Soils of Tunisia

Mtimet A.

in

Zdruli P. (ed.), Steduto P. (ed.), Lacirignola C. (ed.), Montanarella L. (ed.).
Soil resources of Southern and Eastern Mediterranean countries

Bari : CIHEAM
Options Méditerranéennes : Série B. Etudes et Recherches; n. 34

2001
pages 243-262

Soils of Tunisia

Amor Mtimet[1]

Introduction

Pedological studies based on soil survey, photo-interpretation, laboratory analysis, and remote sensing, were implemented in Tunisia since more than half-century. The magnitude of these surveys is so high that they practically cover the whole territory of the country. They were aimed mainly at acquiring better knowledge of country's soil resources in order to use them in land reclamation and agricultural development projects. Therefore, Tunisia is among the few African countries where abundant soil data and studies are available. They include:

- 636 Pedological studies;
- 310 Specialised pedological studies;
- 2,085 Preliminary survey studies; and
- 18 Bulletins published by the Soils Directorate.

Thus totalling 3,049 classified documents.

About 65% of the total surface area of the country is covered by pedological surveys, which equals to about 10,669,000 ha. Nevertheless some of those concerned with agriculture development, often ignore this large mass of valuable soil data. It is becoming evident that the decision-makers are more prone to consider crop and animal production, hydraulic works and management plans rather than the sustainable use of land resources.

In order to benefit from the funds of a new agriculture policy, the use of soil information has become a must, and those who are in charge of the national development should start addressing also the

[1] Direction des Sols, Ministry of Agriculture, Tunis, Tunisia.

sustainable management of soil services. Extension services to farmers are now evolving which would allow them to an easier access to soil information.

Description of the soils

General background

Since Tunisia is at the same time a Mediterranean and a Saharan country the soils show all the sings of this climatic, morphological and geological diversity. According to the French system of soil classification the soils of Tunisia are classified as podzols, vertisoils, red Mediterranean soils, calcic-magnesic soils (dominant soils), brown and isohumic soils, saline and hydromorphic soils and also poorly evolved soils. Their distribution is based on the catena system.

The structural and geo-morphological framework of pedogenesis in Tunisia

The set of the geological data of the Tunisian environment leads to distinguish nine large natural zones from the north to the south of the country (Mtimet 1999):

1. The flysch Oligocene zone of Numidia (Mogods-Kroumirie);
2. The marly calcareous zone of Béjà;
3. The Mejerda valley;
4. The Atlas that subdivides into:
   - Deeper zones, and
   - Transversal ditch zone
5. The Ridge;
6. The Sahel zone subdivided into:
   - Kasserine island or High Steppe;
   - Eastern Plain or Low Steppe, including:
   - Sahel of Sousse and Plateau of Sfax;
7. The domain of the southern Atlas depressions;

8. The Dahar Dome and the Sahara platform; and
9. The coastal plain of Jeffara.

All the above, comprise a high diversity of soils. They include the arid soils of the Northwest as well as soils showing characteristics inherited from Quaternary paleo-climates (ancient, middle, recent). The later cover the slopes and *glacis* – of large valleys and crusts. Among the typical elements of soil formation in Tunisia should be mentioned the harsh climatic conditions, heavy winter showers, variable plant cover, and predominantly calcareous and marly lithology.

The soil cover

The total surface area of the country of about 16,4 million hectares has a length of 900 km and a width of 542 km. It is evident therefore for Tunisia to show from the north to the south a rather strong bio-climatic variability. The distribution of land use and land cover is given below, however those data do not cover the whole territory of the country.

- 1,300,000 ha are used for annual crops (average), which can reach as high as 1,667,000 (1992,1993 data);
- 2,000,000 ha of shrub crops;
- 1,000,000 ha for *maquis* and forest rangeland, of which 680,000 are forests;
- 6,000,000 ha rangeland (this areas are on the decrease);
- 600,000 ha for alfalfa steppe (resources on the decrease);
- Another 5,015,000 ha (or about 30% of the total surface area of the country) consist of inadequate land for agriculture use, made of raw mineral soils and saline soils as found in Erg- Regs- Sebkhas- Chotts- salty lakes (Garaât).

The North

The North includes three bio-climatic areas (humid, sub-humid and semi-arid) and at least 5 natural regions. The major soil groups are:

- Forest soils: leached brunified soils of extreme Northwest and the mull soils;
- Topomorphic and lithomorphic vertisoils are present in depressions and inland plains and are characterised by the presence of swelling clays of dark colour (soils are higher in organic matter content, and show cracking during the dry season);
- Mediterranean red soils or the local Béjà soils, found also in Bou Kornine and Jebel Zaghouan have developed on Jurassic limestone or on *glacis* of the Quaternary. They have fine texture, a well-developed polyhedral structure and calcareous accumulations.
- Carbonate soils (calcic-magnesic) regularly cover calcareous parent materials. Their thickness is variable following the general ground morphology. They exhibit crusted horizons or contain coarse calcareous elements.
- Alluvial soils (poorly evolved) sometimes have a thickness of more than 2 m. They cover large valleys of extended watersheds of Mellegue, Mejerda, and Tassaa. These alluvial soils undergo salinisation processes downstream and in the low valley areas of Mejerda (Mornaguia, Kalaat Landalous) or along the Beni-Khiar, Kélibia (Cap Bon) plain.

The Centre

South of the ridge, the semi-arid domain and part of the arid domain extend southward to Sfax, Gafsa. The Centre includes 4 great natural regions: the High Steppe, the Low Steppe, le Saheland, and the Kairouan region. They present the following soils (prevailing soils are given in decreasing order):

1. iso-humic soils;

2. carbonate soils (calcic-magnesic);
3. saline-sodic soils;
4. poorly evolved soils;
5. mineral soils resulting from erosion.

- Iso-humic soils are brown soils with dominantly coarse texture. They are rather deep with an organic matter content ranging from 0,5% to 1,5%. On the plateaux of Sidi M'hedeb and Sfax, they have calcareous crusting, which allows them to be associated to calcic-magnesic soils. These soils develop over large surfaces, mainly in the low steppes, in the Sahel and in the Sfax region (Centre, Centre East).

- The other types of soil, i.e. calcic-magnesic, alluvial, saline and those resulting from erosion activity, cover almost half of the south-western part of the Ridge and the High Steppe of Kasserine region. The valleys and the slopes are generally covered with calcareous or gypsum nodule-soils. Some areas of the latter were used for fruit trees irrigated by sprinklers after decrusting and subsoiling the hardened pans.

- Saline-sodic soils are found in depressions and in the main Sebkhas like El Kelbia, Sidi El Hani, Monastir, El Gharra and Charita (region of Souassi). They develop on alluvial materials and on quaternary soils mostly consisting of marls, gypsiferous clays and sands. The supply of saline water and the rather fine sedimentation are the main processes that cause salinisation of these areas.

- Saline soils of Sebkahs are slightly saline thanks to the high content of sand and silt. Chloro-sodic groundwater, having various levels of salt concentration depending on the seasons is also present. The piezometric level generally ranges between 0,8 m and 1,40 m. Waterlogging is observed at the base of the soils as well as gley or pseudo-gley spots.

The South

The southern domain of Tunisia extends from the low plains situated south of Gafsa Mountains up to the Sahara boundaries. It includes huge morpho-pedological sets where the parent rock and maritime types of climate of Sahara influence and determines the variety of soils. These soils are:

1. calcic-magnesic soils (calcareous soils containing gypsum and limestone);
2. iso-humic soils (subdesertic called sierozems);
3. saline sodic soils (sebkha - chott);
4. poorly evolved alluvial soils (irrigated oasis soils and soils used for dry farming);
5. raw mineral soils (on hard rocks, coarse colluvium or calcareous and gypsum crusts).

- South West is characterised by large spaces of poorly fertile soils:
  1. wind borne sandy soils; (Erg);
  2. salt-affected or saline-sodic soils (Sebkha - chott);
  3. pebble soils (Regs, Hamadas du Dahar);
  4. loess soils (crusted sierozems, poorly evolved soils developed on old iso-humic soils but truncated and evolved at the surface of 0 to 50 cm;
  5. poorly evolved soils of the watershed formed on alluvial or wind borne parent material

- SouthEast has a rather uniform unit: the Jeffara plain, which stretches from Oued el Akarit, in the North, up to the Libyan boundary in the Southeast. From West to East, three compartments are distinguished: the Upper Jeffara, Low Jeffara sub-set, and the sub-set of the El Ouara plain in the south. The surface area of this region is crossed by *oueds* that drain the streams of Matmata Mountains. Its main soils are calcic-magnesic soils (located largely on footslopes), poorly evolved alluvial soils (low

plains and oued valleys) and saline sodic soils of Sebkhas and Garâats.

- Poorly evolved soils, either wind borne or fluvial, form the best agricultural lands of south west (oasis or Ségui soils). In fact, they are deep (>1,50 m) and have silty-loam to sandy texture. Organic matter can barely exceed 0,5%. Gypsum accumulations could be present at medium depths of 40 - 60 cm and a gypsum borne crust is therefore present almost everywhere at the boundaries of *garaâts* and *chotts*. Of course, salinity appears from bottom to upper layers. Its content varies according to the cultivation patterns. In most cases, these soils show spots of waterlogging and salinity as found in Nefzaoua, Gherib, Jerid, Gafsa regions.

- Sandy soils of the plateaux and eastern Erg. The sandy soils of this last unit are characterised by their particle size distribution (ferruginous coarse sand) and the magnitude and morphology of their sand dunes (Barkhanes, Dunes, Shan interdunes). They are used as desert pasture. Sandy soils of plateaux (Dahar, boundary of chotts) have a finer white and ochre yellow material (fine sand), and are poorly structured. They result from the mechanical and chemical degradation of gypsum or loess material (Sahara loess with calcareous nodules). They surmount by a shallow layer and consolidated layers of gypsum or calcareous crust. These soils thus constitute parts of the rangeland, which are very sensitive to overgrazing or episodic cereal growing during the rainy periods.

- Salt-affected soils (solonchak, solonetz) develop over large depressions: Chott Jerid, Chott Gharsa and the numerous *sebkhas* and *garaats* act as outlets of the major watersheds. They cover large surfaces with saline crust during the dry season or swampy areas with the presence of a sub-surface layer during the cold seasons. Gypsum concentrations can appear at 40-60 cm depth. The boundary of these units (200 to 500 m) is occupied by wind borne sands (*nebkhas*) with halophyte vegetation used by camels for grazing.

- Pebble soils are also called raw mineral soils. They are made of coarse elements, which largely exceed 70% of their volume from the bottom of the valley colluvium to the upper coarse alluvium. These could be Lithosols or Regosols either, if their soil matrix includes finer elements. They cover the Dahar and the slopes of the mountains Chareb and Matmata.

- Iso-humic loess soils (sierozems, poorly evolved soils and Regosols, Mtimet 1983) of Matmata mountains and their edges as well as those of Segui of Gafsa, have developed over wind-originated parent materials. They have undergone through a pronounced pedogenesis (calcareous accumulations as nodules and crusting) during middle and recent Quaternary age.

- These deep soils cover the slopes, the valleys, the large marly depressions of Tamezret, Techine, Beni Kheddache, Beni Zeltene, as well as the plains near Jeffara eastward. Their morpho-analytical characteristics show the relevance of fine sands, coarse silts and a poor structural stability that initiate rill and gully erosion in the form of *jessours*. Rehabilitation works of soil and water conservation are an old practice (e.g. Jebalias) and they are consolidated at present by recent works. The lands are used for tree crops, olive trees and legumes.

The relevance of saline soils and secondary salinisation

Sodium chloride is the salt that, due to its high solubility, influences more the saline environment of south Sahara, however a large part of salt-affected soils also exhibit relevant gypsum spots related to the presence of calcium sulphate in ground water. In the zone of fluctuation of water table or the capillary fringe explored by roots, sulphates can precipitate giving rise to various forms of gypsum accumulation. They occur as nodules, crusts and incrustations of gypsum flower and micro-crystals, as found in Terch, Deb-deb, and Ras-Kelb. These forms are spectacular, particu-

larly in the downstream portion of badly drained old oases and on the boundaries of the *chotts*.

Generally, these soils are not arable except those that, through irrigation, can be leached and drained (oases), as well as some fringes of land that, on the occasion of rainy years, can sustain, due to temporary drainage, episodic cereal growing (barley).

Salinised landscapes

The estimated areas actually affected by ground water rise, are evaluated to be about 10,000 ha in the Low Valley of Mejerda, 1,000 ha in the Middle Valley and about 5,000 ha in the upper Valley. For the oasis, the affected surface areas are about 500 ha in the oasis of Gafsa, 2,500 ha in the oasis of Tozeur, 5,000 ha in the oasis of Kébili and about 2,000 ha in the oases of Gabès. In addition, should be considered other 4,000 ha subdivided into several small perimeters in depressions of the Centre and in Sahel. Many efforts are being made at present (setting up of new drainage systems, reclamation) to remedy such constraints.

Agronomic suitability and soil sensitivity: their efficiency in dry and irrigated farming

The agronomic suitability of the soils is the result of a match between the morphological factors and the physical-chemical properties of the soil in a given climate. Climate remains a decisive factor not only for the different agricultural uses of land (rainfed or irrigated system) but also for the degradation processes of the soil as well. Methods and agricultural practices are associated with the management of agricultural lands in the search for better yields. Following are some considerations for different regions of the country.

The North

- The North West with its natural regions of Kroumirie-Mogod (sub-humid zone) is devoted mainly

to silviculture and animal husbandry. Forest rangelands are covered with fodder crops. Supplemental water is needed at the footslopes of the mountains and terraces to allow the cultivation of tree crops.

The Upper Tell plateaux and internal plains that extend towards Northeast, are the domains of Vertisols and red soils (Chromic Luvisols). They form the cereal-growing zone where the best yields of the country are achieved. (Jendouba - Béja - Le Kef - Siliana). In fact, field crops (durum wheat, soft wheat, barley, and oat, associated with fodder rotations) are mostly suited to these soils.

- The North East which include the sub-humid to semi-arid regions of Bizerte, Ariana, Zaghouan and Nabeul have various type of lands, suitable for field crops, olive trees, fruit trees and vineyards.

The Centre

- Central and Western regions include Central Tunisia and southern slope of the Ridge. The western mountains (Djebels Chemama, and Chambi) are covered with forests (Aleppo pine), rangeland and alfalfa steppe. Below this belt, occur the olive trees and fruit trees associated with cereals (oat), which cover the footslopes of the mountains. The plateaux of centre west, and alfalfa steppe, are used as rangeland up to the plain of Sidi-Bouzid, towards the East. In the plain of Kairouan and Enfida, olive trees, vegetable crops and irrigated cereals cover large surfaces.

- In the Centre and Eastern regions are included the coastal sector of Sahel of Sousse and Sfax, which are covered with olive groves and almond trees as the major agricultural crops. Rangeland is found in the lithological crusted zones: gypsum plateau of Sidi-M'hedeb and the region of Skhira where protected agriculture around shallow wells is now extending on ameliorated soils

(subsoiling, and addition of organic matter supply).

The South

The areas of southern Tunisia are located south of the 200-mm rainfall/year line and thus are included within the arid Sahara bio-climate. Along the edge of Gabes Gulf included are 6 governorates.

- The South West includes the large areas of Chott Jérid, Rharsa and Erg. The only arable lands are found in the traditional (Nefzaoua, Jerid, and Gafsa) or modern oases (new irrigated schemes: Ibn Chabbat, Hazoua, and Régim Mâatoug, el Faouar). The remaining area represents rangelands for semi-nomads around the Chotts or towards Dahar (reverse of Matmata).

- The South East region is mainly cultivated with tree crops, such as olives, figs, and almond trees, which dominate in the plain of Jeffara that benefit from runoff waters. Coastal oases of Gabes, Medenine, Jerba are situated on alluvial soils and are irrigated from deep wells with salty waters (> 3g/l). Episodic cereal crops or some irrigated schemes (Sidi Maklouf, Ben Gardane) are scattered in the region. Saline rangeland soils are found along the edges of *sebkhas* (El Melah, El Adibet) and in El Ouara plain.

Soil suitability and constraints in agricultural production

Tunisian soils are subjected to quite contrasting climatic factors like drought (over 3/4 of the surface of the country), short duration torrential rainfall, and increasingly important anthropogenic factors along the coast (urbanisation, inadequate cultural practices, and land tenure problems). All these factors make the soils fragile and increase their sensitivity to the degradation of their surface and their profile, either mechanical or chemical. To summarise the main processes of land degra-

dation, the importance of the following factors has to be examined:

- water erosion;
- wind erosion;
- urbanisation; and
- salinization and waterlogging.

On average per year, these processes affect about 23,000 ha, most of which is related to water erosion, i.e. 10,000 ha. The present strategy for water and soil conservation to a large extent consists, in decreasing such rates as for example in the region of Kef, Siliana and Kirouan. Several observatories and experimental stations monitor these processes.

The following soil constraints or factors are considered important for agricultural development: slope, thickness, texture, permeability, limestone, salinity and drainage.

Nation-wide, 29% of lands are occupied by agriculture, 36% by rangeland and 35% by lands, which are inadequate for agricultural production. Fertile agricultural lands represent about 21,5% of the total area of the country.

♦ Depending on the bio-climatic regions and their sensitivity, the different types of land cover can be classified in the following order:

  - Cereal-growing lands;
  - Tree croplands;
  - Low plains and oasis irrigated lands;
  - Forest lands of the North and the Centre;
  - Rangeland of the Centre and the South.

Cereal lands

These lands mainly consist of vertic soils or brown red and brown iso-humic soils. Two physiographic and physiological constraints have to be considered for better exploiting these soils. The former re-

lates to the percentage of slope when it exceeds 8% in marly soils, because as result of mechanisation gully erosion and landslides occur. . The latter appears when the slope is too small and lateral drainage is absent. It forms then swampy areas (*marjà*) where waterlogging is considerable. Such areas are quite evident in the regions of Jendouba and Kef. Of major importance for better farming is also the monitoring of water quality and fertility status of the soil.

Tree-crop lands

They include deep brown or alluvial soils with a well-balanced texture. These soils are found into many bio-climatic areas. The lands could be not suitable to young plantations if the following characteristics are observed:

- soil depth is smaller than < 80 cm;
- slope is too high;
- texture is fine (clay to silty clay); and
- a crust layer or gypsum crusting is present close to the surface (< 40 cm).

Tree-crop lands have to be protected from runoff through hydraulic works (terraces, cordons, *tabias, meskat* system, and *jessours*) and thus benefiting from additional water in the rainy periods of the central and southern regions of Tunisia.. Tree-crop lands represent more than two thirds of the cultivated land (3,5 million ha). Olive trees extend over 1,5 million ha of the Tunisian land.

Irrigated lands

Irrigated lands continue to increase in Tunisia as development projects for the efficient use of underground and runoff waters are on the increase. At present irrigated lands equal about 350,000 ha.

The forecasts for the next five-year plans estimate that these surfaces will reach 400,000 ha. Such important projects will contribute to intensify land

productivity and to increase agricultural production in the country.

The development of these areas requires huge credits in order to prevent loss in productivity. Secondary soil salinisation is one of the causes in the lowering productivity of these soils in the irrigated schemes. Its origins are many and diversified and its prevention necessarily needs appropriate land-use policies and efficient irrigation water management.

Control checks for secondary soil salinisation in the irrigated schemes, are officially established as an ordinary activity within the Soil Directorate. They are aimed at localising, in the space, the salinised surfaces, determining the origins of salinisation, its position along the soil profile and formulating possible solutions to reclaim the soils and correct this constraint. Such measures are indispensable, since the diagnosis and precise localisation are useful data that allow precise methods of intervention in order to improve soil productivity.

The irrigated surface area in Tunisia is estimated to be about 350,000 ha. The Northeast includes 32% of this area, the Centre and the West 31%, the Northwest 22%, the South 9% and the Centre and East 6 %. Vegetable crops, field crops (cereals, legumes, fodder and industrial crops) and fruit trees are increasingly extending in the proximity of dams and wells. Compared to other regions, the South and the Centre-West of the country are potentially better suited for extension of irrigated areas.

However, the use of salty water for irrigation in the areas of the Centre West and the South, especially on those soils having fine texture (silty to silty-clay) could result in increasing salinity and therefore reduction of productivity. To avoid this more attention should be paid when drafting irrigation and drainage development schemes.

Salinisation does appear in the dry periods and/or when the well discharge decreases (i.e. year 1993/94). Other causes of salinisation are found

when abundant irrigation water is applied resulting thus in groundwater rise as found in the low plains (Mejerda, Kairouan), in the periphery of Sebkha or of Chott (oasis), where drainage is almost non-existent and waterlogging occur.

Forest lands of the North and the Centre

Forest lands of the North and the Centre include the major Tunisian forests, covering 675,000 ha, and consisting of cork oak, holm oak, Aleppo pine, etc. Cropped soils extend in the chain of Kroumire, High Tell and the Tunisian Ridge. They occur in the mountains, hills, and *glacis* as brown calcareous Mediterranean soils, and/or rendzina soils.

Beyond the forest domain, which is still rather protected, cropland areas are increasingly expanding threatening thus the natural woods and causing erosion by runoff. According to recent studies, the decrease of forest cover in Kassarine region is estimated to be equal to 1% per year (Jebel Chemmama) while since the independence of the country, more than 1,000,000 ha nation-wide have been converted from forests to cropland. Estimated surfaces converted to cropland in the Centre cover about 379,000 ha and 2,800,000 ha of rangeland steppes in the south of the country.

During the last years, the Government has started considerable reforestation programmes for the areas of Northwest, the Centre and the West. The results of these efforts are already visible and remarkable.

Rangeland areas of the Centre and the South – Desertification hazards

In the past years these lands were covered with perennial crops, like alfalfa (especially in the upper parts) and other steppe species (*arthrophyton, rantherium*), but since the 60s they have been subjected to tillage and overgrazing. Meantime, the increasing number of cattle herds has contrib-

uted to further degrading the plant cover and indirectly the soil.

After the70s, the old nomad pastures of southern regions of Tunisia (Sidi Toui, el Ouara), have been replaced by mechanised cereal growing thanks also to some rainy years. This practice has favoured the desertification of many areas of these regions.

From the ecological point of view and in order to highlight the fragile nature of our land resources, it should be reminded that the arid zones (Sahara zone not included) cover over 6,290,000 ha, which are estimated as:

- 12% very degraded areas;
- 40% medium degraded areas;
- 17% marginally degraded areas; and
- 31% not degraded areas.

The structure of Soil Directorate

The Soil Directorate is a technical institution operating under the supervision of the Ministry of Agriculture. The major references presently used by technical services go back to the pedological service set up in 1942 that was restructured with the services of agricultural hydraulic engineering to establish in 1977 the Directorate of Water and Soil Resources (Direction des Ressources en Eaux en Sols - DRES). Finally, the present structure of the Soil Directorate was acquired by decree n° 83-1244 of 22 December 1983 that states its main attributions as follows:

- Soil inventory and mapping;
- Pedological expertise;
- Protection and safeguard of agricultural lands and natural resources;
- Studies on land management;
- Studies for soil recovery and reclamation;

- Analyses for pedological, agro-pedological and environmental purposes;
- Soil information database management, development and updating.

The Soil Directorate includes three sub-directorates and two shared services.

Responsibilities of the Sub-Directorate of Soil Inventory and Mapping

- Soil inventory through the establishment of basic soil maps and of databases in order to improve and update soil classification, and assist in land management and land use planning;
- The drafting and execution of projects aiming at the preparation of different types of maps, including land classification maps for irrigation and also providing assistance to the farmers for the optimal use of soils.

Responsibilities of the Sub-Directorate of Research and Experimentation

- To carry out basic research in the field of soil science in order to increase and deepen knowledge on the different soil types of the country;
- To carry out applied research on soil fertility and to provide guidance for better land use in agriculture through experimentation;
- To control the irrigated schemes and follow up their evolution, especially referring to salinisation.

The Sub-Directorate of Soil Analysis

Is in charge of the following:

- Analytical determination of the physical, chemical and biological characteristics of soils and waters and promotion of new analytical techniques most appropriate for the different soils of the country ;

- Co-ordination and supervision of the regional soil and water analysis laboratories in the country.

Other specialised scientific institutions

Since 22 December 1983 the Soil Directorate of the Ministry of Agriculture is the national responsible agency to study and monitor the soil resources in Tunisia. Nevertheless, there are also other research and teaching centres that may initiate and conduct soil-related actions and programmes. They include:

- L'INRAT (Institut National de la Recherche Agronomique de Tunisie).
- L'INRGREF (Institut National de Génie Rural, des Eaux et des Forêts).
- L'IRA (Institut des Régions Arides).

These actions consist in research studies related not only to soils but also to other components of the environment including water, plant, and human activities.

The presence of international institutions like IRD (former ORSTOM) and GTZ in mission in Tunisia contribute to the development of some research projects. They aim at addressing environmental problems such as soil erosion, salinisation, desertification process, and allow, to a large extent, to benefit from the technological transfer and scientific training.

The List of soil analyses made at the central laboratory

Classical physical and chemical analyses

Particle size distribution, pH (water, K Cl), total carbon, total nitrogen, pF (4.2 – 3 – 2.7), Moisture and saturation, Cation exchange capacity, Exchangeable potassium, Exchangeable sodium, -

Exchangeable magnesium, Exchangeable calcium, Total and active $CaCO_3$.

Specific analyses

Total and free iron, C.p.i. (Chlorosing capacity index), B.d. (bulk density), R.d. (real density), Structural installation index, Leaf analysis (nitrogen, Ca, Na, K).

Future analyses (scheduled)

Heavy metals: Cu, Zn, Fe, Mn, Trace elements (for mineral nutrition).

Location of Soil Laboratories in Tunisia

Tunis, Ariana, Bizerta, Beni Khalled (Nabeul), Jendouba, le Kef, Kairouan, Kasserine, Sidi Bouzid, Monastir, Mahdia et Gabès.

Suggestions

The medium and long-term objectives of the Soil Directorate include the investigation and assessment of the state of soil resources in Tunisia through:

- Sustainable soil development and management in the context of the Mediterranean and pre-Sahara regions;
- Surveying soils and soil ecosystems in different agro-ecological environments;
- Investigating soil distribution within the different landscapes;
- Assess the impact of human-induced activities on soils and environment in both dry and irrigated farming.
- Use of Geographic Information Systems (GIS) for database creation and for making environmental impact assessments;
- Active participation in the Euro-Mediterranean Network of Soil Information.

Acknowledgement

The editors are grateful to Mrs. Maria Amoruoso for translating the original manuscript from French into English

References

(Consulted publications)

Ansiaux, J R. 1977. Le niveau de fertilité phosphorique des Sols - phosphore et agriculture - I S M A, Paris.

Aubert, G., Boulaine, J. 1967. La pédologie, coll. Que sais-je? N° 352.

Bannour, Bonvallot, J., Hamza, A.1978. Problèmes de l'Aménagement anti-érosif d'un bassin versant de la Tunisie centrale : le cas de l'oued el Foul . E. 530

Barbery, J., Delhumeau, M., 1979. Carte des ressources en Sols de la Tunisie au 1:200,000 feuille de Bizerte. E.S 171.

Belgacem, B., Thayer, M.B., Sayol, R. 1993. Cartes Sidi Toui et El Ouara. E.S. 274.

Boulaine, J. 1971. L'agrologie, que sais-je? 125 p - N° 1412.

Bonvallot, J., et Delhoume, J.P. 1978. Etude de différentes accumulations carbonatées soc.sav Nancy -pp 281 - 292.

Blancaneaux, Ph. 1989. Les sols à accumulations calcaires de la Tunisie Centrale et Septentrionale - ORSTOM, 113 p.

Braudeau, E. 1988. Essai de caractérisation quantitative de l'état structural d'un sol basé sur l'étude de la courbe de retrait - Acad. des sciences - Paris -serie II p 1933 - 1936.

Braudeau, E. 1995. Caractérisation des propriétés hydro-strucuturales des sols dans les périmètres irrigués de Tunisie (la rétractomètrie) ES 286 - Direction des Sols.

Brewer, R. 1964. Fabric and mineral analysis of soils Wiley and sons, New York 470p.

Bruand, A., Braudeau, E. 1990. Evolution de la géométrie de l'espace poral des sols lors du passage du domaine ferrallitique au domaine ferrugineux et hydromorphe. Coll; études et thèses, ed. ORSTOM.

Congress of Soil Science 1990 - Committee of soil fertilizers, 152 p.

Coque, R., et Jauzein, A. 1965. Le quaternaire moyen de l'Afrique du Nord. Bull. Ass. Fr. quaternaire, (AFER) Paris, 2ème année n° 3.

Duchauffour, Ph., 1970. Précis de pédologie 3ème ed. Masson 481 p.

Direction des Sols:

- Bulletin de la Direction des Sols - Sols de Tunisie N° 5, 8, 11, 13, 14, 15, 16, 17, 18.

- Carte des aptitudes culturales des sols de la Tunisie en sec - Ech. 1:1,000,000.

- Carte des zones irrigables - Ech. 1:1,000,000.

- Carte bioclimatique de la Tunisie - Ech. 1:1,000,000.

- Carte des états des études pédologiques révisée 1979.

- Cartes des ressources en sols de la Tunisie - Ech. 1:200,000 - 10 feuilles.

- Cartes des sols aptes à la céréaliculture de la Tunisie septentrionale, centrale et méridionale - Ech. 1:50,000 et 1:100,000.

Escadafal, R.,. 1985. Carte des ressources en sols de la Tunisie au 1/200.000 feuille de Tataouine. E.S. 222

Escadafal, R. Mtimet, A., Asseline, J. 1986. Etude expérimentale de la dynamique superficelle d'un sol aride (Bir Lahmar -Sud Tunisien) résultats des campagnes de mesures sous pluies simulées. ES 231 - Direction des Sols, Tunis, 63 p.

F.A.O. 1991. World Soil resources, 1/25.000.000, reports, 66.

Floret, Ch., et Pontanier, R. 1982. L'aridité en Tunisie présaharienne -Série document- ORSTOM.

Floret, Ch., Mtimet, A., Pontanier, R.1989. Caractérisation écologique des régimes hydriques et de l'érodibilité des sols en zones arides ORSTOM, Tunis, CEPE/CNRS, Montpellier, 44p. multigr.

Freytag, J., Mtimet, A. 1994. Soil Carbon in the Arid and Semi Arid Tropics. Driving variables of ecosystems function and global change in tropical regions. ICRAF, Nairobi, February 7-11- 1994.

Gaucher, G., 1968. Le sol et ses caractéristiques agronomiques, Dunod 350 p.

Gueddari, M. 1980. Géochimie des sels et des saumures du Chott El Jerid, sud tunisien. Thèse doc. 3ème cycle, Univ. Paul Sabatier, Toulouse, 131 p.

Grira, M., Loukil, A., Sayol, R., 1993. Carte des ressources en sols et pastorales et de leur sensibilité à la désertification en Tunisie méridionale - Gara Kbira et Régim Maâtoug. E.S. 273 .

Hachicha, M., et Ben Hassine, H., 1990. Irrigation et salure dans le périmètre de Zelba. ES 263 - Direction des Sols.

Hamdane, A., 1991. Histoire et technologie des systèmes d'aménagement hydro-agricole traditionnel en Tunisie, Ministère de l'Agriculture.

Hamza, A. 1977. Typologie des érosions à partir d'une détermination à grande échelle des divers

compartiments morpho-pédologiques du bassin versant de l'oued Hjel . E. 526 .

Henin, S. 1962. Le profil cultural , Paris , la maison rustique.

Hillel, D. 1974. L'eau et le sol - principes et processus physiques. Varroder - Editeur 288 p.

Horchani, A. 1992. Réfléxions sur l'aménagement des lacs et sebkhats en Tunisie. 16 p. Bulletin de la Direction des Sols n° 15.

Institut Mondial du Phosphore, 1980. Le phosphore dans les sols, Paris.

Lal, R., Kimble, J., Mtimet, A., Eswaran, H., Scharpenseel, H. 1997. Global climate change and pedogenic carbonates - International Workshop, Tunis, 13-17 Oct. 1997.

Lozet, J. et Mthieu, C. 1986. Dictionnaire de Science du Sol - ed. lavoisier. Paris .

Mami, A. et Aloui, T. 1982. Carte des ressources en sols de la Tunisie au 1:200,000: feuille de la Goulette. E.S. 200.

Mhiri, A. 1985. Effet de l'irrigation sur la stabilité structurale des sols de texture fine. Ann. Mines Géol, n° 31, T.2., p: 295-301 .

Mizouri, M., Barbery, J., Willaime, P. 1984. Carte des ressources en sols de la Tunisie: Nouvelle approche méthodologique: Feuille de Maktar. E.S. 212.

Mtimet, A., Escadafal, R., 1982. Carte des ressources en sols de la Tunisie au 1:200,000:Feuille de Médenine. E.S. 197.

Mtimet, A. 1984. Carte des ressources en sols de la Tunisie au 1:200,000: Feuille de Zarzis. E.S. 205.

Mtimet, A.1984. Sauvegarde des oasis du Gouvernorat de Gabès (réactualisation sommaire des données pédologiques) ARES Gabès, 13 p. + annexes.

Mtimet, A.1985. L'érosion hydrique dans les Matmata: (une nouvelle approche de caractérisation du matériau dans une optique d'un aménagement antiérosif) ARES, Direction des Sols. ES 234, 113 p.

Mtimet, A.1987. Sauvegarde des oasis du Gouvernorat de Gabès (état de la salure des sols et comportements hydriques - Février - Mars 1987). ES 241, Direction des Sols, Tunis, 118 p., annexes, 8 cartes h.t.

Mtimet, A.1987. Evaluation de la sensibilité des sols à l'érosion hydrique (Etude de simulation de pluies sur les sols d'un micro-bassin type jessour - Matmata. Tunisie présaharienne) ES 240. Direction des Sols, Tunis, 51 p.

Mtimet, A. 1989. Sécheresse et désertification (situation et actions de lutte) Bulletin d'ASDEAR, n° 2, Mars - Avril, 44-45.

Mtimet, A.1990. Soils and desertification problems in south Tunisia (monitoring and evaluation) 15 p. Congrès des Sciences du Sol Kyoto (Japon).

Mtimet, A.1992. Les loess sahariens et l'amélioration de leurs propriétés géotechniques - cas des Matmata et de leurs bordures - L'aridité une contrainte au développement ORSTOM éditions.

Mtimet, A. 1992. Réhabilitation des sols arides, résumé de thèse ES. 266. Direction des Sols.

Mtimet, A. 1992. Tunisia agriculture n° 3, Sols de Tunisie - ressources 14 p.

Mtimet, A. 1993. Etude de l'érosion hydrique et de la conservation des sols dans les régions semi-arides méditerranéennes - Second international Wocat, Workshop Berne. 11-15 Oct.

Mtimet, A. 1994. Aridity and climatic change in the Northern Sahara (carbon as an indicator in the calcic accumulations in arid and semi arid Tunisian) 15th international congress - Mexico.

Mtimet, A., et Hachicha, M. 1995. Salinisation et hydromorphie dans les oasis tunisiennes - «Sécheresse» n° 4 vol. 6.

Mtimet, A. 1996. Connaître et exploiter nos sols pour mieux les protéger (guide des pratiques pédologiques en milieu méditérranéen aride et semi aride) ES 291 - Direction des Sols. 136 p.

Mtimet, A., Dérouiche, CH. 1996. Fond documentaire de la Direction des Sols, B.D.S. système ISIS/UNESCO - Direction des Sols.

Mtimet, A. 1997. L'apport des études morpho-pédologiques à la connaissance historique du quaternaire (cas du Sud Tunisien) colloque international sur le Capsien. Gafsa 30 Oct. 1997 - Ministère de la Culture.

Mtimet, A. 1999 Atlas des sols tunisiens.

Pansu, M., Gautheyrou, j., Loyer J.Y. 1998. L'analyse du sol, Masson, 497 p.

Pontanier, R., Vieillefon, J. 1977. Carte des ressources en sols de la Tunisie au 1:200,000: Feuille de Gabès - Sidi Chemmakh. E.S. 135.

Regaya, K., et al. 1981. Les limons de Matmata - leur sedim. leur diagenèse, Congrès National Science de la Terre, Tunis, p 88.

Ruellan, A., et Dosso, M. 1993. Regards sur le sol, Foucher, Aupelf, 192 p.

Scharpenseel, H., Schiffmann, H. and Becker, P. 1984. Hamburg University radiocarbon dates IV pp 367-383.

Selmi, S. 1976. Milieu géomorphologique quaternaire et érosion des deux montagnes de la région de Tunis et leur piédmont. Djebel Ammar et Djebel Lansarine. E. 508.

Soil Taxonomy. 1973. (US Dept. Of Agriculture) Washington, DC.

SMSS, USDA. 1985. Forum International sur la classification des sols et le transfert de l'agrotechnologie. Tunis, Sept.

Swezeych, et al. 1995. Réponse des systèmes sédimentaires continentaux (exemple de la bordure Nord du grand Erg oriental Sud Tunisien). CNRS, Institut Géologie. Strasbourg. Université Texas, 51 p.

Szabolcs, I., Mtimet, A., Mashali, A., et Redly, M. 1995. International affected soils -Phillipines 6-10 November 1995 - FAO, UNEP.

Vandervaere, J. P., Vauclin, M., Haverkamp, R., Peugeot, C., Tony, J. 1998. Prediction of crust-induced surface runoff with disc infiltrometre Vol. 163. N° 1.