.

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REFERENCES

Buol SW (1986) Fertility Capability Classification System and its utilization. Soil Management under Humid Conditions in Asia and Pasific ASIALAND. IBSRAM, Bangkok, pp. 318-331.

Buol S.W, Sanchez P.A, Cate R.B, Granger MA (1975) Soil Fertility Capability Classification System for fertility management. P. 126-145. In Soil Management in Tropical America. E. Bornemisza and A. Alvarado, eds. North Carolina State University, Raleigh, North Carolina.

Malakouti M.J, Keshavarz P, Karimian N (2008) A Comprehensive Approach towards Identification of Nutrients Deficiency & Optimal Fertilization for Sustainable Agriculture. 7th Edition of the book. Tarbiat Modares University Press, Tehran, Iran.

Sanchez P.A, Buol SW (1985) Agronomic Taxonomy for wetland soils. P, 207-227. In wetland soils; Characterization, Classification, and utilization. Proceeding of a workshop held 26 March to April 1984. Manil, Philippines, and IRRI.

Sanchez P.A, Palm C.A, Buol SW (2003) Fertility Capability soil Classification: a tool to help assess soil quality in the tropics. Geoderma. 114, 157-185.

Smith CW (1989) The Fertility Capability Classification System (FCC)-3rd approximation: a technical soil Classification system relating pedon characterization data to inherent fertility characteristics. PhD dissertation, North Carolina State University, Raleigh. 430 pp.

Smithson P.C, Sanchez PA (2001) Plant nutritional problems in marginal soils of developing countries. In: Ae, N., Arihira, J., Okada, K., Srinivasan, A. (Eds.), Plant Nutrient Acquisition: New Perspectives. Springer Verlag, Tokyo, pp. 32-68.

Soil Survey Staff (2004) Soil Survey Laboratory methods manual, Version No. 4.0, USDA natural resources conservation service (NRCS). Soil survey investigation report No 42, US gov. Print Office, Washington, D.C.

Soil Survey Staff (2006) Soil Survey Manual, USDA, Soil Conservation Service, Agricultural Handbook.

Soil Survey Staff (2010) Keys to Soil Taxonomy. Soil Conservation Service. Eleventh Edition.

Somchai A, Stephen N, Irb K (2009) Interpretability Comparison between Soil Taxonomic and Fertility Capabilty Classification Units: A Case of Some Major Cassava Soils in Northeast Thailand. Kasetsart J. Natural Science, Number 49:9. Pages 9-18.

Tanaka A, Yoshida S (1970) Nutritional disorders of the rice plant in Asia. International Rice Research Institute Tech. Bull. 10. 51 p.

Torabi H, Eghbal M. K, Givi J (2005) Evaluation of Rice Cultivated Soils Using FCC and Parametric Methods and Comparison of them in Guilan province. Pajouhesh and Sazandegi. Number 68, page 20-31.