Indicators and Quality Indices of Soil (QIS) Producer's Barley in the Southern State of Hidalgo, Mexico

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Abstract

The aim of this study was to propose and establish indicators and quality index of soil (QIS) to enable rapid assessments and estimates in feedlot soils of the southern state of Hidalgo, Mexico. An indicator is a variable that summarizes or simplifies relevant information by which a phenomenon or condition of interest is made visible and quantified, measured and communicated. They are known various methods that allow widespread use of indicators and benchmarks for assessing environmental quality, land quality, sustainable development, risk, vulnerability, territorial planning, among others. Consideration was given eight indicators were standardized on a 0-1 scale, representing respectively the worst and best condition from the standpoint of quality, regardless of the absolute values measured for each indicator. The maximum and minimum values for some attributes were set to optimal conditions. The QIS found in this region was 0.48 which places it in kind of moderate quality. This value is strongly influenced by low values of soil organic carbon (SOC), as property that is affecting these soils. This decrease of SOC is also the main cause of the low values of aggregate stability and infiltration and an indicator of the values of bulk density. These changes affect the physical properties of soil surface condition leading to increased erosion processes, with consequent loss of thickness of the surface horizon, reflected by the indicator.

Keywords: *quality indicators, feedlots, quick estimates, aggregate stability soil.*

1.0 Introduction

UN the Conference on the environment and development Rio'92, marked a very special milestone in establishing the need to develop and implement different methodologies to determine the State of the environment and monitor the changes at the local, national, regional and global level.

The determination of these changes could help to make a better assessment of the dimensions of the different environmental problems, identify and evaluate the results of the implementation of international conventions and programmes of action, as well as, guide national policies. A wide range of methodologies are being used to assess the impact of agricultural activities on natural resources and in particular, the change of use and management of soils (Archer *et al*., 2002; Breuer *et al*., 2006; Hati *et al*., 2007; Cantu *et al*., 2009).

The development of various methodologies has found the widespread use of indicators and benchmarks for the evaluation of environmental quality, quality of soils, sustainability, sustainable development, risk, vulnerability, territorial planning, among others. The most important antecedent emerged from the Organization for Economic Cooperation and Development (OECD, 1991) when published a preliminary set of environmental indicators. Subsequently, other organizations have developed programmes where they established lists of indicators for assessing environmental quality, such as FAO, World Bank, and United Nations programmes for the development and for the environment (UNDP and UNEP, for its acronym in English, respectively).

Blum and Santelises (1994) described the concept of sustainability and resilience of the soil based on six human and ecological functions: soil as biomass producer; as reactor with filters; as buffer, transformer of matter to protect the environment, groundwater and pollution food chain; as biological Habitat and gene pool; as average physical and as a source of resources and cultural heritage. These concepts and the suggested by Warketin (1996) were the bases from which the Soil Science Society of America established the concept of soil quality (Karlen *et al*., 1996). Doran & Parkin (1994, 1996) and Doran *et al.* (1996) established quantitative indicators of quality of the soil from these concepts.

An indicator is a variable that simplifies information relevant to making that conditions of interest becomes perceptible and quantify, measured and reported, in an understandable manner, relevant information. The indicators should be preferably quantitative, although they can be qualitative or nominal or variables range or ordinals, especially when there is no quantitative information availability, or the attribute is not measurable, or to quantify costs are too high (Volveré *et* Amézquita, 2009). The main functions of the indicators are: assess conditions or trends, compare transversely places or situations, to assess goals and objectives, provide early preventive information and anticipate future trends and conditions.

Indicators should be: limitated in number and manageable for various types of users; simple, easy to measure and have a high degree of aggregation, i.e., must be properties that summarizing other qualities or properties; interdisciplinary; as far as possible should contemplate the greatest diversity of situations therefore include all types of properties of soils (chemical, physical, biological, etc.); have a variation in the time such as possible to follow the same also, must not have a high sensitivity to climate and/or environmental changes but enough to detect the changes brought about by the use and management of resources (Gallopin, 1995;) Doran *et* Parkin, 1996; Doran *et* Zeiss, 2000; Volveré *et* Amésquita, 2009).

Segnestam (2002) based on the experience carried out by the World Bank pointed out the importance of establishing: the line basis or starting an activity that can impact positively or negatively on the environment; You thresholds to control or monitor negative impacts that should not exceed a predetermined threshold and addition goals or targets to assess if the positive impact of a response is sufficiently long.

Lists of indicators of universal thinking in all possible situations and all possible land use have been developed (Doran and Parkin, 1994, 1996). On the other hand, have submitted lists designed for regional or local situations (Brejda *et al*., 2000; Segnestam, 2002; Cantú *et al*., 2002; Lilburne *et al*., 2004). The aim of this work was to propose and establish indicators and quality index for soils (QIS) that allow quick estimates and evaluations. It proposes the implementation of a methodology for rapid diagnosis, easy repetition and simple communication, based on the use of proper local indicators.

2.0 Materials and methods

The study area comprises a group of plots located in the municipalities of Apan, Almoloya and Emiliano Zapata, all of them with soil dedicated to the cultivation of barley quality maltera system of monoculture for more than 40 years, located in the South of the State of Hidalgo, Mexico.

Proposed, following the criteria established by other authors (Breuer *et al*., 2006; Hati *et al*., 2007; Cantu *et al*., 2009) applied as indicators for rapid assessment of soil quality producing barley following parameters:

- pH
- Organic carbon
- Percentage of saturation of bases
- Percentage of stable aggregates in water (> 0.5 mm).
- Speed of infiltration
- Apparent density
- Zeta potential pZ
- Thickness of the horizon

Another published work (Rodriguez *et al.*, 2009) concerns the inclusion of other parameters such as the respiration of soils and phosphors contents. This study took into account the inclusion of potential Zeta (pZ), not reported in the consulted bibliographies.

The determination of the pH of the soil, was carried out by potenciometría (relationship soil-water 1: 2), under the NOM 021 RECNAT 2000 and on the basis of the extract of saturation (methodology AS-16). The organic carbon content was determined by the method of Walkley and Black (Jackson, 1987). The saturation of bases by the method of ammonium acetate (NOM-021-RECNAT-2000; methodology AS-21). The percentage of stable aggregates in water (> 0.5 mm) according with Certini *et al.* (2002) and according to what is established in USDA-NRCS (1999). Lat speed of infiltration using the method of the double ring (ASTM D 3385-88;) (USDA - NRCS, 1999) and apparent density by the method of the cylinder (Blake *et* Hartge, 1986; USDA - NRCS, 1999).The thickness of the horizon of the sampled soil was valued at field (Soil Survey Staff, 2006).

The indicators methodology has as an essential support in a cartographic basis so that from it feasible analysis in space and in time. In this case the base mapping was performed using maps satellite (Figure 1).

To perform the evaluation of the quality of the soils out-of-State, taking into account the number of indicators minimum suggested, proposed indicators and indices that are seen in table 1. To obtain a single value for each parameter for each municipality, was an average weighted according to the proportion that represents each handling in the total area under study. The indicators were then standardized using a scale 0-1 represents, respectively; the worst and best condition from the point of view of quality, regardless of the absolute values measured for each indicator and obtained experimental results.

The maximum and minimum values were established in different ways for each indicator. For some attributes, especially for optimum conditions, were considered thresholds calculated from the values of the soils of reported in references (Breuer *et al*., 2006; Hati *et al*., 2007; Cantú *et al*., 2007; Cantú *et al*., 2009), while others used theoretical criteria reported for soils dedicated to the cultivation of barley (Vera *et al*., 2002; Alvarez *et al*., 2006).

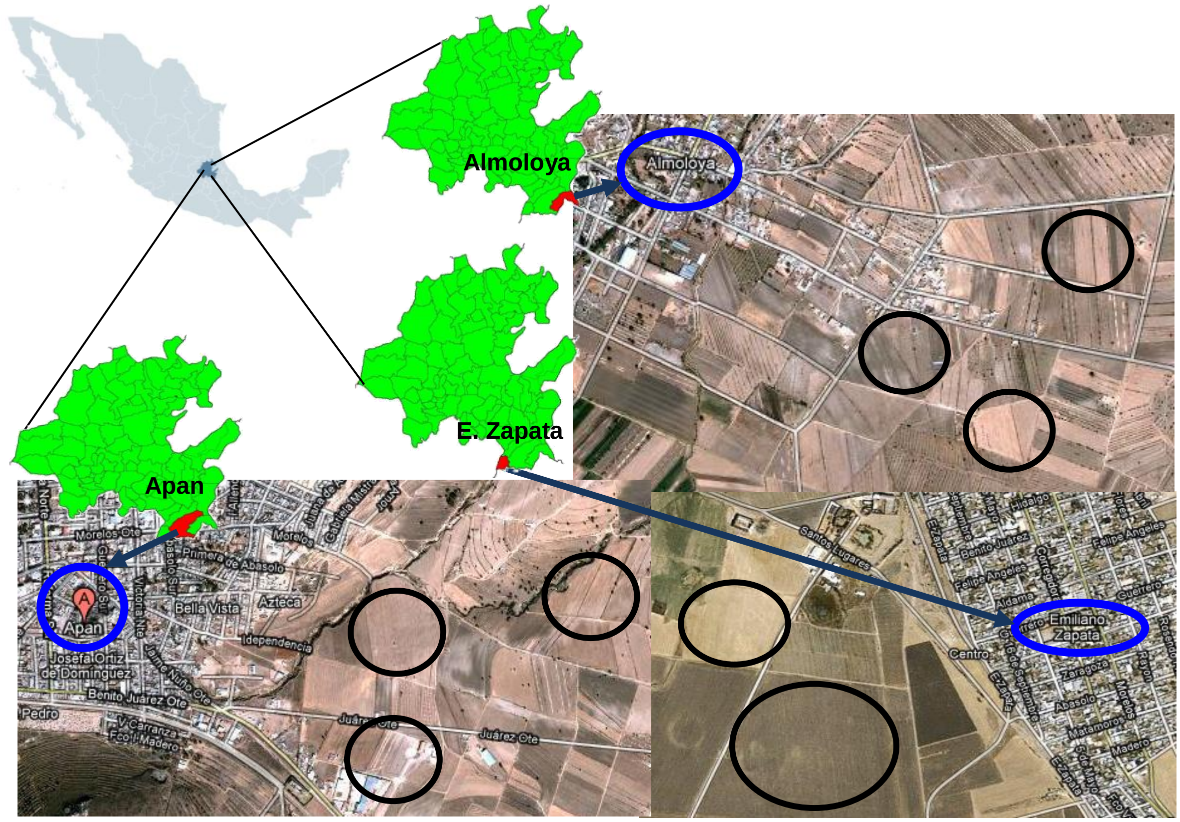

Figure 1. Location of the studied plots of soil out-of-State in the municipalities of Almoloya, Apan and Emiliano Zapata.

Table 1. Indicators proposed for evaluation of quality of soils (QIS) out-of-State, units of measure, and indexes such as minimum and maximum values defined for the municipalities.

Indicator	U.M.	QIS	
		Max.	**Min.**
Ph	-	8.50	5.00
SOC	%	6.00	1.00
Saturation of Bases	%	100	50
Stable aggregates in water	%	75	10
Speed of infiltration	cm/h	10	1
Apparent density	$Mg.m^{-3}$	1.50	1.05
pZ	mV	+30	-30
Thickness of a horizon	cm	45	0

For the SOC, was considered as a minimum, the requirement to comply with the condition of mollic (Soil Survey Staff, 2006) and a maximum average of the values measured in the soils of reference (Álvarez *et al*., 2006; Hati *et al*., 2007; Cantú *et al*., 2007; Cantu *et al*., 2009); the minimum 1% and the maximum in 7%, is considered which is also due to the classification indicating by Boulding (1995) for not volcanic soils. The minimum value of pH was established considering the point of toxicity for the development of the cultivation of barley in the area (pH 5.0) and the maximum of quality corresponded to the pH in larger amounts can be considered as suitable for the cultivation of barley (Vera *et al*., 2002; Alvarez *et al*., 2006; Soil Survey Staff, 2006; Polished *et al*., 2009). To the saturation of bases were taken the minimum value (50%) and the maximum (100%) required to meet the condition mentioned above mollic (Soil Survey Staff, 2006). For indicator of stable aggregates in water, the maximum value was obtained by averaging values measured in work reported in the literature (Shepherd *et al*., 2001; Holeplass *et al*., 2004; Side *et al*., 2004; Márquez *et al*., 2004; Bronik *et al*., 2005; Polished *et al*., 2009).

The minimum corresponded to the minimum values measured in the region.

In the case of the speed of infiltration, was taken as a minimum speed which have been documented problems of infiltration in the region (Gómez *et* Magallanes, 2004) and maximum values of infiltration expected according to the characteristics of the soil (Soil Survey Staff, 2006) that in this case classified between franco clay sandy and Frank Sandy. The minimum bulk density corresponds to the average of the values measured in the soils of reference (Márquez *et al*., 2004; Bronik *et al*., 2005; Polished *et al*., 2009) and the maximum to the maximum values measured in the region.

For the indicator of potential zeta (pZ), is the first time that it is used for such purposes; was taken as a criterion of maximum and minimum as reported in the literature that values < - 30 mV and > + 30 mV, where are stable colloidal suspensions of extracts of saturation of soils (Prieto *et al*., 2009). It has been reported (Unzueta *et al*., 2007) that the increase the capacity of infiltration of the soil with water (generally by temporary effect) as well as the increase in the stability of aggregates against water and mechanical agents, may be governed by an action such as the decline of the soil particles (pZ) Zeta potential. With the variation of acidity the pZ decreases their negativity and in some cases, can reach positive values. These changes affect the speed of the electroosmotic flow, that it has been observed that the flow rate decreases when the pH of the electrolyte is approaching neutrality or increases the alkalinity (de la Rosa *et al*., 2007).

In the case of the indicator the horizon thickness, maximum thickness corresponds to the measured on average in soils of reference (45 cm), while the minimum was established as zero (superficial level of the arable layer). Finally, settled an index of quality of soils (ICS) averaging the values of all the indicators. For the interpretation of the ICS used a scale of transformation in five kinds of soil (from 1 to 5) as shown in table 2.

Table 2. Soil quality classes.

Quality index soil (QIS)	Scale	Class
Very high quality	0.80-1.00	1
High-quality	0.60-0.79	2
Moderate quality	0.40 0.59	3
Low quality	0.20 0.39	4
Very low quality	0.00-0.19	5

There are two possible situations (Cantú *et al.*, 2007; 2009): the first when the value maximum of the indicator (I_{Max}) corresponds to the best situation of soil quality (standard value of the indicator: $V_n = 1$) and the calculation is:

$$V_n = (I_m - I_{min})/(I_{max} - I_{min})$$

The other situation is when the value I_{max} corresponds to the worst situation of soil quality ($V_n = 0$) and is calculated as:

$$V_n = 1-(I_m - I_{min\ max} / I - I_{min})$$

where V_n = normalized value, I_m = measure of the indicator, I_{max} = maximum value of the indicator, I_{min} = minimum value of the indicator.

3.0 Results and discussion

The evaluation of the quality of the soils producing barley in the South of the State of Hidalgo, taking into account the number of minimum indicators suggested, and the unique values standardized obtained for each municipality are represented in table 3; the indicator which presented the lowest value on average for the three municipalities, was the SOC (0.18) while the largest corresponded to the saturation of bases (0.94). The pH and the apparent density presented values intermediate averages (0.49 - 0.59), close to 50% and the remaining indicators varied between values from 0.34 to 0.45. The new indicator proposed, pZ, scored an average QIS of the southern region of 0.71.

Table 3. Indicators and of quality indicex of soils (QIS) for municipalities.

Indicator	QIS values for indicators			QIS
	APAN	Almoloya	E. zapata	Average
pH	0.59$^{a.}$	0.49$^{(b)}$	0.56$^{a.}$	**0.55**
SOC	0.20$^{(c)}$	0.18$^{(c)}$	0.17$^{(c)}$	**0.18**
Saturation of Bases	0.94$^{(d)}$	0.89^{e}	0.98$^{(d)}$	**0.94**
Stable aggregates in water	0.41$^{(f)}$	0.38$^{(f)}$	0.23$^{(g)}$	**0.34**
Speed of infiltration	0.56$^{(h)}$	0.42$^{(i)}$	0.38$^{(j)}$	**0.45**
Apparent density	0.56^{k}	0.52^{k}	0.48^{l}	**0.52**
pZ	0.67^{m}	0.83^{n}	0.62^{m}	**0.71**
Thickness of a horizon	0.36^{o}	0.34^{o}	0.32^{o}	**0.34**
AVERAGE VALUES	**0.51^{p}**	**0.51^{p}**	**0.49^{p}**	**0.50**

Different letters in rows, represent significant differences ($p < 0.05$).

PH indicator presents on average value of quality of 0.55. In the majority of the soils of the region there is a tendency to the decrease in pH in the surface horizon (A) with respect to reference soils. This situation has also been reported by other researchers (Pulido *et al*., 2009), when referring to that in monoculture systems this trend is observed for many types of soils. However, the values measured still considerably far from toxicity point established for the cultivation of barley (< 5.0).

The average value of the COS indicator for soils of the southern region of the State of Hidalgo out-of-State, evidence of a decline in the quality of 82 per cent over the soil taken as reference. The marked decline in organic matter has been observed in various investigations in the region (López *et al*., 2005; Prieto *et al*., 2009).

The value of the indicator saturation of bases is very close to the maximum of quality (0.94). In this case also the indicator largely reflects the situation of the local soils. Materials loésicos on those who develop these soils (Medina *et al*., 2006) they are rich in calcium and therefore, saturation of bases is very high, despite the use of soils in system of monoculture that dates back more than 40 years and the low content in organic matter.

The indicator stable aggregates in water presents a value of average quality bass of 0.34. The significant decrease in the percentage of macroagregados in the region, with respect to reference soils, reflects the influence of negative management in this property as it was pointed out by some authors at the local level (López *et al*., 2005; Prieto *et al*., 2009) and international (Gregorich *et al*., 1994;) Doran *et* Safley, 1997; Cantú *et al*, 2007). The use of systems of monoculture corroborate the Affectations in the texture of the soil and thus to the formation of stable aggregates (Pulido *et al*., 2009).

The value of the indicator speed of infiltration 0.45 points out that this property in the region evaluated is far from 55% of the values of infiltration expected according to the characteristics of the soil (Soil Survey Staff, 2006). This parameter is affected greatly by the values of the soils of the municipality of Emiliano Zapata (0.38), which corresponds with classified as sandy soils. Research, has pointed out that the decline in the rate of infiltration would be associated to the compaction of the surface and subsurface horizon (Prieto *et al*., 2009).

The indicator apparent density reveals that soils have a medium level of compaction, given that the weighted average value of the region lies between the minimum values from reference sites and the maximum measured in the region. This value would not be restrictive for the growth of roots of the cultivation of barley in this type of soil (Vepraskas, 1994; USDA - NRCS, 1999).

On the pZ, which refers to the stability of colloidal suspensions in saturation of soil extract, it should be noted that it is the first time that these results are reported. You can see that on average is an QIS allowing them to qualify as high quality soils; however it should be remembered that these colloidal suspensions are of low concentrations because they correspond to low content of organic matter (SOC). The greater this dispersive force (pZ), greater stability will have the solution and the greater its capacity to carry particles in suspension; or load capacity (de la Rosa *et al*., 2007). Saturation of soil extracts are presented with values of pZ that located them in a threshold of mild dispersion to moderate by low concentration of organic matter available can be understood in this sense.

The low value indicator thickness from the horizon to (0.34) shows the marked decrease on the soils of references (Holeplass *et al*., 2004; Side *et al*., 2004; Márquez *et al*., 2004; Bronik *et al*., 2005), which reaches 66% in these soils evaluated. This is mainly due to processes of water erosion have been estimated in the area by direct in field measurements and results of sandy Frank textures.

The index of average quality of the soils of this barley producing region (QIS: 0.50) obtained through this minimum set of indicators, is located in class 3, of moderate quality of soils (table 2). This value of the QIS is heavily influenced by the SOC indicator, which is owned by the most affected by the management of these soils (monoculture system). The SOC is considered a key attribute given its strong influence on most of the properties of the soil (Gregorich *et al.,* 1994). The decline of the SOC would be the main cause of the low values of the indicator stability of aggregates and infiltration and the indicator means apparent density. These changes in the physical properties affect the surface condition of the ground causing an increase in the processes of erosion, with the consequent loss of thickness of the surface horizon, reflected by the corresponding indicator.

The set of indicators used to assess the quality of the soil meets the most important criteria for use as indicators. It's a minimum number of variables or attributes of the soil that integrate information from other associated variables, incorporates indicators physicists, chemists and physicists, and are mostly easy measurement. The foregoing evidence the suitability of selected indicators to reflect, in terms of quality, changes in each one of the properties. In the construction of the set were considered the main properties of the soils of the area so that the indicators represent local conditions.

Were discarded indicators that, while they are part of lists very used in other parts of the world (Doran *et* Safley, 1997), do not have local validity. Therefore, it is important to note that these indicators of soil resource State are not universal but they must be chosen according to the type of atmosphere and soil of the region in study. These results represent a vision of the moment, for the situation of these soils in the period 2007-2010. To give the temporary sense will be necessary to perform sequential measurements in periods of time such that allow registering changes in the used attributes linked to the conditions of use and management of soils (Cantú *et al*., 2007).

4.0 Conclusions

Proposed and indicators used to assess the quality of the soil (QIS), comply with the criteria required for use as indicators. They are a minimal number of variables of the soil that they integrate information from other associated variables, incorporating indicators physicists, chemists and physicists, and are easy measurement. The results represent the situation of the years 2007-2010 in the South of the State of Hidalgo out-of-State soils. Quality index average (QIS) soils in this region which places him in class 3, of moderate quality. This value is strongly influenced by the low values of SOC, as property that is affecting these soils. This showed a decrease in the quality of them by 82%. This decline in the SOC is also the main cause of the low values of stability of aggregates, as well as the use of systems of monoculture that corroborate the Affectations in the texture of the soil and thus the formation of stable aggregates. Infiltration rates and values of apparent density have also been affected. These changes in the physical properties affect the surface condition of the ground causing an increase in the processes of erosion, with the consequent loss of thickness of the surface horizon, reflected by the corresponding indicator.

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