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EXTRAPOLATING THE SUITABILITY OF SOILS AS NATURAL REACTORS USING AN EXISTING SOIL MAP: APPLICATION OF PEDOTRANSFER FUNCTIONS, SPATIAL INTEGRATION AND VALIDATION PROCEDURES

[EXTRAPOLANDO LA APTITUD DE LOS SUELOS COMO REACTORES NATURALES, USANDO UN MAPA DE SUELO EXISTENTE: APLICACIÓN DE FUNCIONES DE PEDOTRANSFERENCIA, INTEGRACIÓN ESPACIAL Y PROCEDIMIENTOS DE VALIDACIÓN]

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SUMMARY

The aim of this study was the spatial identification of the suitability of soils as reactors in the treatment of swine wastewater in the Mexican state of Yucatan, as well as the development of a map with validation procedures. Pedotransfer functions were applied to the existing soils database. A methodological approach was adopted that allowed the spatialization of pedotransfer function data points. A map of the suitability of soil associations as reactors was produced, as well as a map of the level of accuracy of the associations using numerical classification technique, such as discriminant analysis. Soils with the highest suitability indices were found to be Vertisols, Stagnosols, Nitisols and Luvisols. Some 83.9% of the area of Yucatan is marginally suitable for the reception of swine wastewater, 6.5% is moderately suitable, while 6% is suitable. The percentages of the spatial accuracy of the pedotransfer functions range from 62% to 95% with an overall value of 71.5%. The methodological approach proved to be practical, accurate and inexpensive.

Key words: retention of organic matter; mineralization; soil carbon evolution; map accuracy; Yucatan.

RESUMEN

El objetivo de este trabajo fue la identificación espacial de la aptitud de los suelos como reactores en el tratamiento de las aguas residuales porcinas en el estado de Yucatán, así como la elaboración de un mapa con los procedimientos de validación. Las funciones de pedotransferencia se aplicaron a la base de datos de suelos preexistente. Se aplicó un enfoque metodológico que permitió la espacialización de las funciones de pedotransferencia que son datos puntuales. Se elaboró un mapa de aptitud de las asociaciones de suelos como reactores, así como un mapa del nivel de precisión de las asociaciones mediante el uso de técnicas de clasificación numérica como el análisis discriminante. Los suelos con mayor índice de aptitud son Vertisoles, Stagnosoles, Nitisoles y Luvisoles, El 83.9% de la superficie del estado de Yucatán es marginalmente apta para el uso de los suelos como receptores de aguas residuales porcinas, el 6.5% es moderadamente apta; el 6% es apta. Los porcentajes de precisión de la espacialización de las funciones de pedotransferencia van desde 62% hasta un 95%, con un valor general del 71.5%. El enfoque metodológico resultó ser práctico, preciso y de bajo costo.

Palabras clave: retención de material orgánica; mineralización; evolución de carbono; precisión del mapa; Yucatán.

INTRODUCTION

The current global environmental crisis has led to the recognition of the role of soils as a "reactor which filters, buffers and transforms matter to protect the environment, groundwater and food chain from pollution" (Blum *et al*., 2006). Under these circumstances, integrated studies have been conducted relating soil, water and pollutants (IUSS, 2006), and hydropedology has emerged as a hybrid discipline the aim of which is to enhance pedological and hydrological knowledge in order to provide solutions to issues related to sustainable land use planning (Lin, 2003; Bouma, 2006). Among the principal concerns of this discipline is the generation and use of pedotransfer functions (PTF).

These are mathematical models using widely known soil properties, reported in soil surveys or easily measured in the laboratory, to estimate processes that are difficult to measure, mainly those related to soil hydraulic properties (Rawls *et al*. 2003; Pachepsky *et al*. 2006). For this reason, most of the pedotransfer functions reported in the literature have been for the estimation of hydraulic conductivity and infiltration in soils (Wösten *et al*., 2001; Sobieraj *et al*., 2001; Nemes *et al*., 2005). Recently, Aguilar *et al*., (2011) designed pedotransfer functions with which it is possible to estimate the retention and mineralization processes of dissolved organic matter (DOM) from swine wastewater (SWW) in the soils of Yucatan. Pedotransfer functions of this type suggest the potential use of soils as natural reactors, considered a low-cost option for environmental management of organic waste, especially in developing countries (Friedel *et al*., 2000; IUSS, 2006.) The application of pedotransfer functions requires as extensive a database of soils as possible. For zonification, it is desirable to have an existing soil map, created with a geomorphopedological approach (Zinck, 1988), as well as a technique to evaluate the accuracy of extrapolation (McBratney *et al*., 2003; Mendonça-Santos, 2007).

The state of Yucatan, Mexico, has suitable conditions for soil mapping of environmental functions since, on the one hand, there is a serious problem of swine wastewater management, with the generation of 6,095,500 m^3/year, of which 37% receives no treatment (Drucker *et al*., 2003) constituting a source of contamination of soils and aquifers (Pacheco *et al*., 2004, Herrera and Morales, 2009); and on the other, it has enough inputs to conduct a statewide spatial extrapolation. These inputs include: i) Pedotransfer functions on the use of soils as natural reactors (Aguilar *et al*., 2011; Bautista *et al*., 2010), ii) a database of soils comprising 400 profiles with field and laboratory data (INEGI, 1984abcdef; Estrada, 2000, Bautista *et al*., 2003ab, 2004, 2005, Amaya *et al*., 2005; Hernández, 2005; May and Bautista, 2005); and iii) an existing soil map created with a geomorphopedological approach (Bautista *et al*., 2007; Ihl *et al*., 2007). An accurate map can be created with the above inputs, using multivariate numerical classification techniques such as discriminant analysis, whereby it is possible to ascertain the percentage of individuals correctly assigned to groups previously formed through the analysis of continuous variables that characterize the groups (Bautista *et al*., 2003 b, Bautista *et al*., 2009b, Giasson *et al*., 2008, Feldman *et al*., 2009).

Under these circumstances, the objective of this work was the application of pedotransfer functions to the database of soils of the state of Yucatan in order to estimate the retention and transformation of dissolved organic matter in soils and spatially identify the suitability of soils as reactors in the treatment of swine wastewaters; as well as the development of a map with validation procedures. This practical information constitutes a valuable instrument for decision making in the field of environmental conservation.

MATERIALS AND METHODS

Study area

The state of Yucatan is located in the north of the Yucatan Peninsula, southeast Mexico. The geological formations in this state are made up of Tertiary limestone, which are sequentially distributed from younger in the north (Pliocene-Miocene) to older in the south (Eocene). The main soil groups in the southern part of the state of Yucatan are Cambisols (CM), Luvisols (LV), Vertisols (VR) and Leptosols (LP) (Figure 1), overlaid by sediments of the Pliocene epoch that constitute karstic plains and hills, mainly comprising Cambisols and Leptosols. The coastal zone is made up of plains of sediments from the Quaternary period, consisting mainly of Arenosols (AR), Solonchaks (SC), Gleysols (GL) and Histosols (HS) (from the Pleistocene and Holocene epochs) (Bautista *et al*., 2007; Ihl *et al*., 2007). Yucatan is characterized by a “warm” to “very warm” climate, and there is a gradient of average annual precipitation ranging from 200–400mm in the northwest to 1000–1200mm in the southeast (Bautista *et al*., 2009 a). The climate in Yucatan, based on Köppen’s classification, as modified by García (2004), has the following subtypes: semi-arid and subhumid warm. The distribution of the vegetation is a consequence of the climatic zones and of the rainfall regime. The types of vegetation present in Yucatan are from coastal dune scrub to seasonal deciduous forest.

Handling of soil database and application of pedotransfer functions

The state of Yucatan Mexico has the software "Multilingual Soil Profile Database" (SDBm) (De la Rosa *et al*., 2002), with the registration of 400 soil profiles, 100 are field descriptions and 300 are profiles with analytical data. All profiles are classified under the World Reference Base for Soil Resources (WRB) scheme (IUSS working group WRB, 2006). The pedotransfer functions were applied to 202 records of soil profiles that included the properties of organic matter (OM), cation exchange capacity (CEC) and percentage of clay (PC). The pedotransfer functions enabled estimation of the retention of DOM (RDOM) and DOM mineralization through soil carbon evolution (SCE) and potential anaerobic nitrogen mineralization (PANM), the PTF were (Aguilar *et al*., 2011):

RDOM = 41.5 + (2.8*CEC) - (0.81*PC) - (3.5*OM) r= 0.81
SCE= 542.3 + (20.1*OM) + (4.6*CEC) - (2.7*PC) r= 0.96
PANM = -8.4 + (3.45*OM) + (1.12*PC) - (2.2*CEC) r= 0.88

Spatial integration: Mapping the suitability of soils as natural reactors

With the results of the pedotransfer functions, and also considering the total depth profile (TDP) of the soil, multi-criteria analysis was performed in order to obtain a suitability index (SI) for each soil group classified according to the WRB (IUSS working group WRB, 2006) (Figure 2). The retention of dissolved organic matter (depuration), the soil carbon evolution (decomposition) and the total depth profile (TDP) (protection factor), are considered to be environmental properties, and the anaerobic nitrogen mineralization potential as a criterion of fertility. The proposed suitability index is: SI = (RDOM * 0.25) (SCE * 0.25) (PANM * 0.25) (TDP * 0.25).

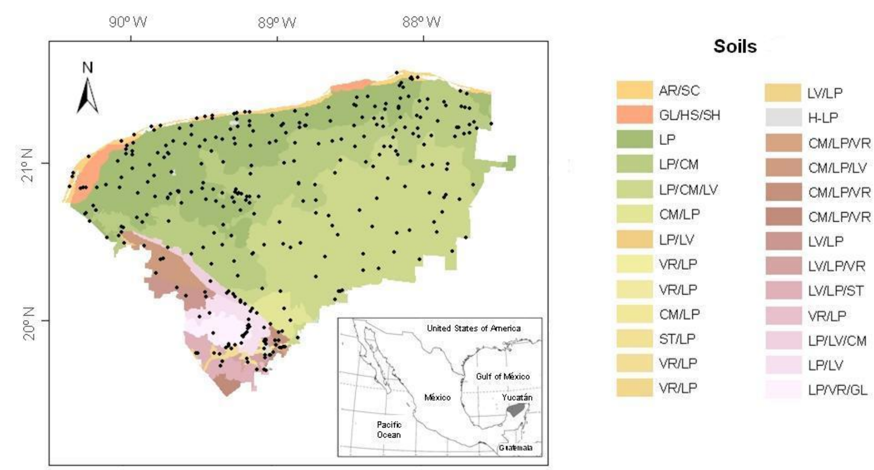

Figure 1. Study area location. Points indicate the database soil profiles (Modified from Bautista *et al*., 2007 and Ihl *et al*., 2007).

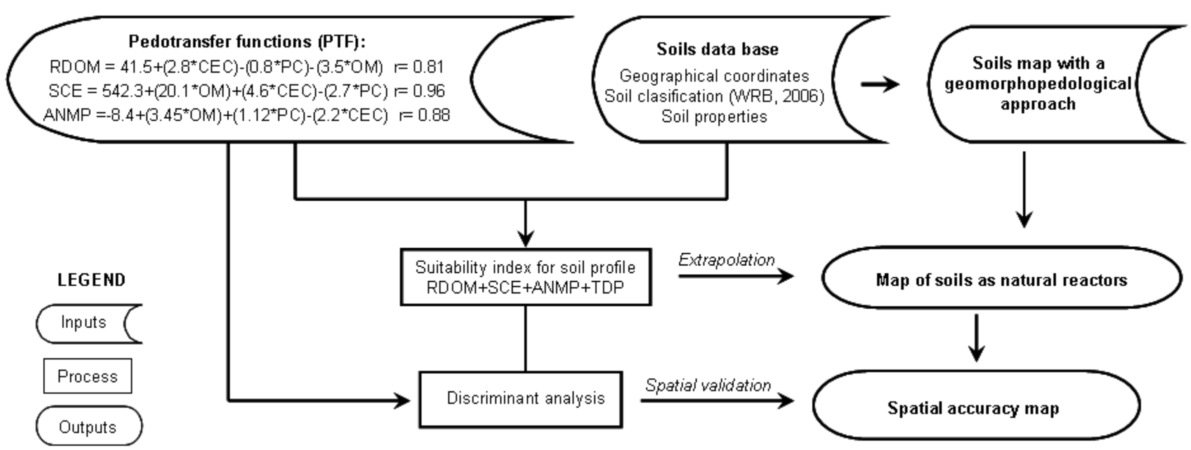

Figure 2. Methodological flow diagram

The suitability index values were transformed to percentages and equal weights (0.25) were assigned to the variables. The SI selects soils with lower adverse effects and greater benefits from the use of swine wastewaters (Auxiliadora and Manera, 2003).

The 1:250,000 scale soil map reported by Bautista *et al*., (2007) and Ihl *et al*., (2007), with some modifications such as the changes in geomorphic nomenclature, and the inclusion of new data from soil profiles in areas without soil information, was used as a cartographic base (Figure 1). This map shows the geomorphic units of Yucatan differentiated by morphometric attributes (altitude and slope) (Ihl *et al*., 2007) and contained within each geomorphic unit is the soil association information (Bautista *et al*., 2007), which are the soil groups with the largest representation at that level. A Total Suitability Index (TSI) was calculated per soil association. In assessing the suitability level of the soil associations, the LP of the isolated hills or lined hills was not considered because they occupy the upper part the micro-relief, which is why their use is very limited in agriculture. In cases where there is only field pedological information, averages of the profiles of other geoforms were used for each soil group to estimate the suitability index of the soil association.

The Total Suitability Index was obtained by allocating a percentage weight to the Suitability Index of each soil group according to its dominance in the association: a) TSI = SI_1 from soil; b) TSI = (SI_1*0.6) + (SI_2*0.4); c) TSI = (SI_1*0.5) + (SI_2*0.3) + (SI_3*0.2).

Suitability classes of soils as natural receptors of swine wastewaters per soil association were: a) S1, Suitable, b) S2, moderately suitable; c) S3, marginally suitable, and d) U, unsuitable. The map was developed using the *ArcGIS* software, according to the suitability classes of the soil associations as receptors of swine wastewaters.

Validation procedures: spatial accuracy map

To test if the soil group determined the retention of dissolved organic matter, soil carbon evolution and potential anaerobic nitrogen mineralization regardless of the geoform in which it is found, a discriminant analysis was implemented in which soil group (AR, CM, GL, LP, LV, SC, ST and VR) was the classification variable (categorical variable) and the explicative variables were the estimated process with the pedotransfer functions as retention of dissolved organic matter, soil carbon evolution and anaerobic nitrogen mineralization potential, and also the suitability index (continuous variables). If discriminant function analysis is effective for a set of data, the classification table of correct and incorrect estimates will yield a high percentage at correct assignation (Bautista *et al*., 2009 b). The discriminant analysis was applied to 179 data of soils using the software *STATGRAPHICS Plus*. Groups such as: CL, KS, NT and PH are not included in the associations of soil and were not considered in the discriminant analysis, thus reducing the number of profiles from 202 to179.

With the correct allocation percentages (accuracy) for each soil group, a precision map of soil associations was developed following the same procedure as for the overall suitability map and using four categories of precision: A) greater than 90%, B) between 80 and 89%, C) between 70 and 79%, and D) between 60 and 69%.

RESULTS

Suitability of soils as reactors

The soil groups with greatest retention of dissolved organic matter were the Phaeozem (PH), VR, CL, LP and CM with 99, 89, 78, 75 and 71%, respectively (Table 1). The soil carbon evolution was higher in the LP with 895 mg C kg^{-1} soil. The anaerobic nitrogen mineralization potential showed two patterns of behavior: a) soils with negative values, and b) soils with positive values. The soil groups with the highest suitability index are VR, NT, ST, and LV. The suitability index generated by the integration of retention of dissolved organic matter, soil carbon evolution, anaerobic nitrogen mineralization potential, and total depth profile generally shows low variability.

Map of evaluation of soils as reactors

The suitable areas (S1) have indices with values ranging from 40-45, with the highest rates occurring when soil associations present two groups of deep and clay soils, such as Luvisols, Vertisols and Stagnosols (Table 2). In general, class S1 occupies 6% of the area of the state, which corresponds to 2350 km^2 (Figure 3), and it is in these sites where the opportunities for agricultural use of swine wastewater exist.

Moderately suitable areas (S2) have index values ranging between 34 and 38, where within the association there are two groups of soils and the first is a clay soil, such as VR/LP, ST/LP and LV/LP, or when the soil association is of three groups and at least one group is a deep and clayey soil, such as CM/LP/LV and LP/VR/GL (Table 2). Together, these represent 6.5% of the area of Yucatan, equivalent to 2516 km^2 (Figure 3), and consist of zones with areas from 21 km^2 to 802 km^2.

Table 1. Suitability index of soils as natural reactors of swine wastewater

Soil Group	N	RDOM (%)		SCE (mg kg^{-1})		PANM (mg kg^{-1})		TDP (cm)		SI	
		χ	α	X	A	χ	A	χ	α	χ	α
VR	12	89	36	623	46	-10	29	100	16.7	45	1
NT	1	22		604		39		150		44	
ST	4	51	34	564	90	17	27	92	7	44	2
LV	29	51	20	655	123	12	22	93.3	32.2	42	4
AR	4	35	5	580	26	0,2	6	102.3	6.3	38	1
CM	48	71	42	769	144	-7	38	65.5	30.7	36	7
CL	8	78	46	779	170	-13	36	50	14	33	6
PH	8	99	15	824	117	-29	11	37	13.3	30	3
KS	2	56	34	698	66	2	29	38	2.8	28	0
GL	1	32		581		7		50		27	
LP	78	75	25	895	169	-12	21	18.4	7.9	26	4
SC	7	36	17	680	107	9	15	27.3	12.4	24	4

RDOM = retention of dissolved organic matter; SCE= soil carbon evolution; PANM= potential anaerobic nitrogen mineralization; TDP= total depth profile; SI= suitability index; χ= mean; α= standard desviation. VR= Vertisol; NT= Nitisol; ST= Stagnosol; LV= Luvisol; AR= Arenosol; CM= Cambisol; CL= Calcisol; PH= Phaeozem; KS= Kastanozem; GL= Gleysol; LP= Leptosol and SC= Solonchak

Marginally suitable areas (S3) have suitability index values ranging from 26 when the Leptosol group dominates the cartographic unit and is of a large area, to zones with a suitability index equal to 32. In this class of suitability the associations are of two groups of soils, where LP is usually the dominant group. There is only one site with an association of three groups of soils (LP/CM/LV) in which there is a deep and clayey soil, but it is less dominant, which is why its weight in the index is lower (Table 2). In general, these areas represent 83.9% of the area of Yucatan, equivalent to 32,732 km^2, and are where all the pig farms in the state of Yucatan are found, mainly in the city of Merida and its surroundings (Figure 3).

Unsuitable areas (U), while still showing index values that could be considered between the classes S3 and S2, were not thus classified due to the nature of the Arenosols, Solonchaks, Gleysols and Histosols (Table 2), all of which lack agricultural importance because of low fertility, salinity, poor drainage and high susceptibility to degradation, respectively. Moreover, these soils are located in biodiversity protection areas of great ecological and environmental importance, such as the Peten, mangrove and coastal dune scrub. They cover 3.6% of the area of Yucatan, equivalent to 1395 km^2 (Figure 3).

In the associations with suitable level, the group LP is always associated with a group or two groups of deep soils of high clay content, such as LV, VR and/or ST. However, this rule is similarly evident in associations classed as moderately suitable, although there are some differences in some associations where the CM group is dominant. The associations classified as marginally suitable present CM or LP as dominant soil groups; LV is present in some associations, but to a lesser extent.

Mapping the spatial accuracy

Discriminant analysis, using soil group as the discriminating variable, gave a 71.5 % correct assignation, thereby resulting in a correct validation between soil groups and the soil properties estimated with the pedotransfer functions (Table 3).

More specifically, soil groups with greater certainty for the extrapolation of the pedotransfer functions and suitability index are AR and GL (100%), LP (95%), VR and SC (75 and 71% respectively). The soil groups with less certainty for the extrapolation of the suitability index were the ST (50%), LV and CM, both with 48%. For further study, the use of primary qualifiers in the case of LV and CM is suggested, as well as an increase in the number of ST profiles to increase the percentage of correct allocation and improve the extrapolation of the use of the pedotransfer functios in these soils.

Table 2. Suitability of soil associations for the application of swine wastewater

Soils	Suitability index	Class	Surface (km^2)	Accuracy (%)
LV/LP/VR	45	S1	194	68
LV/LP/ST	44	S1	728	63
VR/LP	44	S1	39	83
LV/LP	43	S1	555	67
LP/LV	40	S1	834	76
VR/LP	38	S2	22	83
VR/LP	38	S2	21	83
CM/LP/LV	38	S2	802	62
LP/LV/CM	38	S2	344	72
LP/VR/GL	38	S2	753	90
VR/LP	37	S2	74	83
VR/LP	37	S2	77	83
LV/LP	37	S2	18	67
ST/LP	36	S2	53	68
CM/LP/VR	35	S2	29	68
CM/LP/VR	34	S2	156	68
CM/LP/VR	34	S2	169	68
CM/LP	32	S3	759	67
LP/CM	31	S3	9664	76
LP/CM/LV	31	S3	12373	72
CM/LP	31	S3	40	67
LP/LV	30	S3	27	76
LP	27	S3	9827	95
LP	26	S3	43	95
AR/SC	33	U	740	88
GL/HS/SC	26	U	645	88

S1= suitable; S2= moderately suitable; S3= marginally suitable; U= unsuitable

The first category of greater accuracy (> 90%) occupies 10,623 km^2, which corresponds to 27% of the total study area, and occurs in soil associations with a dominance of LP, as well as an area of VR and GL. The second category of accuracy (80-89%) has an area of 1,618 km^2 which corresponds to 4% of the area of Yucatan and are areas with VR/LP associations.

The third category (70-79%) occupies the largest area at 23,242 km^2, which corresponds to 60% of the study area; the LP group dominates these areas in all the associations and is associated with CM and LV or with both groups.
The fourth category (60-69%) covers 3,501 km^2, which is 9% of the area of Yucatan; the main characteristic of these areas with this level of accuracy is that in all soil associations, the main group can be CM, LV or ST, which are those groups with lower percentages of correct allocation according to discriminant analysis, another characteristic is that the second soil group in the association is always an LP, thus increasing the accuracy. If the association is of three groups, the accuracy is higher when this includes a VR but lower when associated with a ST or LV (Table 3, Figure 4).

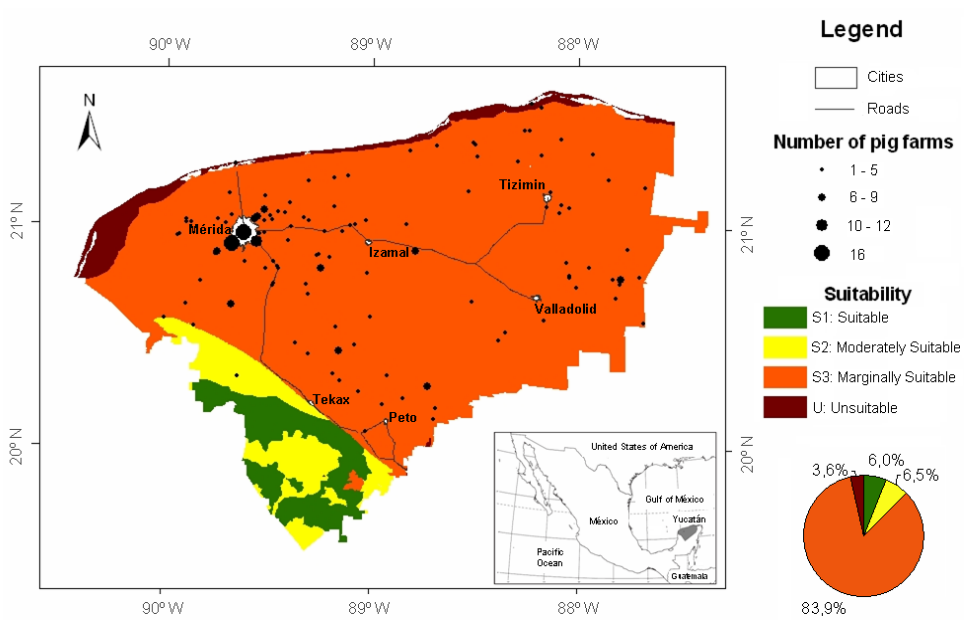

Figure 3. Map of the suitability of soils in Yucatan as swine wastewaters receptors

Table 3. Numerical classification based in RDOM, SCE and PANM values using soil group as the discriminant variable.

Soils	Correct classification (%)	AR	CM	GL	LP	LV	SC	ST	VR	Total
AR	100	4	0	0	0	0	0	0	0	4
CM	48	0	23	0	8	10	3	2	2	48
GL	100	0	0	1	0	0	0	0	0	1
LP	95	0	0	0	70	0	4	0	0	74
LV	48	0	2	0	1	14	1	9	2	29
SC	71	0	1	0	1	0	5	0	0	7
ST	50	0	0	0	0	1	0	2	1	4
VR	75	0	0	0	0	1	0	2	9	12
Total	71.5									

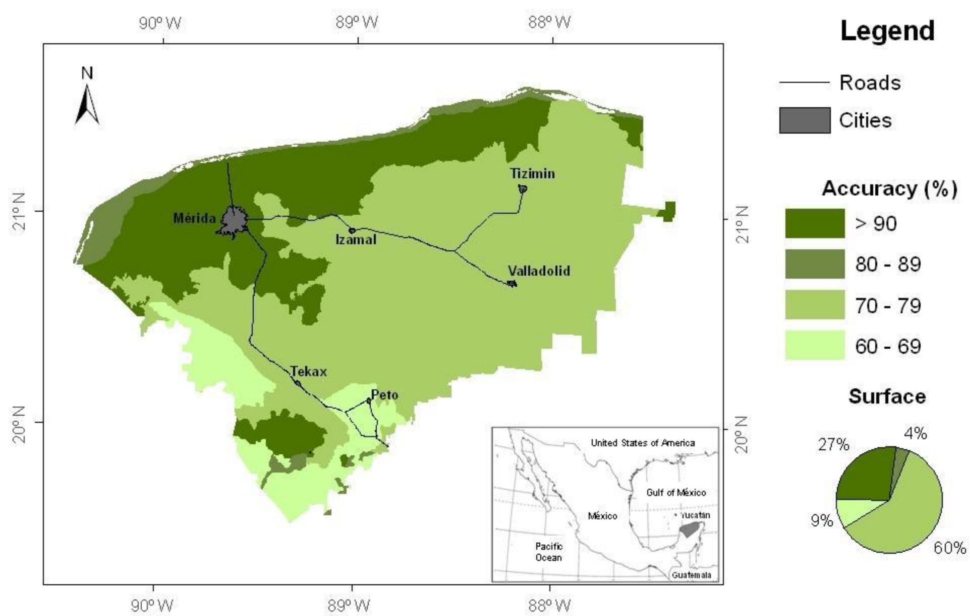

Figure 4. Accuracy map through the correct assignations per soil association

DISCUSSION

Suitability of soils as reactors

Dissolved organic matter is one of the most common contaminants of water bodies. However, in the soil it can act as an improvement or as a pollutant depending on the properties of the soil receptor (Bautista *et al*., 2000, Bautista *et al*. 2010). In both cases, each soil functions to different degrees of intensity due to their particular chemical, physical, mineralogical and biological properties. Recently, the role of soil as a buffer against pollutants has been recognized (Bouma, 2009), and the need to design pedotransfer functions (Bouma, 2006) in order to use pre-existing soil databases in the estimation of soil properties that are difficult to measure, such as the retention and mineralization of organic matter. For this reason, soil databases are an essential input in the spatial estimation of retention and mineralization of carbon and nitrogen in soils, i.e., of the function of soils as reactors in the treatment of wastewaters of high organic load.

Although each soil acts differently, in this particular study the variation in suitability index values are minimal per soil group, which allowed the use of intervals of only five units to form suitability classes by soil association.

There are some reports on the mineralization of organic matter in the soils of Yucatan, for example, levels of 532-1143 mg CO_2 kg^{-1} and 15.6 to 25.32 mg kg^{-1} NH_4 have been reported in Luvisols (Amaya *et al*., 2005, Castillo *et al*., 2010), and the values obtained in this study fall into both of these ranges. By contrast, the soil carbon evolution values of Vertisols and Cambisols in this study can be regarded as very high (Haney and Franzluebbers, 2009) and high (Rasul *et al*., 2008), respectively, but it must be considered that the application of dissolved organic matter promotes microbial activity.

Evaluation map of soils as reactors

The map of suitability of soils as reactors on a scale 1:250,000 i.e. a scale of recognition, allows a general overview of the distribution of soils in a wide area or region.

The marginally suitable class occupies a large area and is in the same polygon where all the pig farms are located (Government of Yucatan, 2010) (Figure 3) it is therefore necessary to consider other strategies to differentiate this polygon in greater detail, such as the inclusion of negative forms of relief in the geomorphopedological analysis (Huang, 2007, Brinkmann *et al*., 2008, Lindsey *et al*., 2010).

From the environmental point of view and considering the vulnerability of groundwater to contamination, the reclassification of suitability levels should include other important variables of geographical context. These include: a) the thickness of the subsoil as a protective layer above the aquifer; the thickness can be inferred by the average height above sea level, because it is documented that there is a direct relationship between this and the depth of groundwater (Gonzalez *et al*., 2002), i.e. at lower elevations, the groundwater is shallow and vice versa; b) soil permeability (Perry *et al*., 2002), such as the areas of high permeability of the center and east of Yucatan; c) the intensity, frequency and distribution of rain due to a humidity gradient from northwest to southeast (Delgado-Carranza, 2010), since precipitation is the main vehicle by which pollution with organic matter can reach the groundwater.

Moreover, it is important to consider that the application of the pedotransfer functions developed for a particular region or database can be used with confidence only within a narrow distribution of soil groups (Romano and Palladino, 2002; Wösten *et al*., 2001, Pachepsky *et al*., 2006; Merdum *et al*., 2006), however, in the face of the lack of technical information the empirical approaches to the use of data already available or more readily available using the pedotransfer functions are justified (IUSS, 2006). This supports the implementation of the method in areas surrounding the study area such as the states of Campeche and Quintana Roo, which have similarities in soils due to their similar karstic origins.

Mapping the spatial accuracy

The spatialization approach used in this study is a combination of expert knowledge (soil geomorphological units with soil associations and groups) with multivariate numerical methods of classification (discriminant analysis), which together could be called deterministic-stochastic modeling, such as that proposed by McBratney *et al*., (2000).

The variability and uncertainty within the mapping units are generally not included in soil maps (Kværnø *et al*., 2007; Mendonça-Santos, 2007) and also the extent to which the models can give a valid prediction has been little studied (Grinand *et al*., 2008). In this study however, discriminant analysis allowed an understanding of the degree of accuracy of the suitability map. In this way, there is generally a 71.5% accuracy of the extrapolation however, per soil group; LP was the group with a high accuracy (95%), being that with the largest area in the study. Contrary to what happens with the ST group which, while statistically low (50%), is spatially suitable because it does not have a high presence in the corresponding geomorphological unit and this is demonstrated by calculating the correct assignations by soil association, in which is reflected the assignation percentages with respect to the dominance of the soil. Thus, we can see that, in all cases, spatial precision exceeds 60%.

In this study, the geomorphological map (Ihl *et al*., 2007) and the database of soil profiles (Bautista *et al*., 2007) were basic inputs to the spatialization of pedotransfer functions, without which it would not have been possible to achieve the objectives of this study.

The discriminant analysis allowed estimation of the percentage of accuracy of the pedotransfer functions related soil groups. This method is important, especially for areas where available soil data and information are scarce or inadequate for other techniques (Mendonça-Santos, 2007). For example, a geostatistical analysis, regardless of topography and soil cover, would not be appropriate because the outcome would be dependent on the number of sampling points (Kværnø *et al*., 2007). However, sometimes the assumptions of geostatistics do not always correspond to the reality of the variability of soils in the landscape (Mendonça-Santos, 2007). McBratney *et al*. (2000) propose an integration of deterministic and stochastic models, with the knowledge of the processes of formation and distribution of soils in the landscape, with a quantitative criterion with techniques used in pedometry, in order to predict with greater speed and accuracy, and at lower cost, the soil classes and/or properties in a given territory.

There are other techniques that allow the use of categorical variables, such as classification trees to assess the accuracy of the digital mapping of soils in an unsampled area (Grinand *et al*., 2008); Giasson *et al*., (2008) used logistic regression and reported percentages from 61% to 71% of correct assignations by using relief variables to predict the occurrence of soil classes. This study had continuous variables that permitted the use of multivariate methods.

CONCLUSIONS

The soils with the highest suitability as reactors are VR, ST, NT, and LV. Some 83.9% of the area of Yucatan State is marginally suitable for land use as a receptor of swine wastewaters, 6.5% is moderately suitable, with 6% of the area of the state representing areas classed as suitable. The percentages of accuracy of the spatialization of the pedotransfer functions range from 62% to 95% with a general value of 71.5%.

From information of the role of soils as reactors per specific soil group, of a soil database, of a pre-existing morphometric and geomorphopedological map, this study presents a practical, accurate and inexpensive methodological approach that allows the spatialization of data points (map of suitability of soil associations as reactors) and their level of accuracy by using numerical classification techniques such as discriminant analysis.

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