Agrochemical Evaluation of Soil Quality Parameters

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Abstract
The analyzes show that the majority of soils are between neutral (6.5 < OS$_{10}$, OS$_{11}$ ≤ 7) and alkaline (7 < OQ$_3$, AL$_5$, S$_{6,7}$ ≤ 7.5), with 1/7 considered as very acidic soil (SA$_{19}$ < 5.5). For humidity measurement, OS$_{10}$ & OS$_{11}$ are the most humid. For the NO$_3$- concentration, it decreases from Oued Quibane to Had Lghoualem (17.8 ppm). The soils of this study have a low C/N factor between 1 and 6. The results also showed that the soils have a relatively low average OM level. Soils do not indicate a salinity value (EC < 250 μS/cm) with the exception of S$_7$ and OQ$_3$ (250 < EC (25 °C) < 750 μS /cm). Soils marked a dominance of P-Ca, the results discussed in this document indicate a probable difficulty to constitute reserves of P able to be directly up taken by crops.

Keywords: Semi-arid areas, soil quality, chemical analysis.

1. Introduction
Morocco presents a diversified soil-landscape (Touhtouh et al., 2014) (Badraoui et al., 2001)), we distinguish several types of soils that have developed on different geological substrates and in various climatic and topographic contexts (El Idrissi, 1992). In the semi-arid areas of Morocco, agricultural soils are degraded by excessive exploitation (Mrabet et al., 2004). Whereas, soil quality, according to more recent concepts, is defined as the capacity of soils to fulfill their various functions at the interface with ecosystems (Ruellan, 2003).
However, the study of the agrochemical properties of soils is a necessity not only to determine their qualities and behaviors with regard to the different uses (agricultural or non-agricultural) but also to ensure their preservation against the factors that threaten their sustainability (Akesbi, 2006). This part of study will focus on the chemical properties of soil samples taken from various points in the Chaouia region. These data are used to evaluate and interpret the factors that can block or promote the uptake of the phosphate fertilizer which is the objective of our future studies.
**Area of study**

The total area of Morocco is about 72 million hectares. However, only 9.2 MHa are cultivable and much of this area is severely threatened by various degradation phenomena (Akesbi, 2006).

The territory of the Chaouia-Ouardigha region covers an area of about 2.4% of the total national area. The region articulating around four provinces: Settat, Khouribga, Berrechid and Ben-Slimane.

The region has great natural and economic assets and potentialities (Akesbi, 2006), including:
- Its cereal production contributes 17.6% of the national production. The three main cereals (barley, durum wheat and bread wheat). (DPAE, 1990).
- 63.7% of the national phosphates market production.

The climate is semi-arid (Fig.1) with a tendency towards temperate climate in the extreme north, with an oceanic influence.

It is one of the hottest sub-Atlantic regions. This results in increased pumping and overexploitation of the water table during dry seasons.

![Figure 1: Location of the study area, Chaouia, Morocco.](image-url)
Soil distribution by climate zones (MADREF, December 1999) (Akesbi, 2006)). Rainfall (Fig.3) in this area is irregular and moderately low, confirming the semi-arid nature of the area (2008-2016 Series, National Agriculture Council, DRCA_CS).

![Annual precipitation reports](image)

**Figure 2:** Annual precipitation, series 2008-2016.

This is the main adverse condition in rainfed agriculture in Morocco, aggravated by water limitation, high temperatures, and shallow and eroded soils. (Driouech et al., 2010).

![Rainfall during 2015-2016](image)

**Figure 3:** Rainfall during 2015-2016.

There is considerable variability in rainfall from one year to the next (Fig.2), with a Max of 619 mm recorded for the year 2009-10, against a Min of 193.1 mm at the level of 2015-16, during this year.
the wettest month is March with 60.90 mm followed by February (Fig.3). On the other hand, we note that April which corresponds to the month of our sampling, recorded no precipitation.

2. Materiel and Methods

2.1. Map situation of soils used in the study:

In order to properly distribute the sampling stations across the study areas, a sampling plan was established using the data base provided by CRRAS for ferti-Map and via ArcGIS 10.1. For this study, 18 agricultural fields are selected at the beginning of April, located in the Chaouia-Ourdigha region (Table 1).

The soil is taken in zigzag (a composite sample of 3 points on average on the horizon of the unfertilized lines), with a depth of 0 - 20 cm, the choice of this depth is related to two reasons: (1) Selected sites are not very deep. (2) The deepness of soil where the roots thrive by fixing the plant on its support and feeding it to various factors of plant growth: Temperature, water, nutrients; It is also here, where the notion of the fertility of a soil is well correlated.

<table>
<thead>
<tr>
<th>N°</th>
<th>X</th>
<th>Y</th>
<th>Soil-Type</th>
<th>Area-Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>344632</td>
<td>256690</td>
<td>Fersialtic</td>
<td>Meglou</td>
</tr>
<tr>
<td>2</td>
<td>264347</td>
<td>275277</td>
<td></td>
<td>Oulad Abou</td>
</tr>
<tr>
<td>3</td>
<td>292803</td>
<td>237400</td>
<td>Vertisols</td>
<td>Oued Qibane</td>
</tr>
<tr>
<td>4</td>
<td>274345</td>
<td>255153</td>
<td></td>
<td>Ouled Said</td>
</tr>
<tr>
<td>5</td>
<td>285052</td>
<td>258140</td>
<td></td>
<td>Ali Moumen</td>
</tr>
<tr>
<td>6</td>
<td>297508</td>
<td>269066</td>
<td></td>
<td>Settat (1)</td>
</tr>
<tr>
<td>7</td>
<td>302087</td>
<td>286586</td>
<td>Calcimagnesic</td>
<td>Dower Lhaya Ben Ahmed</td>
</tr>
<tr>
<td>8</td>
<td>299756</td>
<td>279399</td>
<td>Isohumic</td>
<td>Ouled Said</td>
</tr>
<tr>
<td>9</td>
<td>306117</td>
<td>285833</td>
<td>Isohumic</td>
<td>Oule Said</td>
</tr>
<tr>
<td>10</td>
<td>269495</td>
<td>251677</td>
<td></td>
<td>Ali Moumen</td>
</tr>
<tr>
<td>11</td>
<td>265513</td>
<td>260417</td>
<td></td>
<td>Oued Qibane</td>
</tr>
<tr>
<td>12</td>
<td>272214</td>
<td>247209</td>
<td>Vertisols</td>
<td>Ouled Said</td>
</tr>
<tr>
<td>13</td>
<td>284524</td>
<td>258008</td>
<td></td>
<td>Ali Moumen</td>
</tr>
<tr>
<td>14</td>
<td>292827</td>
<td>237252</td>
<td>Fersialtic</td>
<td>Ouled Said</td>
</tr>
<tr>
<td>15</td>
<td>265358</td>
<td>260014</td>
<td>Isohumic</td>
<td>Ouled Said</td>
</tr>
<tr>
<td>16</td>
<td>272248</td>
<td>246957</td>
<td>Isohumic</td>
<td>Dower Fhabta</td>
</tr>
<tr>
<td>17</td>
<td>300114</td>
<td>279423</td>
<td>Vertisols</td>
<td>Dower Fhabta</td>
</tr>
<tr>
<td>18</td>
<td>302158</td>
<td>286592</td>
<td>Calcimagnesic</td>
<td>Settat (2)</td>
</tr>
</tbody>
</table>
The soils of this 1st sampling are mixed, dried, ground and sieved according to the reference NF ISO 11464, before passing to analysis of available phosphorus and pH. An acidic soil from Had Leghoualem (SA19), was added to the second table, characterized by its low water retention capacity, and its low level of organic matter. The sampling adopted in this study consists on exploiting the main soil classes which characterize Chaouia region. Also, the selected sites are representative in terms of available P and in terms of acidity levels (Table 2).

The reference standards needed to assess the state of soil fertility have been defined according to regional specificities. And, the illustration of the results is made according to the reference, Agro Services, Inc. (ASI): Levels of soil analysis, Nutrient Expert (2017).

**Table 2:** Designation of the profiles of the 2nd sampling (type of soil according to the site)

<table>
<thead>
<tr>
<th>Description / Type</th>
<th>Area-Name</th>
<th>Geo Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red soil, rich in iron oxide and aluminum oxide. With an Important content of clay which gives it a specific structure: It retains water considerably. (Fersiallitic).</td>
<td>Oued Qibane (OQ3)</td>
<td>N 32° 42' 41.9'' W 7° 36' 32.3''</td>
</tr>
<tr>
<td>Deep soils with a coarse texture. Black, very fertile, very rich in organic matter. (Isohumic)</td>
<td>Ouled Said (OS10)</td>
<td>N 32° 54' 40.7'' W 7° 54' 28.1''</td>
</tr>
<tr>
<td></td>
<td>Ouled Said (OS11)</td>
<td>N 32° 47' 42.1'' W 7° 49' 51.2''</td>
</tr>
<tr>
<td>Soils with a depthness less than 40 cm, rich in limestone. Having a generally dark color. (Vertisols)</td>
<td>Ali Moumen (AL5)</td>
<td>N 32° 53' 49.9'' W 7° 42' 8.9''</td>
</tr>
<tr>
<td></td>
<td>Dower Hbata (S6)</td>
<td>N 33° 05' 35.9'' W 7° 32' 25.1''</td>
</tr>
<tr>
<td>Soil with a medium-deep, developed on a limestone substrate.</td>
<td>Dower Lhfaya (S7)</td>
<td>N 33° 9' 30'' W 7° 31' 12.5''</td>
</tr>
</tbody>
</table>

**2.2. Techniques used in this study:**
Analytical methods used for the chemical characterization of the studied soils. (Pansu et al., 2003); (Gobat et al., 2010).

- **Total Phosphorus (P<sub>tot</sub>):** The determination of the total phosphorus is carried out by an acidic attack (HNO<sub>3</sub> / HCl).
Available Phosphorus \((P_{av})\): Extraction with a sodium bicarbonate solution at pH 8.5 in: \(m / V\) ratio of 1/20.

Phosphorus Bray II: Extraction with a solution of 0.03N ammonium fluoride and 0.1N hydrochloric acid in: \(m / V\) ratio of 1/7.

Potassium (K): Extracted in \(CH_3COONH_4\) (1N at pH 7), the determination is made via the flame photometer.

Total Nitrogen (N): By the Kjeldahl method: (1) Digestion of the sample in concentrated \(H_2SO_4\) at high \(T^\circ C\) (2) Determination of \(NH_4-N\) in the extract by titration of \(NH_3\) evolved by steam distillation.

Nitrates: By the Chromotropic method, via a spectrophotometer at a wavelength of 410 nm.

The carbonate content: Determination using a Bernard calcimeter.

Ca CO\(_3\): The determination of the active limestone relates to the calcium fraction of the carbonates which is precipitated by a solution of ammonium oxalate.

Macro & Oligo-elements: S, Mg, Fe, Al, by ICP spectrometry.

Organic Carbon: By the method of Walkley and Black. \(%\) OM = \(%\) C x 1.724.

Humidity Measurement (H %): The samples are dried at 105 °C. ± 5 °C. until constant mass. About 15 hours. The difference between the weight before and after drying expresses the water content of the initial sample.

\[
\text{Volumetric humidity: } Hv = d \times Hp
\]

\[
\text{Porosity: } P = 1 - \rho_{a}/\rho_{s}
\]

Index of vacuum: \(Iv= P/(1-P)\).

\(pH\) (\(H_2O\) & KCl): The measurement is carried out using a combined glass electrode dipping into a soil suspension in a \(1 \text{ g} / \text{ Volume ratio of 2: - In water: } pH\ H_2O\)

- In the KCl (1 mol/L) : \(pH\ KCl. \ pH = -\log_{10}[H^+]\). \(K_{H_2O} = [H^+] \cdot [OH^-] = 10^{-14}\).

Electrical Conductivity (CE): The measurement is performed by conductivity apparatus. Salts concentration (mg/l) = 640 x C.E

3. Results and Discussion

It was agreed that the fragmentary structure is the most appropriate for most cultures. And that the most favorable texture is that with a suitable balance between fine and coarse particles.

The texture is influenced by several elements including: Frequency of work, type of tillage, and machinery used. In turn it influences the germination of seedlings, as well as on the whole yield.

In practice, soil texture is an essential physical property that the farmer should know. In this study, however, the greatest interest is in the chemical properties of these soils.

3.1. Humidity Measurement (H %):

Water affects both the physical characterization (cohesion, stability, structure, etc.) as well as the chemical and biological properties of soils (alteration, transport of dissolved elements, aeration, etc.).

The water content in the sample is in the form of:

- The separation of water chemically bound produces a destruction of the crystal structure.
Physically bound water, of which two forms can be distinguished; the adhering water forming the outer film of the grains and the capillary water retained by the interstices of the product. The removal of this second form of water during the drying process made it possible to study the humidity of soil.

The soils studied have different water retention potentials. It is the isohumics, which have the higher level, the growth of the root system (SR) will be better in this soil because the mechanical resistance of the soil to the penetration of the root is lower there.

For OS\textsubscript{10} and OS\textsubscript{11}, air occupies a porous space of \(\frac{1}{4}\) of the total volume, this can be deduced by the ability of this type of soil to retain water bound to its structural state, which forms a set Coherent bond of the elementary particles by chemically bonded water.

After the soils of Ouled Said, we find those coming from Ali Moumen, Dower Hbata with a minimal Iv of 11\%, and then the soil of Oued Qibane, the latter contains clay in the form of major granulometric fraction, Giving it a malleable shape.

While the acidic soil has a lighter texture, it is the driest, with a humidity content not exceeding 0.6\%, and an Iv in the vicinity of 43\%, poorly drained soil, which Will cause immobilization of transport of the dissolved elements. If this type of soil (SA\textsubscript{19}) is intended for pots, this requires regular control, otherwise it takes a very characteristic structure (our experience with this type for the cultivation of chickpea, proved it). In order to better retain water and nutrients so that these elements are longer available to plants, while avoiding their leaching, an alga has developed strategies to resist stress, its name is Ascophyllum-Nodosum Effects have been scientifically proven (Professor Geert Haesaert, University of Ghent, Humifirst-Tradecorp), very rich in complex sugars, antioxidants and Oligo element. Once sprayed on the soil, it penetrates the plant and causes reactions that stimulate its physiology. This implies an increase in the storage capacity of the water present in excess by the soil,
contributes to the efficiency of the fertilizers and the absorption of the nutrients by the plants, which is especially important for the soils with a lighter texture. As in this case study, SA_{19}.

3.2. The acidity of Soil:

The soil has a buffering capacity, which makes it suitable for resisting pH variations. This ability is related to the presence of colloids, but the available amount of essential nutrients is influenced by its pH, with the ideal range being generally between 6.5 and 7.3.

![Figure 5](image)

**Figure 5**: The active acidity of action zones

pH (H_{2}O)

Active acidity is due to H^{+} ions in the soil solution, which is very important because it determines the solubility of several elements and provides the soil solution medium in which plant roots and microorganisms are exposed. The results obtained for this type of pH, show that these soils are in three acid-base statuses (Fig.5):

- 7 < OQ_{3}, AL_{5}, S_{6}, S_{7} ≤ 7.5: Alkaline soils.
- 6.5 < OS_{10}, OS_{11} ≤ 7: Neutral soils.
- SA_{19} ≤ 5.5: Very acidic soil.

The pH of SA_{19} increases the availability of Mo (Tran et al., 1995). On the contrary, the majority of the calcium present in this soil has been depleted (the soil is decalcified). Thus, this acidity can cause a much repaired deficiency of boron in the form of boric acid ((FAO, 1998); (Razafindramananana et al., 2015)).

On this side, in this acidic medium (≤ 5.5), the phosphates evolve towards insoluble crystalline forms, according to the reaction process (retrogradation):

\[
Ca(H_{2}PO_{4})_{2} + H_{2}O \rightarrow CaHPO_{4} + H_{3}PO_{4} \rightarrow H^{+} + H_{2}PO_{4} \rightarrow 2H^{+} + HPO_{4}^{2-} \rightarrow 3H^{+} + PO_{4}^{3-}
\]
This pH disrupts the electrochemical equilibrium and prevents the absorption of nutrients by the plant. The efficiency of fertilizers is then reduced since the elements supplied remain stuck in the soil. High acidity has important implications for soil quality and structure. It is, for the most part, considered a handicap for crops. Some chemical elements become toxic. This is the case for aluminum, which can account for more than 80% of the total exchangeable elements, leading to potential risks of toxicity to plants (it is in a form that blocks plant metabolism, Has caused to die).

**pH (KCl)**

The exchangeable acidity is due to aluminum and hydrogen adsorbed on the complex, easily exchangeable by other cations, as with K⁺ in a KCl solution.

![The exchangeable acidity of the soil](image)

**Figure 6**: Presentation of exchange acidity in soil.

Based on the results shown in this figure, pH (KCl) is always as low as pH (H₂O) with:

- An average exchangeable acidity for Oulad Saïd soils: \(0.6 < \text{OS}_{10}, \text{OS}_{11} < 1\)
- A low exchangeable acidity for other soils: \(\text{OQ}_3, \text{AL}_5, \text{S}_6, \text{S}_7, \text{SA}_{19} < 0.5\).

**Electrical Conductivity:**

The most conductive soils are those which contain most of the salts.

<table>
<thead>
<tr>
<th>Table 3: Ionic Conductivity.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Category</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Soils - Reference</td>
</tr>
<tr>
<td>E.C (mmhos/cm)</td>
</tr>
</tbody>
</table>
3.3. Organic Matter:

Table 4: Organic Matter content (% OM).

<table>
<thead>
<tr>
<th>Soil Analysis Levels (%)</th>
<th>Average level 2 - 4</th>
<th>Low Level &lt; 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil - Reference OS10, OS11, S6, OQ3, S7, AL4, SA19</td>
<td>% OM 3.0, 3.02, 3.78, 3.77, 2.67, 2.61, 1.02</td>
<td></td>
</tr>
</tbody>
</table>

The main components of soil organic matter are C (52-58%), O (34-39%), H (3.3-4.8%), and N (3.7-4.1%), the other predominant elements are P and S. Its decomposition produces CO₂, NH₄⁺, NO₃⁻, PO₄³⁻ and SO₄²⁻. As the pH increases, the number of negative charges increases as a result of the deportation or dissociation of H⁺. In semi-arid Moroccan areas, agricultural soils are degraded by excessive exploitation. This degradation is manifested by the reduction of the contents of organic matter and oxidation (Mrabet et al., 2004). The results obtained showed that the soils had a relatively low OM level, with a low soil content from Had Leghoualem. In very acid environments (Fig. 5), soil bacteria develop badly, so the nutrients are not available to be absorbed by plants because mineralization is limited. The 1% MO content could be considered as a threshold value below which the aggregates become unstable, increasing the risk of degradation and causing low structural stability (battance).

3.4. Nutrient status in soil:

Probably, the most important and unique property of soils is their ability to retain and release ions to the soil solution and to plants (Sumner et al., 1996). Indeed, the ions can be retained by the adsorbent complex of the soil in exchangeable form (Rhoades, 1982).

Complex M⁺ + X⁻ → Complex X⁻ + M⁺

The intensity with which the cations are retained (the fixation follows a preferential order) is as follows:

Na⁺² < K⁺ < Mg²⁺ < Ca²⁺ < Al³⁺ < H⁺

However, the anion binding energy would be as follows, in descending order:

PO₄³⁻ > SO₄²⁻ > NO₃⁻ > Cl⁻

The nutrient status is therefore evaluated by measuring the concentrations of elements available in soils: Table 6.

In this semi-arid zone (Chaouia), the soil exchange complexes are saturated. Calcium is the exchangeable cation occupying the exchange sites.

In the presence of atmospheric carbon dioxide, calcium becomes calcium carbonate. (CaO= Ca x 1.34):

CaO + CO₂ → CaCO₃ ;

Ca (OH)₂ + CO₂ → CaCO₃ + H₂O

In the soils of Had Leghoualem, calcium carbonate dissociates:

Ca CO₃ + H₂O → Ca²⁺ + HCO₃⁻ + OH⁻
If the soil is enriched with Calcium, in the case of soils OQ, AL, S, and S, the potassic fertilizer is introduced, this contribution will cause a decalcification of soil, the K-Ca ion exchange process is used to rebalance the concentration of the soil solution.

The presence of iron ions in soils S and SA is relatively low, already in the soil observation phase of SA, its color (white) was an indication of its absence. While the red color of the soil from Ouled Qibane indicated the presence of crystallized non-hydrated iron oxides (FeO). The presence of Al ions in the SA soil becomes exchangeable, while forming aluminum hydroxides.

\[
\text{Al}^{3+} + 3\text{H}_2\text{O} \rightleftharpoons \text{Al(OH)}_2 + 3\text{H}^+
\]

If not, they combine with the sulphates (SO$_4^{2-}$) is an osmotic regulator, coming from the mineral reserve of the soil: CaSO$_4$, 2H$_2$O(s) $\rightleftharpoons$ Ca$^{2+}$ + SO$_4^{2-}$ + H$_2$O) and render them insoluble.

In the laboratory, soil analysis most often expresses the potassium content available for plants, which is measured by exchange by saturating the soil sample with NH$_4^+$, This analysis shows, with the exception of SA, a high level that exceeds 200 ppm for all sites. This high amount of K$^+$/Mg$^{2+}$ causes a magnesium absorption limit. The boron deficiency is also induced to an excess of potassium.

From a nutritional point of view, the excess of one of the three cations Ca$^{2+}$, Mg$^{2+}$ or K$^+$ causes a phenomenon of antagonism towards the other two. Means that the magnesium fertilization is deficient for five sites of these studied soils (Table 6).

### 3.5. Nitrogen:

Quantifying of mineral nitrogen in soil is a widely used analysis which show how much mineral nitrogen (ammonification, nitrification) contains soil before the development of the crop.
The nitrogen (N) content of the soils studied varies between 0.3 and 0.5%. The threshold values corresponding to the level reported in the regional recommendations show the depletion of the nitrogen fraction. This makes its level in many soils, one of the first factors limiting agricultural production.

In order for nitrogen not be the limiting factor of yield, it is necessary to adjust the period of supply, the quantities of nitrogen are therefore available of plant cycle needs. Nitrogen tends to be converted to nitrate (NO$_3^-$), and because of its negative charge, the nitrate ion has a high affinity for water, it remains free to move through the soil profile. For these case studies, the NO$_3^-$ concentration decreases by half from the Oulad Quibane soil (the high value of NO$_3^-$ can affect the carbon cycle) to the soil of Had Lghoualem (17.8 ppm).

The factor of dynamics (C/N) shows that these soils have a low factor (C/N) varying between 1 and 6, that means there is no enough nitrogen to allow the decomposition of carbon, the% of C, for the soils: OS$_{10}$, OS$_{11}$, S$_{6}$, S$_{7}$, AL$_{5}$, SA$_{19}$, OQ$_{3}$ are successively: 1.7, 1.8, 2.2, 1.6, 1.5, 0.6, 2.2. This may also indicate that organic matter will be rapidly mineralized, i.e. Organic matter with a low (C/N) (less than 8) will have a low impact on the humus stock of a soil.

3.6. Phosphorus:
The problem of phosphorus nutrition is often linked to the problem of the mobilization of reserves, which is always difficult in an acid environment as well as in a neutral or basic environment (Duchaufour, 1997). Indeed, according to the concept of mobility of Bray, an immobile element is considered adequate only if it is present in sufficient quantity on the surface of the roots where it is immediately absorbed. The moving elements can reach the roots by diffusion or by following the movement of the water in the soil (mass flow).

As a result of this introductory presentation, we can easily see that on all the soils studied, and without taking into account the phenomena of resorption which singularly complicate the interpretation of the results, phosphorus becomes insoluble by the plant.

**Table 5:** Distribution of soils according to their percentage in exchangeable bases and potassium.

<table>
<thead>
<tr>
<th>Element Soil</th>
<th>% Ca</th>
<th>% Mg</th>
<th>% Fe</th>
<th>% Al</th>
<th>K (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OQ$_3$</td>
<td>6.69</td>
<td>1.98</td>
<td>4.81</td>
<td>7.76</td>
<td>669</td>
</tr>
<tr>
<td>SA$_{19}$</td>
<td>0.14</td>
<td>0.23</td>
<td>1.69</td>
<td>2.59</td>
<td>117</td>
</tr>
<tr>
<td>AL$_{5}$</td>
<td>7.01</td>
<td>0.94</td>
<td>3.77</td>
<td>7.68</td>
<td>212</td>
</tr>
<tr>
<td>OS$_{10}$</td>
<td>1.27</td>
<td>1.08</td>
<td>5</td>
<td>10.2</td>
<td>221</td>
</tr>
<tr>
<td>OS$_{11}$</td>
<td>1.23</td>
<td>1.02</td>
<td>5.01</td>
<td>10.2</td>
<td>272</td>
</tr>
<tr>
<td>S$_{6}$</td>
<td>6.33</td>
<td>1.24</td>
<td>3.52</td>
<td>6.88</td>
<td>311</td>
</tr>
<tr>
<td>S$_{7}$</td>
<td>5.59</td>
<td>0.43</td>
<td>1.5</td>
<td>1.33</td>
<td>282</td>
</tr>
</tbody>
</table>

Correlations between the elements extracted on the 7 agricultural sites.
The ions most likely to ensure the phosphate nutrition of plants are found mainly in fractions: P-Al for SA$_{19}$, and P-Ca for soils: OQ$_{3}$, Al$_{5}$, S$_{7}$, S$_{6}$, OS$_{10}$ and OS$_{11}$, which precipitate in calcium phosphate form causing an retrogradation, by formation of tricalcium phosphates in varying proportions within each of these conditions. These interactions with cations drastically limit the P availability and mobility.

![Figure 8: Bi-varied adjustment of available P (ppm) by total P (ppm).](image)

There was a significant positive correlation around 0.93 between the levels of the two types of phosphorus for the 7 observations. However, according to the regression equation, the estimate of P available as a function of the determined contents of the total P appears difficult. (Table 6, Fig. 8).

However, for the determination of total phosphorus, it is rarely required because it has very little agronomic interest (Baize, 2000). As for the estimation of available phosphorus, it is particularly delicate according to chemical extraction methods, and to the supposedly bio-available and combined forms in the soil under multiple aspects (J.-C. Fardeau et al., 1988).

For a simple understanding, the available P is relatively the phosphorus ion forms (HPO$_4^{2-}$, H$_2$PO$_4^{-}$) which can rejoin solution system for a compatible time with the possibility of its absorption by the plant during its growth (J. Fardeau, 1993b, Morel, 2007).

On the basis of the results expressed (Fig. 8), as regards total phosphorus, according to an energetic attack by fusion of the two acids, the soil from Oued Qibane shows the highest contents. Whereas, in all seven cases the maximal nutrition fraction of crops does not exceed 10%, without taking into consideration the soil chemical environment, this percentage can be reflected by the very high dominance of P-Ca.

The phosphorus easily extractable with water is also very little represented ($P_{SE} = 2.13$ ppm as a Max value for OQ$_{3}$), even for the soil with a relatively weak fixing power (S$_{7}$). This confirms that regardless of the total P richness of a soil, only a low percentage of this P is available to plant during their development cycle. (J. Fardeau, 1993a).

A study carried out on a database contains more than 700 soil profiles distributed in Chaouia region, within the Regional Center for Agronomic Research in Settat, showed that only 20% of agricultural soil needed only the Phosphate as a fertilizer element.
This study confirms the categories of our soils analyzed, namely:

1. Soils where bioavailability is intermediate:
   \[ 10 \text{ ppm} < S_{A_{19}}. \text{ Al}_{5}. O_{S_{10}}. O_{S_{11}} < 40 \text{ ppm} \]
2. 1/7 for high bioavailability:
   \[ O_{Q_{3}} > 40 \text{ ppm}. \] For low to medium-demanding crops, it is not necessary to adding fertilizers.
3. 1/7 with a probable deficiency:
   \[ S_{7} < 10 \text{ ppm}. \]
   Phosphate ions react with many soil constituents, whereas the results discussed in this paper indicate a probable difficulty in mobility P reserves directly absorbed by the crops (Compaoré et al. 2001).

4. Conclusion

The qualitative interpretation of soil fertility is done by comparing the results of analysis at threshold values, below which the soil presents a risk of deficiency.

This interpretation is only indicative, since the region has an important pedological diversity. This interpretation of the analytical data resulting from the extractions requires for an accurate diagnosis of deficiency, not only mechanistic approaches but also a foliar analysis.

References

