

(:)

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(/ / : / / :)

t t

(t t)

(RMSE)

(R²= /)

(R²= /)

/ /

:

...

(Karlen *et al.*, 2003)

(Lal & Stewart, 2010)

(FAO, 2006)

(Chang & Borrough, 1987)

(Borrough, 1989)

(FAO, 2007)

Tang *et al.*,)

1991; Borrough *et al.*, 1992; Tang & Van Ranst,
1992; Davidson *et al.*, 1994; Van Ranst *et al.*,
1996; Braimoh *et al.*, 2004; Sicut *et al.*, 2005; Joss
(*et al.*, 2008

(McKenzie *et al.*, 2008)

(Zadeh, 1965)

AND OR

NOT

(FAO, 2007)

(1991)

(Peneva & Popchev, 2003)

t t

(AWO)

(Soasa & Kaymac, 2002)

FAO, 1976;)

(Choudhury & Jansen, 1998

Grabisch,)

FAO,)

(1995

(1976

¹ Averaging Weighted Operators

(CLO)

Grabisch,)

(1995; Kojadinovik, 2007

(FI)

(Torra & Narukawa, 2006)

Grabisch, 1995;)

(Kojadinovik, 2007

.()

UTM

(Torra & Narukawa, 2006)

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(Pham & Yan, 1997)

(CI)

Murofushi & Sugeno, 1989; Chiang, 2000;)

Meyer & Roubens, 2006; Wang *et al.*, 2006;

(Grabisch & Labreuche, 2008

(Yang *et al.*, 2005)

(Crawford, 2010)

(USDA, 2010)

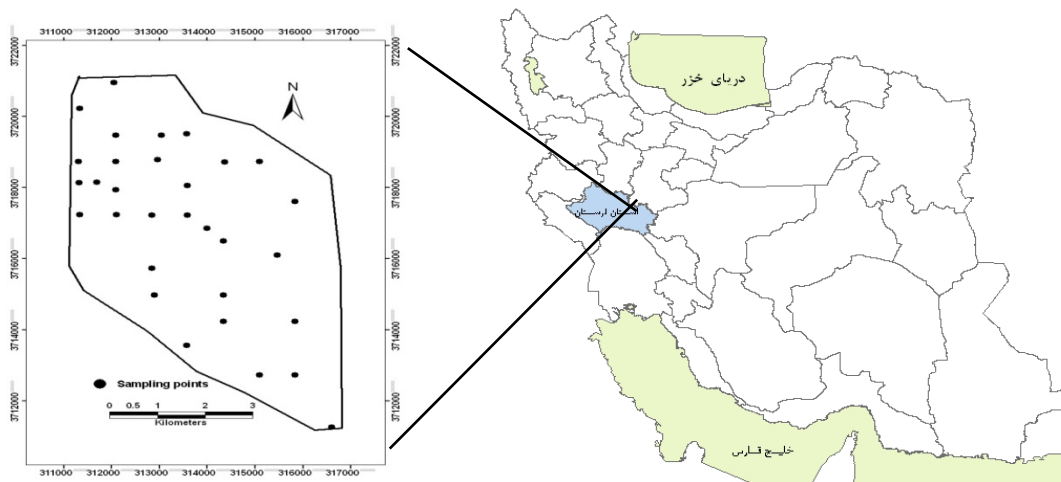
Calcixerepts, Haploxerepts,

Xerorthents Xerofluents

³ Combined Lukasiewicz Operator

¹ Fuzzy Integral

² Choquet Integral



x X A (\quad)

Zimmermann,)

:(1992

$$A = \{(x, \mu_A(x)) | x \in X\}$$

(McLean, 1982) pH

(Rhoades, 1982)

Nelson,) HCl

Nelson &)

(1982

(Sommers, 1982

x

x

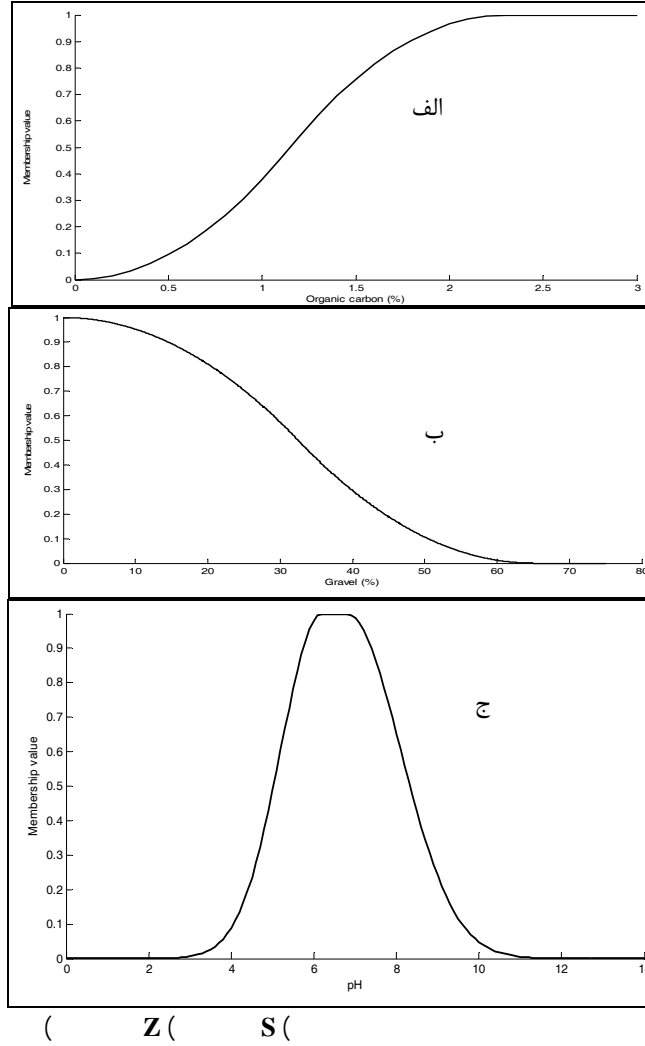
A

A

\times

.(Tang *et al.*, 1997)

Z



& Yuan, 1995; Sousa & Kaymak, 2002;
 (Baczynski & Iyaram, 2008

T

t

[0,1]

T

$$T: [0, 1]^2 \rightarrow [0, 1]$$

(Sousa & Kaymak, 2002)

¹ Angular norm

Zimmermann, 1992; Klir)

$X = \{x_1, x_2, \dots, x_n\}$ (2002)
 $P(\Xi)$
 $g: P(X) \rightarrow [0, 1]$

$g(\emptyset) = 0, g(X) = 1$
 $g(A) \leq g(B)$ then $A \subset B$, and $A, B \subset P(X)$ If

$A \cap B = \emptyset$ with $A, B \subset X$

$\lambda > -1$
 $g(A \cup B) = g(A) + g(B) + \lambda g(A)g(B)$

$g(X) = 1$
 $\lambda + 1 = \prod_{i=1}^n [(1 + \lambda)g_i]$

$A = \{x_1, x_{1+1}, \dots, x_n\}$
 $[g(A)_i]$

$[g(A)_n] = g(x_n) = g_{\Xi}$

$[0, 1]$ b, a (T_{LK})
 Baczyński & Jayaram,)

$T_{LK}(a, b) = \max(a + b - 1, 0)$ (2008)

S t $[0, 1]$

$S(a, 0) = a$ $S: [0, 1]^2 \rightarrow [0, 1]$

$[0, 1]$ b, a (S_{LK})
 Baczyński & Jayaram,)

$S_{LK}(a, b) = \min(a + b, 1)$ (2008)

(Pham & Yan, 1997)

(Van Ranst *et al.*, 1996)

$= \min(c_1 + c_2 + \dots + c_n, 1)$ LSI
 $c_i = \max(0, \mu_i + w_i - 1)$

LSI
 μ_{Ξ}
 w_{Ξ}

Sousa & Kaymak,)

³. Ξ - measures

¹ - Angular conorm
² - Land suitability index

\mathbf{R}^{-}

RMSE

For $1 \leq i \leq n$ (

$$E[g(A)_i] = g_i + g(A_{i+1}) + \lambda g_i g(A_{i+1})$$

$h(x_1), h(x_2), \dots, h(x_n)$

g

Tang *et al.*, 1997; Braimoh)

(*et al.*, 2004

$$\int_X h(\cdot) = g(\cdot). \quad ($$

X

$$E_g(h) = \sum_{i=1}^n [h(x_i) - h(x_{i-1})] [g(A)_i] \quad ($$

$$h(x_1) \leq h(x_2) \leq \dots \leq h(x_n)$$

$$h(x_0) = 0$$

(\mathbf{R}^{-})

(RMSE)

RMSE

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N [(Z(x_i)) - Z^*(x_i)]^2} \quad ($$

$Z(x_i)$

$Z^*(x_i)$

N

¹ Root Mean Square Error

...

		CV(%)	SD	Max	Min	Mean*	
/	/	/	/	/	/	/	EC(dSm ⁻¹)
/	/	/	/	/	/	/	(%)
/	/	/	/	/	/	/	(%)
/	/	/	/	/	/	/	(%)
/	/	/	/	/	/	/	CaCO ₃
/	/	/	/	/	/	/	(%)
/	/	/	/	/	/	/	pH
/	/	/	/	/	/	/	(%)
/	/	/	/	/	/	/	(%)
	/	/	/	/	/	/	kg h ⁻¹
							(¹

CV Mean, Min, Max, SD :*

Van Ranst *et al.* (1996)

(*et al.*, 1996; Tang *et al.*, 1997)

EC

(

t)

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t

S

Z

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pH

Saaty, (1980)

(AHP)

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.(1980)

/ /

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(A)

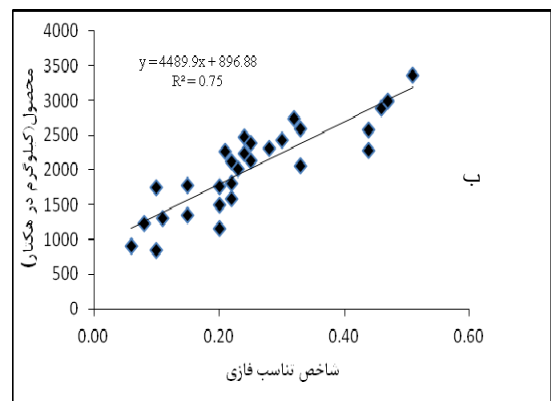
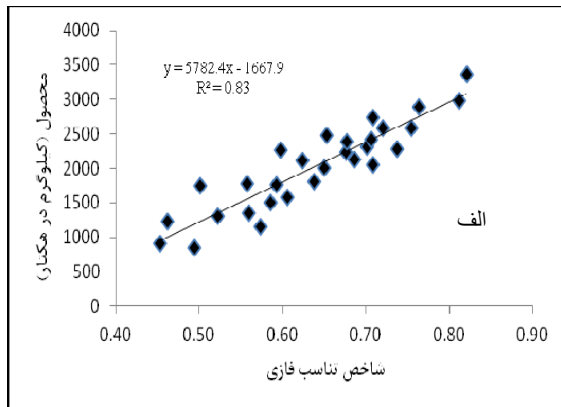
$g(A)$	A	$g(A)^*$	A^*
/	$\{x_1, x_2, x_3, x_4\}$	/	\emptyset
.	.	.	$\{x_1\}$
.	.	.	.
.	.	.	.
/	$\{x_4, x_5, x_6, x_7\}$.	.
/	$\{x_1, x_2, x_3, x_4, x_5\}$	/	$\{x_7\}$
.	.	/	$\{x_1, x_2\}$
.	.	.	.
.	.	.	.
/	$\{x_3, x_4, x_5, x_6, x_7\}$.	.
/	$\{x_1, x_2, x_3, x_4, x_5, x_6\}$	/	$\{x_6, x_7\}$
.	.	/	$\{x_1, x_2, x_3\}$
.	.	.	.
.	.	.	.
/	$\{x_2, x_3, x_4, x_5, x_6, x_7\}$.	.
/	$\{x_1, x_2, x_3, x_4, x_5, x_6, x_7\}$	/	$\{x_5, x_6, x_7\}$

$g(A) \quad A$

CI

R^2 RMSE

R^2	RMSE
/	/
/	/
	CLO



(

(



/ ()
/
/

.(Peneva & Popchev, 2003)

()

(**R² = 0.83**)

/ pH
pH (Sys *et al.*, 1991)
/

(**R² = 0.75**)

RMSE

.(

/ /

/ /

.(Van Ranst *et al.*, 1996)

(Crowford, 2010)

CI

.()

CI

/ /
()

/ / /

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Performance Assessment of Fuzzy Integrals as Aggregation Operators for Soil Suitability Analysis (Case Study: Silakhor Plain of Lorestan Province)

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Abstract

The traditional fuzzy operators, such as t-norms, t-conorms and averaging operators have been used for soil suitability evaluation to aggregate criteria as an overall suitability index. However, such operators do not account for the degree of compensation common to human aggregation criteria, especially in the presence of conflicting criteria. Fuzzy integrals are powerful and flexible aggregation functions that combine the data provided by several information sources based on fuzzy measures. One of the most known fuzzy integrals is the Choquet Integral (CI) that is often used as a nonlinear aggregation tool that takes into account the interactions among the conflicting and interrelated criteria. CI has hardly ever been used in soil suitability evaluation. In this paper, we tested the CI performance as an aggregation operator to evaluate soil suitability for irrigated rice in Lorestan province, western Iran. To conduct standard fuzzy analysis, soil samples were taken from 29 farms under rice cultivation and for the purpose of validation, average dry matters of the three 1×1m quadrates were used to determine the grain yield of rice in each farm. Fuzzy membership values of seven evaluation criteria were combined using CI to obtain a single suitability index in each land unit. In order to validate the results, the soil suitability indices were tested and compared with the results obtained by Lukasiedwicz's t-norm and t-conorm operator (CLO) by correlation with the measured rice yield. The results show R^2 values were fairly high for both aggregated methods, but the soil suitability index obtained by the CI integral has significantly better agreement with rice yield ($R^2 = 0.83$) than those obtained with the CLO ($R^2 = 0.75$). These results call for further investigation of CI as an alternative, and perhaps a better, aggregation operator for soil suitability evaluation.

Keywords: Land suitability evaluation, Fuzzy Integral, Choquet Integral, Fuzzy operator