Similarity index between irrigation water and soil saturation extract in the experimental field of Yachay University, Ecuador

To cite this article: D V Carrera-Villacrés et al 2017 IOP Conf. Ser.: Earth Environ. Sci. 82 012007

View the article online for updates and enhancements.
Similarity index between irrigation water and soil saturation extract in the experimental field of Yachay University, Ecuador

D V Carrera-Villacrés1,2,3, V P Sánchez-Gómez1, O A Portilla-Bravo1 and D R Bolaños-Guerrón1

1Universidad de las Fuerzas Armadas ESPE, Departamento de Ciencias de la Tierra y Construcción, Carrera de Ingeniería Geográfica y del Medio Ambiente, Grupo de Investigación en Contaminación Ambiental (GICA), Sangolquí, Pichincha, Ecuador

E-mail: dvcarrera@espe.edu.ec

Abstract. Soil monitoring is a job that demands a lot of time and money. Therefore, measuring the same parameters in the water becomes simple because it can be done in situ. The objective of this work was to find a similarity index for the validation of mathematical correlation models based on physicochemical parameters to verify if there is a balance between irrigation water and soil saturation extract in the experimental field Yachay that is known as the city of knowledge that is located in Imbabura province, Ecuador, for which, the sampling of water was carried out in two representative periods (dry and rainy). Sampling of 10 soil profiles was also performed, covering the total area; these samples were obtained results of Electrical Conductivity (EC), pH and total dissolved salts (TDS). With correlation models between soils and water, it is possible to predict concentrations of elements in the irrigation water. It was concluded that there is a balance between soil and water, so that the salts present in the soil are highly soluble, in addition, there is a high probability that the elements in the irrigation water are in the soil. In sample water, the same concentrations were found in the soil, at their saturation point, and very close to the field capacity.

1. Introduction

The experimental field of Yachay is located in San Miguel de Urcuqui in Imbabura, Ecuador. It is a research and higher education center and also a developing industrial park, where one of the main topics is agricultural research. About 1 000 hectares will be destined to the development of experimental agriculture and agribusiness, which will support the change of the productive matrix in the Ecuador [1].

The relationship between soil and irrigation water represents one of the major limitations for agricultural production in many parts of the world [2]. In response to this limitation, models have been generated to predict the dynamics and chemical, physical and biological interactions that exist in an agricultural system.

The characteristics of irrigation water, in terms of salinity level, have a direct impact on the composition of salts present in the soil due to retention capacity of this. Contrariwise, inversely there is also an important relationship, since the soil presents highly soluble compounds, which will be
present mainly in the waters coming from agricultural drains [2].

A case study carried out in Northeast of China establishes the problem in the farmland due to the accumulation of salts, and performs a salinity analysis in the irrigation water to identify soil composition, based on the Close soil-water relationship exists; specifically uses data from water conditions to perform a model of soil salinity dispersion [3].

Mathematical correlation models when evaluating the association or independence degree between tow quantitative variables [4] become a tool used as a quality control method, this is due to the fact that they facilitate the monitoring in field of measurements of parameters that are of interest for the agricultural activity, obtaining in a fast and efficient way the quality of soil and water [5].

The chemical composition and physical-chemical properties of the soil solution are important for the investigation of the processes that occur in it, as well as for crop nutrition [6], in turn, is important as well to analyse the irrigation water, so that it can be identified if there is a balance in the water-soil relationship.

Content of salts in soil or water can be estimated by the electrical conductivity (EC), both in a sample of water and soil extract. Currently one of the classic problems of land degradation has been to control, prevent or improve soils affected by salinity [7].

The problem with salinity can be intensified with other sources as the use of fertilizers and the quality of the water of irrigation. The relative significance of the contribution of each salt supply source depends on soil conditions, drainage effectiveness, irrigation water quality, land/soil overexploitation and agronomic management practices [6].

There are two chemical indicators of salinity in the soil, EC and pH [8, 9]; Whose parameters allow to separate the soils affected by salinity in three groups (table 1)

<table>
<thead>
<tr>
<th>Classification</th>
<th>pH</th>
<th>EC</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saline</td>
<td>≤ 8.5</td>
<td>&gt; 4</td>
<td>Salinization</td>
</tr>
<tr>
<td>Sodic</td>
<td>&gt; 8.5</td>
<td>≤ 4</td>
<td>Sodification</td>
</tr>
<tr>
<td>Sodium-Saline</td>
<td>&lt; 8.5</td>
<td>&gt; 4</td>
<td>Salinization – Sodification</td>
</tr>
</tbody>
</table>

Source: [8, 9]

The accumulation of soluble salts occurs when annual precipitation is lower than evaporation of soil including evapotranspiration of plants, which is associated to a low drainage soil. Concentration of salts causes a soil management problem since its high concentrations of salts generate problems for development of susceptible crops [10].

Percentage of these total dissolved salts changes according to concentration of extract soil/water, depending on the correlation obtained it is possible to predict which percentage of salts pass from solid phase of soil to liquid phase of soil by increasing soil-water ratio. Salinity of irrigation water determines salinity of soils affecting to crops. TDS is a parameter of soils and irrigation water to determine theirs quality and theirs effect over crops [11].

Relationship physic and chemical between soil and water are very useful in formulation of river basin management and management plans, a process to which current territorial ordering is oriented, taking into account basin as a basic unit of environmental development. In addition, this knowledge will provide criteria with scientific and technical justification for development of vegetation exploitation activities and their appropriate use in development projects in which it is involved, either for protection or exploitation purposes [12].

By determining that same soil characteristics can be identified in water, analysis costs required in agricultural soil studies can be minimized. Water is an indicator of lower cost and easier to characterize than soil, which is an advantage when carrying out studies that require the identification of physic-chemical characteristics, hence the importance of this study.

The aim of this work was to determine similarity index for validation of mathematical correlation models of pH, EC and TDS, in order to verify if there is a balance between the irrigation water and
saturation extract of the soil in experimental field Yachay.

2. Materials and methods

2.1. Sampling: water
Sampling of water was carried out in basin along Ambi River, in tributaries, ditches and ravines close to YACHAY City of Knowledge. Samplings were performed at two representative times, determined from precipitation data provided by National Institute of Hydrology and Meteorology of Ecuador, INHAMI.

First sampling was conducted in October 2014, 25 samples were taken (dry season) and in the second sampling, April 11, 11 samples (rainy season) were taken (figure 1). Samples were taken according to NTE INEN 2169 (1998) [13, 14].

![LOCATION OF SAMPLING POINTS: WATER AND SOIL](image)

**Figure 1.** Location map of the sampling points made on the experimental field area Yachay.

2.2. Sampling: soil
Ten soil profiles were taken covering most of Yachay (figure 1). Locations of points were done using zig-zag method according to NOM-021-SEMARNAT-2000 [15]. Soils were monitored covering the entire Northern extension corresponding to agricultural fields to be irrigated, with a simple sample type that represents specific conditions of population in the time that was collected [16]. Samples were taken at depths of 20 cm soil profiles, up to 40 cm depending on soil uniformity in order to determine the concentrations of the different parameters in ratios 1:5, 1:10 and the saturation extract (1:0.2 ≈ 1:0.6).
2.3. Analysis method
The analysis of the water and soil samples were done based on the Standard Methods 20th edition [17], following the procedure described therein, for each water sample were analysed 13 parameters and 16 parameters for soils, from which 3 parameters (pH, EC, TDS) were chosen for correlation analysis. Water samples from first sampling were sent to the HAVOC Analytical Laboratory in October 2014, while samples from the second sampling were analysed at the Environmental Laboratory of the University of the Armed Forces (ESPE) in 2015.

2.4. Correlation models
To generate the correlation models, a spreadsheet was used, where both the mathematical dependence equations between the values obtained in the different parameters of the soil and water samples and the linear regressions between the first and third degree equations were determined.

Clouds of points or dispersion diagram for each variable were obtained in soil and water. Thus, it can interpret intensity of relationship between both variables. Additionally, was obtained a correlation coefficient; when dispersion diagram shows a cloud of highly clustered points around a line, that is mean a strong linear relationship. Correlation coefficient is measure of that relationship [18].

In addition, we proceeded to validate the Model taking as a criterion of goodness of fit the Similarity Index (SI).

2.5. Elaboration of map of location
Thematic maps of location of study area were made by an elaboration of the geodatabase that were entered into GIS software, moved to the geospatial information. Finally the map was generated; Part of the methodology is proposed by Soriano [20].

For analysis of the results, only saturation extract was used because it is considered as medium that gives the best representation of current conditions of soil with respect to natural conditions [21] and this was demonstrated in Yachay.

3. Results
Water sampling was carried out along Ambi river, 2 samples were obtained; at the same time, 10 soil profiles were sampled throughout Yachay’s area (figure 1). Data obtained from the analysis of soil saturation extracts and the first sampling of irrigation water is indicated in table 2.

Table 2. pH values, electrical conductivity and total dissolved salts in water samples and soil profiles.

<table>
<thead>
<tr>
<th>№</th>
<th>pH</th>
<th>EC (dS m⁻¹)</th>
<th>TDS (mg L⁻¹)</th>
<th>P-PO₄ (mg L⁻¹)</th>
<th>N-NO₃ (mg L⁻¹)</th>
<th>East</th>
<th>North</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.37</td>
<td>1.4</td>
<td>1048</td>
<td>0.50</td>
<td>0.30</td>
<td>816808</td>
<td>43382</td>
</tr>
<tr>
<td>2</td>
<td>7.68</td>
<td>0.5</td>
<td>360</td>
<td>0.50</td>
<td>0.30</td>
<td>812633</td>
<td>45710</td>
</tr>
<tr>
<td>3</td>
<td>7.44</td>
<td>0.6</td>
<td>486</td>
<td>0.50</td>
<td>0.30</td>
<td>816561</td>
<td>46224</td>
</tr>
<tr>
<td>4</td>
<td>8.45</td>
<td>0.9</td>
<td>700</td>
<td>0.50</td>
<td>0.30</td>
<td>817487</td>
<td>46958</td>
</tr>
<tr>
<td>5</td>
<td>8.46</td>
<td>0.9</td>
<td>690</td>
<td>0.50</td>
<td>0.30</td>
<td>817600</td>
<td>48469</td>
</tr>
<tr>
<td>6</td>
<td>8.06</td>
<td>2.0</td>
<td>1581</td>
<td>0.50</td>
<td>0.30</td>
<td>818602</td>
<td>51719</td>
</tr>
<tr>
<td>7</td>
<td>8.12</td>
<td>1.3</td>
<td>970</td>
<td>0.50</td>
<td>0.30</td>
<td>816044</td>
<td>43447</td>
</tr>
<tr>
<td>8</td>
<td>8.18</td>
<td>1.2</td>
<td>980</td>
<td>0.50</td>
<td>0.30</td>
<td>816846</td>
<td>43134</td>
</tr>
<tr>
<td>9</td>
<td>8.26</td>
<td>1.2</td>
<td>795</td>
<td>0.50</td>
<td>0.30</td>
<td>811535</td>
<td>47344</td>
</tr>
<tr>
<td>10</td>
<td>8.41</td>
<td>1.8</td>
<td>1143</td>
<td>0.60</td>
<td>0.30</td>
<td>818802</td>
<td>50836</td>
</tr>
<tr>
<td>11</td>
<td>8.26</td>
<td>3.2</td>
<td>1741</td>
<td>0.50</td>
<td>0.30</td>
<td>812269</td>
<td>51845</td>
</tr>
</tbody>
</table>
Mathematical correlation models are used for determinate water quality through systematic measurements of EC, data for obtaining correlation models were processed using a second and third degree polynomial equation that passes through the origin of Coordinates $y=b_1 x+b_2 x^2$, $y=b_1 x+b_2 x^2+b_3 x^3$ since these showed the best values of correlation coefficient, and according to [16] when there are values of "r" between 0.8 is a correlation "Very High" (table 3).

<table>
<thead>
<tr>
<th>Sampling Parameter</th>
<th>Order</th>
<th>Equation</th>
<th>$R^2$</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>1</td>
<td>$y = 0.8553x + 0.4729$</td>
<td>0.7815</td>
<td><strong>HIGH</strong></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>$y = -0.2777x^2 + 5.5113x - 18.987$</td>
<td>0.8306</td>
<td>VERY HIGH</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>$y = -0.8725x^3 + 21.706x^2 - 178.43x + 492.13$</td>
<td>0.8857</td>
<td>VERY HIGH</td>
</tr>
<tr>
<td>EC</td>
<td>1</td>
<td>$y = 0.1054x + 0.664$</td>
<td>0.895</td>
<td>VERY HIGH</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>$y = -0.0215x^2 + 0.2118x + 0.5819$</td>
<td>0.9657</td>
<td>VERY HIGH</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>$y = -0.0002x^3 - 0.0202x^2 + 0.2095x + 0.5829$</td>
<td>0.9657</td>
<td>VERY HIGH</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3. Correlation coefficients.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r=1$</td>
</tr>
<tr>
<td>$0,8 &lt; r &lt; 1$</td>
</tr>
<tr>
<td>$0,6 &lt; r &lt; 0,8$</td>
</tr>
<tr>
<td>$0,4 &lt; r &lt; 0,6$</td>
</tr>
<tr>
<td>$0,2 &lt; r &lt; 0,4$</td>
</tr>
<tr>
<td>$0 &lt; r &lt; 0,2$</td>
</tr>
<tr>
<td>$r=0$</td>
</tr>
</tbody>
</table>

Source: [19]

Two different samples were taken for irrigation water, and the physical-chemical parameters were identified for both cases, however, the best correlation was obtained with values of the first, in table 4 is presented the correlation equations as well as the $R^2$, calculated for both samples.
3.1. Electrical conductivity of irrigation water and soil saturation extract from the experimental field Yachay.

EC is measured to know if the amount of soluble salts is enough to affect the development of plants and level of water absorption. In saturation extracts of Yachay profiles an average EC of 0.83 dS.m-1 (figure 2) was identified. The regulation (NOM021-RECNAT, 2000) [15] proposes a series of effects related to EC. Considering that measurements obtained from soil extracts are lower than 1.0, which means that this soil is non-saline or with negligible salinity. According to regulations TULAS (2014) Book VI Annex 2 [14] and according to the soil quality criteria for agricultural use, the maximum allowable value of 2 dS.m-1 for this parameter is considered.

![Figure 2. Values of EC in soil profiles.](image)

EC in water samples averaged 1.5 dS.m-1 (figure 3).
After this correlation the equations were obtained (figure 4). This analysis resulted in a high correlation.

**Figure 3.** Values of EC in water.

**Figure 4.** Correlation of electrical conductivity in water samples and soil profiles.

3.2. **pH of irrigation water and soil saturation extract of the experimental field Yachay.**

In 1909 a Danish chemist Serenasen defined the hydrogen potential (pH) as the negative logarithm of the molar concentration (more exactly of the molar activity) of the hydrogens, ie: \( \text{pH} = -\log [H^+] \)

pH influences to soil in different aspects; the main relevance is availability of nutrients, such as (Phosphorus, Potassium, Iron, Copper, Boron, among others). At pH levels higher than 6.5 in soils, phosphorus with calcium precipitates are present and when acid soils with pH below 6.0 are present, reactions with iron, aluminium and manganese are present, while phosphorus is not available [22].

Results obtained in both soils and waters are shown in figures 5 and 6, resulting in an average pH for soils of 7.54 and for water of 8.27, in summary, medium alkaline soils [15]. According to regulations TULAS (2014) Book VI Annex 2 and the soil quality criteria for agricultural use, the maximum permissible values between 6-8 for pH are considered [14].
Figure 5. pH in soil profiles.

Figure 6. pH in water samples.

Linear, second and third order correlation equations were calculated. Analysis of pH in waters and soils resulted in a high correlation (figure 7).

Figure 7. Correlation of pH in water samples and soil profiles.

3.3. TDS of irrigation water and extract of soil saturation of experimental field Yachay.
The analysis of soluble salts in soils and waters tries to establish whether there are sufficient quantities of salts in them to interfere with normal germination of seeds, with growth of plants or with intake of water through themselves [23].
Total Dissolved Salts were 525 mg L\(^{-1}\) for soils and 999 mg L\(^{-1}\) for water (figures 8 and 9). Both normative [14] and [15] propose that TDS is a parameter that is closely related to EC and pH properties. Like other parameters, mathematical modeling was performed with first, second and third degree equations, resulting in a very high correlation between variables (figure 10).

**Figure 8.** TDS in soil profiles.

**Figure 9.** TDS salts in water.

**Figure 10.** Correlation of dissolved total salts in water samples and soil profiles.
Correlation obtained has R² from 0.78 to 0.985, which means that there is a balance between water and soil. This is an indicator that the type of salts present in the soil is very soluble, for this reason correlation is high.

4. Conclusions
Due to high correlation between the analysed parameters in soils and waters, it is determined that there is a balance between the two and it is possible to measure in water irrigation and to predict in soils, and thus can reduce costs and optimize time, so as to facilitate analysis of physicochemical parameters in soils and waters.

Mainly parameter in water is the pH that it is measured in aqueous solutions, since a high correlation was obtained, this can be translated into a minimization of costs in the processes of water and soil characterization, since it is only necessary analyse one of these.

Salts present in soil are very soluble, so that the same ions can be found in matrices, soil and water. With this analysis it can be predicted that soil studied in the future will be poor, because the irrigation water leaks all nutrients. According to the slope that has Yachay, these nutrients will be taken to the lower areas of basin that pass through this sector as is the case of Ambi River.

In experimental field of Yachay University it is possible to measure elements in irrigation water with a high probability that these elements are also in similar concentrations in soil, at its point of saturation, and very close to field capacity.

Acknowledgments
Universidad de las Fuerzas Armadas – ESPE, Departamento de Ciencias de la Tierra y Construcción, Carrera de Ingeniería Geográfica y del Medio Ambiente.

References
[11] Torres A and Acevedo E 2008 El problema de la salinidad en los recursos suelo y agua que afectan el riego y cultivos en los valles de Lluta y Azapa en el norte de Chile IDESIA 31-44
[12] Villegas J C 2004 Análisis del conocimiento en la relación agua-suelo-vegetación para el departamento de Antioquia. EIA, n/d
Muestras
[14] TULAS Texto Unificado de Legislación Ambiental Secundaria 2014 Obtained online:
http://www.industrias.ec/archivos/CIG/file/CARTELERA/Reforma%20Anexo%2028%20fe
b%202014%20FINAL.pdf
[16] Sepúlveda T V, Velasco J A and De la Rosa D A 2005 Suelos Contaminados por metales y
metaloides: Muestreo y Alternativas para su remediación (1era edición) (México: INE-
SEMARNAT)
(Baltimore: American Public Health Association-Port City Press)
con los paquetes SPSS-X, BMDP, LISREL y SPAD (Vol I y Vol II) Barcelona: PPU.
Geología. Facultad de Ciencias. Universidad de Zaragoza. Enseñanza de las Ciencias de la
Tierra 3.3 184-90
Obtained online: http://www.sian.inia.gob.ve/repositorio/manualessuelos/
metodos_analiticos_suelos/VIII.pdf
Fresno CA 233
[23] Richards 1959 Suelos Salinos y Sódicos Personal de laboratorio de salinidad de los Estados
Unidos de América Manual de Agricultura 60 172