PRELIMINARY ASSESSMENT OF THE SOIL FERTILITY STATUS OF THE MAPPED AREA OF CHAOUIA[1]

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ABSTRACT

The importance of soil survey maps for agricultural development lies in how effectively they can used as a basis for rational land use planning. Analyses to indicate soil nutrient levels can be used to formulate general fertilizer recommendations and influence fertilizer forms being used. Fertility surveys can be quickly ans reliably carried out according to mapped soil types.

Wheat fileds were sampled from 25 mapped soils in Chaouia. In addition, three "benchmark" soils near Settat were intensively sampled, while a sampling was done around the phosphate mining area of Khouribga. Most of the samples were deficient in NO_3, with only a small percentage being deficient in P or K. Similarly, micronutrient deficiency was in the order Zn, Fe, and Cu with none for Mn. Differences were evident based on soil type. All samples near Khouribga were high in P.

The results suggest that major emphasis should be put on promoting N use and reducing and, in some cases, eliminating P and K, especially for dryland crops. Fertilizer formulations should reflect these fertility levels. The study highlights the importance of soil testing in agricultural development, particularly when based on soil maps. In doing so, it underscores the necessity of expansion of soil surveys in all Morocco's cropland.

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INTRODUCTION

The purpose of a soil survey is to obtain information about the soil resources of a country or region. This time-consuming process involves studying soil properties in the field and laboratory, and subsequently defining taxonomic units and preparing maps to show the spatial distribution of soil units or types (Soil Survey Staff, 1951). Depending on the purpose intended, soil maps may be general, schematic, or detailed (Miller and Nichols, 1979). Interpretive maps can, in turn, be constructed from detailed maps; these involve grouping several mapping units into a few broad categories related to specific properties or uses, e.g., susceptibility to erosion.

Because of the costs involved, detailed surveys are usually confined to high-use intensity land. While early surveys were oriented towards the agricultural use of land, modern surveys are more technical and consider land use for a variety of non-agricultural purposes, i.e., recreation, road and building construction, waste disposal, and land valuation (Roberts, 1979). Despite the increasing technical nature of soil survey reports, continued effort must be made to communicate soil survey information to those who can, or should, use ut (Oschwald, 1975). Indeed, recent efforts have been made to expedite the process of soil survey communication (Golding and Hoerauf, 1985). The underlying principle in any survey or mapping endeavor is to identify a strategy for efficient and sustained use of land.

While soil resources in developed countries are usually well documented in soil maps and accompanying reports, developing countries are not so fortunate. In many cases, the only available maps are schematic one whose usefulness is limited. Such maps are useful in national or multi-national planning, but of little value at farmers' level. In the semi-arid areas of the world, mapping efforts have focused on irrigation project areas to the neglect of rainfed areas (e.g., Qudah and Jaradat, 1988). Most developing countries lack a comprehensive and systematic soil classification system; many are characterized by surveys conducted at different times by different agencies and according to different systems. While the U.S. system, Soil Taxonomy (Soil Survey Staff, 1975), has gained widespread acceptance, a bewildering array of classification systems are still in use, in addition to the FAO-UNESCO are that combines elements of the major ones (Buol *et al.,* 1973). The French system is used almost exclusively in Francophone countries.

While using the French system, Morocco has only a small proportion of its land area described by soil maps. Most of the survey work has been concentrated on special irrigation projects and the higher rainfall zone between the Atlas Mountains and the sea. While much of the semi-arid, i.e. 200-450 mm, zone remains unmapped, two projects have been completed in this area, i.e., Chaouia (Stitou, 1985) and at the southern fringe in Safi (Oumri *et al.,* 1984). When interpreted and used correctly, these maps can provide valuable information on many aspects of land use; soil fertility is one where immediale benefit can be derived.

As such maps identify the spatial distribution of soil types, they enable researchers to conduct field research on major or "benchmark" soils, and thereby generalize findings to similar soils in the same agro-ecologival zone (Silva, 1985). Indeed, the approach of the initial soil fertility research at Morocco's Aridoculture Center in Settat focused on three mapped soils, i.e., Chromoxerert, Calcixeroll, and Rendoll, for soil test calibration studies (Abdel Monem *et al.,* 1988a). More recently, Ryan *et al.,* (1989b) used the soil maps to examine soil fertility relationships at agricultural experiment station within the semi-arid zone. Despite the obvious advantage of using a soil map as a basis for assessing soil fertility in any region, there is little evidence of such application.

As soil analyses can determine ranges of deficiency, adequacy, or toxicity for major (Halvorson *et al.,* 1985) and minor elements (Lindsay and Norvell, 1978), fertility surveys can reflect fertilizer needs of a region. Soil test data can be arranged according to region, major crops, or soil type (Cope and Rouse, 1973), and can help prioritize and complement fertility research. As the need for soil testing services increases, and increasing numbers of samples are analysed each year, data summaries can indicate trends in fertilization and the need for change in fertilizer practices and formulation (Donahue, 1987). Indeed, surveys on a country-by-country basis indicate general problems with mineral deficiencies (Sillanpäa 1982).

Though soil testing is in its infancy in Morocco, it has a potentially important role in crop production and land management in general. In this survey, we used the soil map of Chaouia (Stitou, 1985) as a base fot soil sampling according to soil type in order to assess nutrient deficiency and fertilizer needs in the cereal growing rainfed semi-arid area of Morocco. An additional concern was that land near the phosphate mining area may be well supplied with P and therefore need no commercial fertilizer application.

PROCEDURE

The basis for this survey was the soil map by Stitou (1985) of the Chaouia region (Fig. 1), which used the French classification system. Despite the diversity of soils in the region and complex distribution in some areas, a sampling strategy was devised to reliably reflect the fertility status of each of the major mapped soil types. As the region is devoted mainly to dryland wheat, and the potential implications of the study are mainly related to wheat fertilization, only fields currently cropped to wheat were included in the survey. Four fields from each of the principal mapped soil types or units cropped to wheat were selected on as random as possible basis. A composite sample from each consisted of 10 random subsamples taken in a zigzag pattern to a depht of 0 to 20 cm. As the soil was dry at time of sampling (October, 1988), the samples were sieved through a 2-mm sieve in the field.

The sampling strategy was modified to accommodate two additional objectives. In view of the importance of P mining in the Khouribga area were unmapped, samples were taken between 1 to 10 km west to Berrechid, and 2 to 12 km adjacent to the road to the east to Oued Zem. These samples are indicated on a sketch (Fig. 2). Because of the importance of some soil types in soil test calibration studies (Abdel Monem *et al.*, 1988), a more intensive survey approcah was adapted. The soil types were Unit 15 (shallow Rendoll), Unit 18 (moderately deep Calcixeroll) and Unit 10 (deep Vertisol). In this case, composite samples were taken from a total of 25 wheat fields on each of these three soil types.

Soil samples were subsequently analyzed in the laboratory for pH (1:2.5, soil solution) on an electronic meter; organic matter by the standard Walkley-Black procedure; $CaCO_3$ by the calimeter; NO_3-N by colorimetry using chromothropic acid; P by the standard Olsen $NaHCO_3$ procedure followed by measurement with molybdenum blues; K by IN NH_4OaC and determined by atomic absorption; and micronutrient cations according to the chelate extraction procedure ot Lindsay and Norvell (1978).

These data were interpreted in terms of critical values, i.e., measurements below which a deficiency would be likely to occur and a crop response likely if that particularly element were added as a fertilizer. For NO_3, the threshold range was considered as 7 to 10 ppm, 5 ppm for $NaHCO_3$-P, and 150 ppm for K (Halvorson *et al.*, 1985), and 5.0, 0.8, 0.2, and 1.0, for Fe, Zn, Cu, and Mn, respectively (Lindsay and Norvell, 1978).

RESULTS

The total number of wheat fields sampled from 25 soil types provided overall values of soil nutrients (Table 1). Virtually all samples were calcareous. As a consequence, most pH values were about 8.1. The mean NO_3-;N value of 6.2 ppm suggested that at least a significant fraction of the fields were deficient as this value was less than the critical value of 7 to 10 ppm. Indeed, this was reflected in the wide range in values, i.e., 3.0 to 19.3 ppm. The mean P values of 14.1 ppm suggested that most samples were adequate in P in view of the critical P values of 5 to 7 ppm. Overall K levels also suggested adequacy. an obvious exception was Unit 5, which was sandy in texture with very little clay. This shallow soil is of limited distribution in the area. While mean Fe, Zn, and Cu values appeared adequate, some were obviously less than the critical level for these elements. For all nutrients, the wide range and variability, as reflected by SD and CV values, suggested a closer look at the data.

Mean values for each of the 25 soils are presented in Fig. 3 (soil numbers correspond with numbered soil units in Stitou's map). It was evident that most samples were deficient in NO_3. while only a few soils were low in P or K. There was no apparent relationship between O.M. and any of these elements. Though O.M. varied widely, it tended to be higher on the shallower soils, i.e., Unit 5 (Rendoll). Presentation of the micronutrient data revealed further disparities (Fig. 4). From this figure, it was apparent that virtually all soils were well supplied with both Mn and Cu. However, few soils were above the critical trends were quantified and presented graphically fot the two categories of micronutrients. These show that 56, 8, and 12 % of the samples were deficient in N, P and K (Fig. 5). The corresponding figure for ZN, Fe, Cu, and Mn were 84, 28, 4 and 0 %, respectively (Fig. 6).

The second type of survey was more intensive rather than extensive, since 25 rather than four fields were sampled from only three major or "benchmark" soils. Though the most common soils in the environs of Settat, wide differences with respect to fertility were observed. Average values along with S.D. are presented for major (Fig. 7) and micronutrients (Fig. 8) in relation to critical levels for each element.

These data, particularly for major nutrients, illustrated important differences due to soil type. While mean NO_3 values for the three soils were less than the critical values; NO_3 in the Vertisol (Unit 10) was considerably less than the other shallower soils. This soil is intensively cultivated and no fallowing is practiced. However, yields on this soil are normally much higher than on the Rendoll (Unit 15), where fallowing is common. Phosphorus, on the other land, exhibited a different pattern. All mean values were less than the critical value, with the samples from the Sidi el Aydi-Berrechid plain area (Unit 18, Calcixeroll), being well supplied with "available" or $NaHCO_3$-P. Potassium, too, was well above the supposed critical level for two of the soils and marginally so for Unit 18. Thus, of these elements, NO_3 in the only one that one would need to be concerned about. Mean micronutrient values not only varied between soils for any element, but the general level for adequacy varied for any element. For instance, Cu and Mn were well above their respective critical values. However, they followed the same relative order between soils. The two elements which may pose possible plant nutrition problems were Fe, where mean values were just above the accepted critical level, and Zn, which was marginal for two soils (Units 10, 15) and considerably lowel for Unit 18.

DISCUSSION

Though this study was conducted on a relatively small part of the total rainfed semi-arid area of Morocco, it may have important implications for a much larger area. The data confirm observation from fertility and agronomic trials regarding the importance of soil type (Abdel Monem *et al.*, 1988). Some of these fertility differences may be natural or inherent, i.e., organic matter and micronutrients, while others may be man-induced by fertilizer addition, i.e., NO_3, P, and K.

While organic matter is important for maintaining soil structure and serving as a long-term reserve of nutrients, its relationship with available nutrients is often tenuous at best, particularly in semi-arid areas where it is subjected to continuous cycles of mineralization and immobilization. This process is environmentally dependent and is modified by the form of organic matter and its complexes with soil mineral elements. Differences in O.M. are likely to be consistent within any soil type and would not change in the short-term, except with intensive cultivation.

In view of the ephemeral nature of N in soil and its essentiality for all non-leguminous crops, it was not surprising that so many samples were less than considered adequate for crop growth. The almost universal response of crops to applied N and the widespread symptoms of N deficiency in the semi-arid zone corroborate these general findings for soil NO_3. Where N was adequate, the explanation may lie in the fact that legumes had been grown in that field the previous year, as shown in recent soil test calibration studies (Abdel Monem *et al.*, 1988a). The NO_3 data from this survey provides compelling evidence of the need for N fertilization, especially for cereals.

The P data, in contrast to N, presented, a picture of being generally adequate for most soils of the region. Indeed, these findings coincide with crop response data which showed that P was not needed where soil test levels were above 5 - 7 ppm. At higher levels, no response to fertilizer P would occur, nor would there be a difference in application method (Abdel Monem *et al.*, 1989b). It is likely that the high P values found in the intensively cultivated soils, e.g., Units 10 (Vertisol) and 18 (Calcixeroll), were due to a gradual build-up of P. Present data (Abdel Monem *et al.*, 1988 c) from Sidi El Aydi Experiment Station show how rapidly this process can be. On the other hand, the high levels of P in the Khouribga area, where crop productivity is low due to shallow droughty soils, is probably due to high native availability associated with the extensive rock phosphate deposits in the region.

One can therefore conclude that P fertilization is unnecessary in the Khouribga area and that P use could be reduced in extensive cereal growing areas such as the Berrechid Plain. Under these circumstances, considerable cost savings could be made by recuding this expensive input and/or increasing the amount of money invested in N fertilizer. As P levels are relatively stable in soils, periodic testing could establish if fertilizer P was needed. Sabbe and Marx (1985) suggested a 3 to 5 year sampling interval. The obvious implication of these findings for fertilizer manufacturers are that compound fertilizers should reflect the wider disparity between N and P needs.

Consistent with observations from other semi-arid areas of the world, the K data appeared adequate. While differences did exist between soils which reflected their differing mineralogies, it is safe to conclude that K fertilization is of little concern in Morocco's semi-arid rainfed zone, especially in view of the fact that cereals require relatively little K. Similarly, compound fertilizers or dryland crops should reflect this minimal need for K. Potassium nutrition through fertilization may, however, be required in irrigated areas with crops such as potatoes, sugarbeets, and bananas which have a high K requirement.

The survey also indicated that micronutrients were, in general, a low priority concern in the semi-arid zone. However, little research has been conducted with micronutrients in Morocco, despite the fact that the soil's high pH and $CaCO_3$ would suggest an environment in which some deficiency would occur. While the DTPA micronutrient test is not calibrated for dryland conditions, the survey suggests that deficiency of Zn and Fe may occur. Such deficiency is highly crop-specific. Fortunalety, cereals rarely exhibit deficiency under rainfed conditions. Crops such as legumes, sorghum and ornamentais are sensitive to Fe, while corn is sensitive to Zn. Indeed, both deficiencies do exist in the area. Iron deficiency has been reported with chickpea, and is widespread on ornamental shrubs in Settat and other areas. The authors have shown Zn deficiency in a range of corn lines in the greenhouse (Ryan *et al.*, 1989a) and observed it in the field. The possible field significance of both Fe and Zn will be the subject of future research. The survey also indicated that neither Cu nor Mn are of any concern in crop nutrition in the region.

In conclusion, the validity of this fertility survey points to the usefulness - indeed the essentiality - of soil surveys and maps. Only when the entire area has been mapped can we effectively generalize findings from on-farm research. In essence, a soil survey is essential for technology transfer and for increasing the efficiency of agricultural research. With limited resources and increasing need to enhance agricultural output, a soil survey of the semi-arid rainfed zone is more vital than ever.

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LIST OF TABLES AND FIGURES

Table 1. Mean soil analyses of wheat fields from 25 soil types in Chaouia.

Parameter	pH	$CaCO_3$	O.M.	NO_3-N	P	K	Fe	Zn	Cu	Mn
		%		ppm						
Mean	8.1	4.7	3.2	6.7	14.1	220	5.5	0.9	0.5	23.3
Minimum	6.4	0	1.1	3.0	3.6	15	2.0	0.1	5.0	5.0
Maximum	8.6	21.3	6.2	19.3	37.4	1450	24.0	4.3	1.4	4.7
Std. deviation	0.4	5.3	1.2	2.6	9.8	167	3.0	0.7	0.2	1.1
Coef. variation	4.9	113.1	37.5	38.0	69.7	75.5	54.1	65.2	46.2	6.8

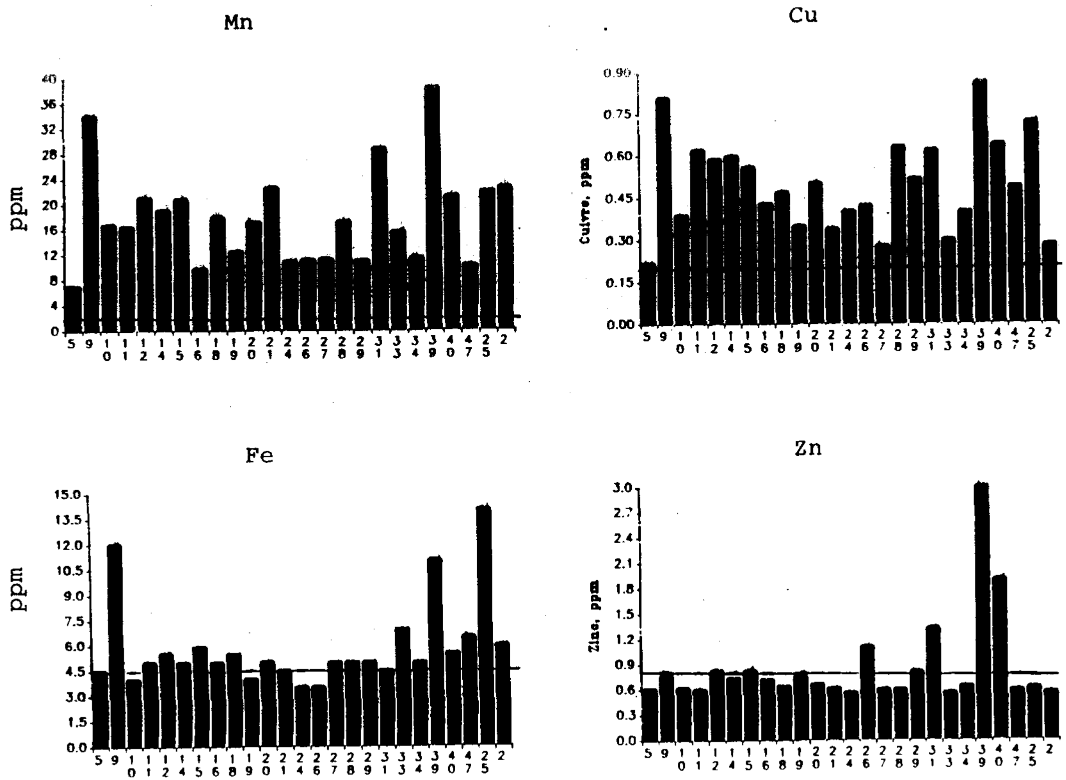

Fig. 4 : Mean Values for Fe, Zn, Cu and Mn according to Soil Type (i.e. Unit no)

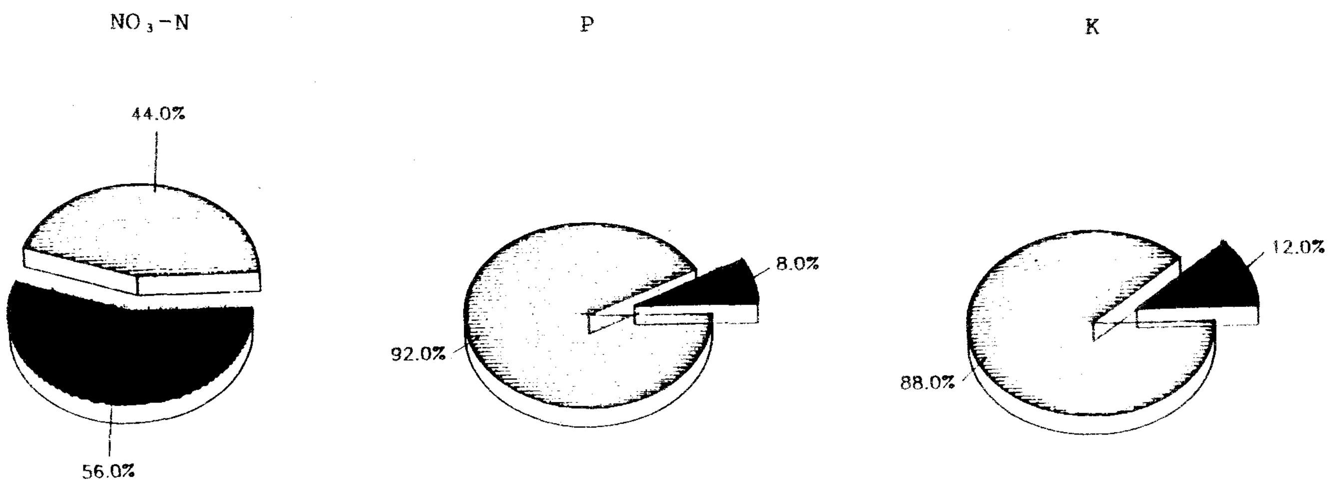

Fig. 5 : Percentage of Samples Deficient for Macronutrients (indicated in black).

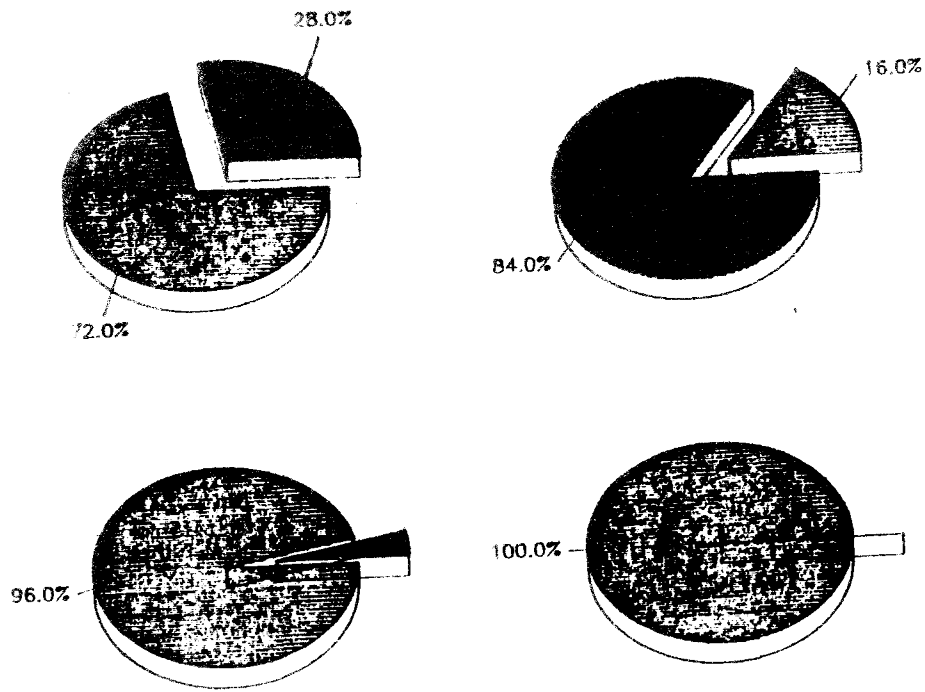

Fig. 6 : Percentage of Samples Deficient According to the DTPA Test (indicated in black).

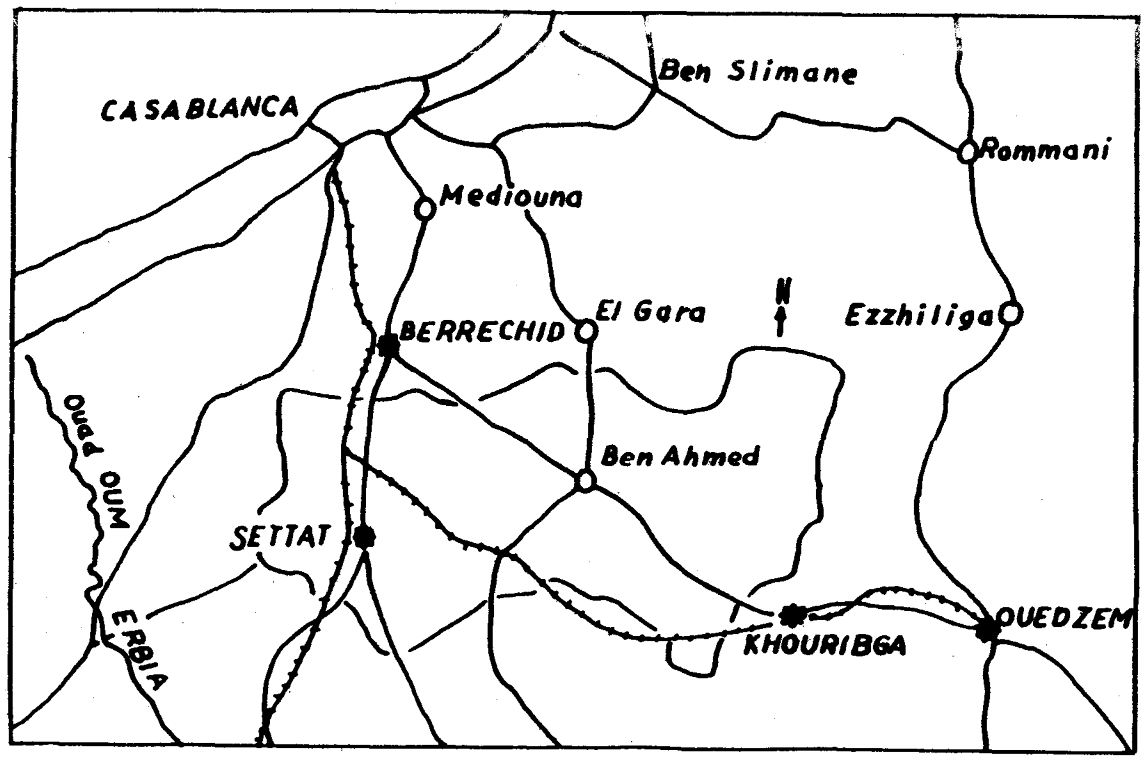

Fig. 1 : Location of Mapped Survey Area in Chaouia.

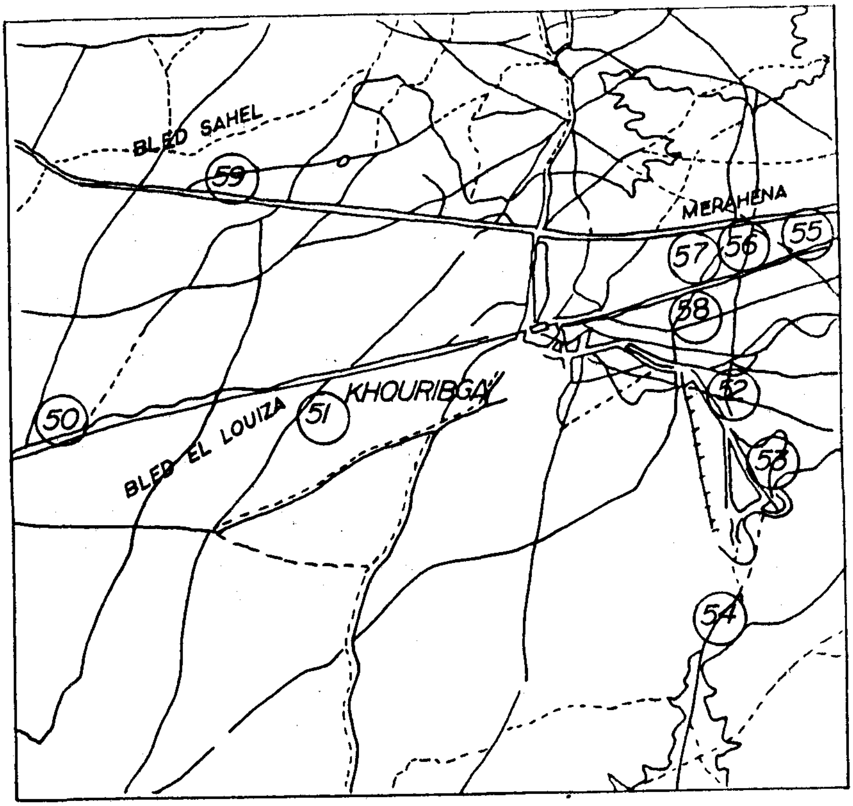

Fig. 2 : Location of sampling sites in Khouribga area.

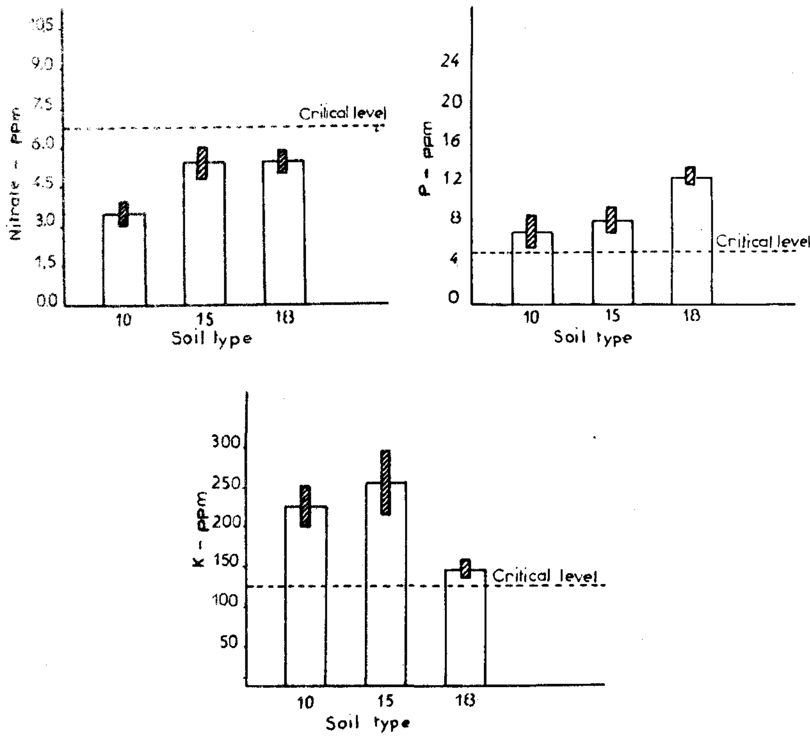

Fig 7 : MEan Values for Macronutrients on Three Major Soil Types.

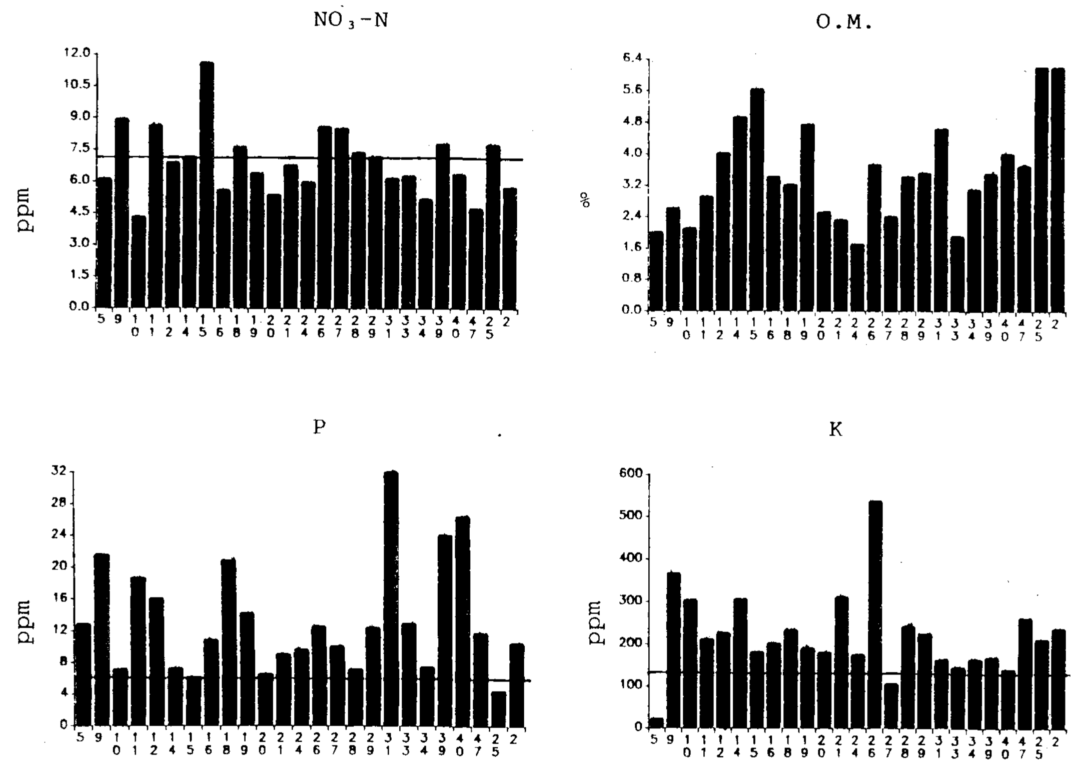

Fig. 3 : Mean Values for O.M., NO_3-N, P, and K according to Soil Type (i.e. Unit no.)

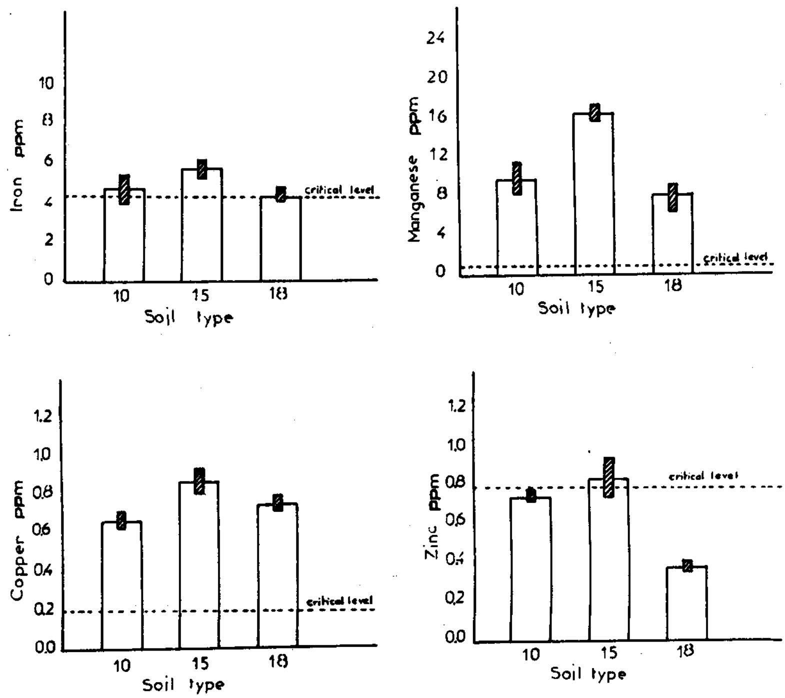

Fig. 8 : Mean Values for Micronutrients on Three Major Soil types.

ملخص

حصر مبدىء لحالة خصوبة التربة لمناطقق الشاوية المرفوعة على الخرائط

محمد عبد المنعم، جون راين ومحمد الغروس

تكمن أهمية استعمال خرائط حصر الأراضي في التطور الزراعي في كيفية استعمالها استعمالا صحيحا. وقد يمكن استعمال تحليلات عينات التربة والتعرف على مستوى المغذيات بها للحصول على توصيات سمادية عامة وكذلك اشكال الاسمدة المستعملة. ولهذا فإن دراسة خصوبة الاراضي دراسة حصرية يمكن أن تكون سريعة ويمكن الاعتماد عليها طبقا لخرائط انواع التربة.

في هذه الدراسة فانه تم اخذ عينات تربة من 25 نوع من أنواع التربة طبقا لخريطة تقسيم الاراضي في الشاوية بالاضافة الى 3 أنواع من الاراضي تعتبر علامات هامة بالقرب من خريبكة.

ومن نتائج هذه الدراسة وجد ان معظم هذه العينات كانت ناقصة في نسبة الازوت النتراتي - بينما نسبة مئوية قليلة كانت ناقصة في الفوسفور والبوتاسيوم - كذلك وجد بعض النقص في الزنك - الحديد - النحاس والمنغنيز ويلاحظ أن الاختلافات كانت واضحة بالنسبة لكل نوع من أنواع التربة. وكذلك لوحظ ارتفاع كمية الفوسفور في العينات المأخوذة بالقرب من مدينة خريبكة.

ومن هذه النتائج يتضح أن المجهود الاكبر يجب أن يتجه الى تشجيع استعمال السماد الازوتي - وبالنسبة للفوسفور والبوتاسيوم فانه يمكن التقليل من استعمالها او في بعض الاحيان النصح بعدم استعمالها اطلاقا في المناطق الجافة ايضا يمكن النصح بأن أشكال الاسمدة المستعملة يجب أن تعكس احتياجات الاراضي منها.

ومن هذه الدراسة تظهر أهمية استعمال تحليلات التربة في عملية التنمية الزراعية وخاصة اذا كانت معتمدة على خرائط التربة.

Evaluation préliminaire du statut de la fertilité des sols cartographiés de la zone de la Chaouia

L'importance des cartes pédologiques pour le développement agricole réside dans la façon dont elles peuvent être utilisées efficacement et rationnellement comme base dans la planification et l'utilisation des terres. Les analyses de sol en vue de déterminer leur niveau en éléments nutritifs permettent à la fois de formuler une recommenciation générale en éléments fertilisants et juger de l'influence de la forme du fertilisant utilisé. Un diagnostic de fertilité peut être rapidement et fiablement mené selon les types ou les unités de sols cartographiés.

Vingt-cinq échantillons de sols ont été pris dans les champs de blé répartis selon la zone cartographiée de la Chaouia. En plus, des échantillons ont été intensivement prélevées sur trois catégories de sols de "référence" dans les environs de Settat alors qu'un autre échantillonnage a été prélevé à proximité de la région phosphatière de Khouribga. La majorité des échantillons ont montré une carence en NO_3 mais seulement une petite partie avait une carence in P ou K. Les carences en microéléments concernaient Zn, Fe et Cu sans qu'il y ait carence en Mn. De nettes différences existaient selon les diverses catégories de sols. Tous les échantillons prélevés à proximité de Khouribga avaient une teneur très élevée en P.

Ces résultats démontrent que l'accent doit être mis sur la promotion de l'utilisation d'azote et la réduction, voire dans certains cas, l'élimination de phosphore et potassium surtout pour les cultures en zones arides. La formulation et la "Recommandation" en engrais doivent être basés sur ces niveaux de fertilité. Cette étude souligne l'importance des analyses de sols pour le développement agricole, en particulier lorsqu'ils sont effectués à partir des cartes pédologiques. La poursuite de cette procédure et son utilité soulignent la nécessité d'étendre la prospection pédologique sur tout les sols cultivés du Maroc.

L'évaluation de la fertilité des sols des Stations Expérimentales dans les régions de la Chaouia, Abda et Doukkala

Les niveaux de fertilité des sols, qu'ils soient en carence ou en excédent, comptent parmi les caractéristiques les plus importantes pour les essais réalisés aux champs. Puisque les niveaux en éléments nutritifs ont tendance à augmenter dans les sols des stations expérimentales par suite d'une utilisation continue de fertilisants, des évaluations régulières sont nécessaires pour permettre un transfert efficace des résultats aux agriculteurs. Dans cette étude ont été traités l'état de la biomasse, les principales substances nutritives (NO_3, P, K) les microéléments (Fe, Zn, Mn, Cu) et dans certains cas, le niveau de salinité, à cinq stations expérimentales de la région semi-aride du Maroc (Aïn N'Zagh, Sidi El Aydi, Jemaâ Shaim, Khemis Zemamra et Monnin Lucien). Des variations existent entre, voir à l'intérieur, des différentes stations, la caractéristique principale étant la haute teneur en NO_3 à Sidi El Aydi et en P sur toutes les autres stations. Ceci était dû en grande partie à la fertilisation. Les teneurs en K étaient élevées et sur quelques stations le niveau en Fe et Zn étaient mineurs. Les résultats de cette études ont des implications pour les chercheurs ainsi que pour les administrateurs travaillant sur les stations expérimentales.