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FINAL REPORT
on

THE AMERICAN SYSTEM OF SOIL CLASSIFICATION AS APPLIED TO THE SOILS OF SUDAN

by

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1. TERMS OF REFERENCE

Under the general supervision of the Project Manager the Consultant will work closely with the project staff and will advise on the American system of soil classification as applied to the soils of the Sudan. He will carry out training programmes for counterparts in the use of the above system and perform other related duties as required.

2. ACKNOWLEDGEMENTS

The consultant wishes to extend his appreciation to those who made this program possible. The F.A.O. staff assisted at all times and were helpful in the preparation of this report. This staff of M.F. Purnell, W. Van der Kevie, F. Nachtergaele, R. Pacheco, and E.Z. Arlidge is to be congratulated. The consultant particularly expresses his gratification of the enumerable questions asked and the kindness of Mohamed A. Ali, soil correlator and Acting Director. During the consultancy many kilometers were travelled and the drivers Melegi, Abd El Tam, and Noah were considerate and helpful. The clerical staff and the library staff assisted the consultant whenever asked. This report could not have been completed without the excellent clerical and typing skills of Marie-Noelle Khodary.

Thanks also is extended to all the members of the Soil Survey Administration, too numerous to mention, who made this consultant feel at ease whereever he travelled.

3. ABSTRACT

In the course of this assignment the consultant was required to assess the use of the American system of soil classification in the Sudan. He also was to give training on classification. To accomplish this mission the consultant travelled by land rover over 11,000 kilometers to many parts of the Sudan. Soils were studied as far north as Atbara, east to Kassala, west to El Fula and Umm Agaga areas, and south to Wau and Juba areas. Over 150 observations of soil pits, and auger borings were made. Of these observations 116 are discussed in Appendix 3. A location of the stops is in Appendix 1.

The consultant has concluded that the American system of soil classification, Soil Taxonomy, is applicable to the soils of Sudan. Many of the soils are accommodated by the system however a few soils are not. The system, Soil Taxonomy, does provide for additions or changes. Where this is necessary it is recommended in various sections of this report.

As most of the mapping to date has been in and around the Central Clay Plains mapping procedures and techniques need to be reviewed and changed when working in other areas of the Sudan. The comments and suggestions in the following sections are intended to assist the department with ideas for higher quality surveys and reports and to increase the quantity by techniques not now used.

4. GLOSSARY

Dura	Great millet - Sorghum vulgare
Feddan	Area of land = 1.038 acres; 0.42 hectare
Hafir	A pool usually excavated to collect and store water
Jebel	Mountain
Khor	Water course, usually dry
Qoz	Sand dunes
Simsim	Sesame; Sesamun orientale (Linn.)
Wadi	The bed or valley of a stream in arid regions that is usually dry except during the rainy season.

5. SUMMARY OF RECOMMENDATIONS

There are comments and recommendation throughout this report in the different sections and Appendixes. Below is a brief list of the major recommendations.

1. That a review be made of all soil series to reclassify them if necessary using the latest edition of Soil Taxonomy.

2. That new proposals for taxonomic placements be submitted to the appropriate persons in Washington D.C. supported by descriptions and analyses. (See Appendix 8.10 Procedures for Amendments).

3. That all the soil series should be revised and updated based on comments in this report. This should be completed within one year.

4. That soil scientists describing soil profiles be more careful in observing horizonation especially in the upper 50 cm of the soil. Also that soils should be described to at least 2 meters where possible.

5. That mapping techniques need to vary in different areas of the Sudan. Techniques used in the central clay plains may not be applicable in Juba, or Babanusa or other areas of the Sudan. One must adapt techniques to the changing landscape.

6. That a review be made of the existing photocoverage and much effort used to obtain adequate high quality coverage.

7. That more emphasis be placed on regional reconnaissance soil surveys to obtain a wide basis for future recommendations about areas needing more detailed work.

8. That the soil survey reports be reviewed and that possible new presentation of data be adopted. Also a new position be created in the Soil Survey Administration to be in charge of editing manuscripts.

9. That the soil correlator, Mohamed A. Ali, attend an intensive training course in the United States in soil classification, correlation, and soil survey operations.

10. That the proposed new appointee to the position of editing manuscripts attend a series of special seminars and workshops in the U.S. or other country providing that kind of training.

11. That the soil survey staff hold more seminars and workshops as training ~~techniques~~ to improve their skills

6. FINDINGS AND CONCLUSIONS

6.1 Soil Classification

The Soil Survey Administration adopted the USDA Soil Conservation Service system of classification during Phase I of the Project for Strengthening of the Soil Survey Division. At that time it was known as the 7th Approximation. A major distribution of the 7th Approximation was made in 1967 along with additions, revisions and supplements. Most of the soil series have been classified using the 1967 supplement. In December 1970 another major revision and supplement was printed and distributed by the USDA. At that time the name was changed to Soil Taxonomy. However only 2 copies were available for use by the Soil Survey Administration staff. One copy belonged to a FAO UNDP staff member and the soil correlator had the other copy. The latest edition of Soil Taxonomy is a draft of the copy for official printing and is dated October 1973. The consultant obtained one extra copy for the soil correlator Mohamed A. Ali. Problems with correlation because of the lack of current editions are discussed in the Soil Correlation section.

The USDA system of classification, Soil Taxonomy, is applicable in the Sudan and with the latest edition can be used to classify their soils. Some of the problems encountered during the course of 4 months consultancy are given below.

1. Many soils are not classified properly because of insufficient profile descriptions. No classification system would work if the pedon that is to be classified is not properly described. Many of the soils were described as having one surface horizon from 0 to 20 and up to 50 cm thick. When the consultant examined the same profiles many horizons were identified which in turn altered the classification of that particular pedon. See stops 24, 88, 90, 97, and 113 in Appendix 3 as examples.

   It is hoped by the consultant that the soil scientists here will be more observant when describing soil profiles. The application of soil Taxonomy would then be much easier and more correct as to the placement of soil series.

2. In accordance with the above comments laboratory data from horizons that are sampled and analyzed are meaningless if those horizons represent a mixture of many subhorizons. Major diagnostic horizons are lost completely because of this oversight. As an example of this refer to the laboratory data of both before and after redescribing the Muwalla series. (Stop 24 in Appendix 3).

3. Soils of the Sudan other than the Central Clay Plains cannot be properly classified until additional data is determined by the laboratory and standard techniques adopted. Many recommendations were made by the Soil Chemist Consultant, John W. Dewis, in April 1974. Yet many of these have not been completed. Exchange acidity, exchangeable calcium, and magnesium, free iron oxides, fragments greater than 2 mm, bulk density, 1/3 and 15 bar moisture, base saturation by methods suggested in Soil Taxonomy are some of the determinations that need to be made. A close relationship should be established between the soil correlator and the head chemist to coordinate classification requirements and laboratory determinations.

   Professor P. Buringh, consultant to FAO, also discussed soils and their formation with relationship to soil salinity and alkalinity (sodicity) in February 1967. His comments are still relevant and should be reviewed by the Administration.

   A procedure should be established to have at least one of the laboratory personnel visit the sites where soils are sampled. This would help to establish a better understanding of the needs of the soil scientist to properly classify soils. It would also help the laboratory personnel to become acquainted with the soils of Sudan as they occur on the landscape.

4. Mr. Van der Kevie has written a report on the climate of Sudan and its relationship to soil classification. To clarify and better understand some of the soil moisture regimes, soil moisture studies should be conducted and studied at various locations throughout the year. It is very difficult in this country during the wet season to travel but an effort should be made to gather this data where ever possible. Refer to the discussion of soil moisture in Appendix 3 stops 10-16 and general discussion of stops 85-89.

5. Some of the mapping units have been named miscellaneous land types when in fact they are soils and can be classified. Even though these areas are very poor for agriculture and no use is intended at the present this does not mean that these areas are not soils. A list of definitions and comments on miscellaneous land types is given in Appendix 5. An example of a miscellaneous land type that was classified is given in Appendix 3 stop 104.

6. One of the main problems of the soil scientist in using the Soil Taxonomy (7th Approximation) is in the use of the keys at various categoric levels. The tendency is to look ahead where a soil should be placed without going step by step through the keys at each category. As an example, a soil has very red colors (2.5YR) and an argillic horizon. The user commonly automatically classifies this soil as Rhodustalfs without using the keys because it is very red. However if the clay in the argillic horizon does not decrease by 20% of the maximum within a depth of 1.5 m and meets other requirements the soil would key out as Paleustalfs before Rhodustalfs. Special emphasis should be placed on using the keys step by step at the order, sub-order, great group, and subgroup categories.

7. If adequate profile descriptions are made and the proper techniques used for laboratory analysis, the classification of soils is possible by using the Soil Taxonomy. Even without the laboratory analysis provisio[illegible] classification can be made in order to give approximations

of the soils of different regions of the Sudan. A discussion of the provisional classification of soils in the west and the south is given in Appendix 3 stops 37-89.

Prior to 1974 most soils were classified into the following Orders: Alfisols, Aridisols, Entisols, some Ultisols, and Vertisols.

On recommendations of the FAO staff and this consultant the recognition of the cambic horizon whould be used as a subsurface diagnostic horizon. Many soils that were originally classified as Entisols have a cambic horizon, and therefore should be classified in the Inceptisols. The landscape in many areas of the Sudan is very old and soils have had time to have altered horizons that have lost bases or iron and aluminum but have retained some weatherable minerals. Soils that have horizons of accumulation of translocated silica, iron, or bases are permitted as cambic horizons. The definition of Inceptisols is unavoidably complicated but should be studied and reviewed so that it can be used where applicable.

In the southern provinces of Sudan the Order of Oxisols should be reviewed. If not the Order the subgroups of several Great Groups should be investigated. Some examples are as follows: Ustoxic Dystropepts, and the Oxic subgroups of the Haplustalfs, Haplustults, Paleustalfs, Rhodustalfs, and the Ustropepts. These soils, however, cannot be properly classified unless laboratory analysis is determined based on the criteria as given in the subgroups or in the discussion of the oxic horizon in Chapter 3 of Soil Taxonomy.

Another Order that must not be ruled out completely in the Sudan is the Mollisols. Some soils could have formed under past conditions that are not reflected at the present time. If the requirements are met for this Order, then an attempt should be made to group or classify the soils accordingly. At the present time it appears that there are no soils in this Order. One of the main reasons is a general lack of organic carbon content in the soils reviewed that is as high as 0.6%. If the organic carbon is 0.6% or more the soils usually lack the base saturation, color, or structure requirements of a mollic epipedon. However, one must have a receptive viewpoint and consider all the alternatives even though they are not apparent.

If requests for soils surveys occur in the Sudd (the swamp or marsh areas along the River White Nile north of Gemmeiza) or in areas that have been wet for long periods, these areas might have accumulated enough organic matter to be considered Histosols.

Some soils have high or very high (50 to 80%) clay contents and have some cracks and other features diagnostic of the Vertisols. However, by strict adherance to the definition of the criteria the soils do not qualify for the Order Vertisols. Until these soils are thoroughly described at both the wet and at the end of the dry seasons, the consultant would classify them as Vertisols. If not the Vertisols, at least into a Vertic subgroup. Because most of these soils exhibit similar properties and soil qualities they should be grouped with those soils with like problems in the Vertisols or Vertic subgroups.

The intent of Soil Taxonomy is to group soils together that have similar use and management or other interpretive uses. Some of these groupings are not clearly understood at this time, but with testing these groupings should become evident; to remain, to combine with other groups, or to establish new groups.

There are some categories and subgroups that need to be established for soils of the Sudan. The Soil Taxonomy (7th Approximation) is flexible and additions can be made, and revisions of existing criteria, without affecting other criteria and the placement of soils already in use. Several additions or changes have been suggested in the discussions of the various stops in Appendix 3 and in the correspondence given in Appendix 9 to the Director of Soil Survey Operations of the Soil Conservation Service in the U.S. A partial list of those mentioned is given below. A provisional revision should be made and then tested in the Sudan to see if the soils that are placed in the new taxonomic categoriss are logical and are meaningful separations for use and management. After testing, detailed descriptions with laboratory data should be submitted for action by the office in Washington D.C. of the Soil Conservation Service. Several copies of the instructions on how to do this were given to the Soil Correlator. (See Appendix 9). The numbers refer to stops in Appendix 3 where these revisions might be appropriate.

Alfisols

- Ustalfs
    - * Tropustalfs 56, 71, 73, 74, 75, 80, 83
    - Haplustalfs
        - * Rhodic 44, 56
        - * Petroferric
    - Paleustalfs
        - * Ustertic or Vertic 4
        - * Petroferric
    - Rhodustalfs
        - * Ustertic or Vertic 4

Aridisols

- Argids
    - Haplargids
        - * Natric 94, 108 and other Haplargids of the arid zones.
        - * Salic
- Orthids
    - Calciorthids
        - * Natric 94, 114
    - Camborthids
        - * Natric

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* New proposals

Entisols

Psamments

Quartzipsamments

* Ustic 45, 60

Inceptisols

Tropepts

Dystropepts

* Aquic 82

* Petroferric 82

* Rhodic 59

Ustropepts

* Petroferric

* Rhodic

Ultisols

Ustults

Tropustults 71, 73, 74, 75, 78, 83

The soil scientists of the Sudan have a great opportunity to contribute to the development of revisions in Soil Taxonomy that would affect the soils of their country. There is much needed information on tropical soils on ironstone formations that can be added.

6.2 Soil Correlation

Various methods have been used to correlate the soils of Sudan since the beginning of the early surveys. The last major effort to update all the soil series was from 1968 to 1972. However to date there is no record of all the soil series that have been mapped by the Soil Survey Administration. It is imperative that a concerted effort begin to update the list of soil series and the revision of all series. At this writing the compilation of the list of soils in Sudan is underway. If at all possible, all the soil series should be reviewed and updated by this time next year. If this job is delayed or postponed, the effectiveness of the correlation process is minimized. It has been noted that sometimes instead of establishing new series phases are combined with existing series. If there is sufficient feddanage to establish a new series it would be the consultant' view point to set up new series rather than combine or phase it to an old series. Until more is known about a soil and its characteristics, its behaviour, and other features, it is easier to keep track of it as a series rather than a phase. This is especially important when information about the soils is in the early stages. If after a few years study of yield data, how they are managed, etc., little difference is recognized between two soils they can be combined.

Some other problems encountered or suggestion for improvement are given below.

1. There is a list of tentative soils dated November 1973. However the series themselves have not been given wide distribution. It is suggested that eventhough a series is tentative it is described and printed for circulation so others may also know of the latest series proposed. At a later date when final decisions have been made, the tentative series can be updated and circulated as an established series. One way to do this would be to establish series upon completion of the final correlation of a soil survey area when the report is published or printed.

2. As mentioned above a serious effort should be made to revise and finalize decisions for all series. A review was made of many soil series and survey reports. There are many series with ranges of characteristics that cross class or category boundaries of the Soil Taxonomy. An example would be to have a soil in the coarse-loamy family with up to 18% clay have in its range of characteristics texture that range from sandy loam to clay loam with 30% clay. The clay loam textures in this case are outside the class boundaries for coarse-loamy. Another example of descriptions that need revision is the Shamfur series. The series is classified as a Typic Paleustalfs yet the laboratory data does not support the presence of an argillic horizon. As the series are revised care must be used not to overlap ranges of characteristics. Each series should be mutually exclusive from all other series.

3. Correlation samples - The Administration has a system of collecting correlation samples. Soil samples are placed in rectangular tins about 8-10 cm wide, about 25 cm long and 6-8 cm deep. This system provides very good visual displays and the container is usually large enough to allow whole natural peds to be placed in it. There are some disadvantages. The containers are bulky and are somewhat difficult to transport. Also when the Soil Survey Administration increases in size and more areas are mapped a storage and retrieval problem is foreseen. One of the main reasons to have correlation samples is to be able to refer to them quickly and efficiently. One way to overcome this problem and still have correlation samples is to use small plastic vials. One size that is commonly used is about 8-10 cm long and about 2.5 to 3 cm in diameter and have snap on lids. These are available from many sources and are relatively inexpensive. Hundreds of vials can be stored in flat map drawers and are readily accessible for use during correlation conferences.*

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* This personal opinion of the advantages of vials is not agreed to by other project staff.

4. As soon as the final decisions have been made and approved at the final correlation conference a document should be prepared listing the approved series names and their phases. Also the decisions that were made on each series. This document, the Final Correlation Report, should be completed and distributed to the appropriate persons within 2-3 weeks after the conference. If these reports are delayed for several weeks or months the ability to keep in mind the decisions that might affect other surveys becomes less and less. This problem will become more as the number of soil surveys and soil series increase.

5. A situation that has existed for some time and apparently will continue greatly affects the soil correlator. For more than a year the Soil Survey Administration has essentially been without a Director or Deputy Director. The soil correlator has been Acting Director and trying to do the work of 3 positions. The responsibilities of a single soil correlator for the whole of Sudan is mostly certainly a full time job. It is impossible to keep up with the technical responsibilities of a soil correlator and also be responsible for the administration of the whole Administration. Through no fault of the correlator, the correlation process for soils of the Sudan is seriously being affected. This soil consultant might have been more effective if the consultant and the correlator could have had more time together.

6. As mentioned in the section on soil classification there are various editions of Soil Taxonomy (7th Approximation) being used to classify soils. They date from 1967 to 1973. Many of the additions, corrections, and revisions are not in the earlier edition. To be used effectively each soil scientist should have a copy. When the new Soil Taxonomy is printed (expected date June-July 1975) some problems in correlation will be helped.

7. To assist in the use of laboratory data one may visually display the data to assist in observing the relationships between similar soils by using charts or graphs. For examples of one way how this might be done refer to Appendix 4 Aids in Using Laboratory Data. Also refer to the discussion of stop 24 in Appendix 3. There are many profiles with data and more use could be made of this data once it becomes available.

6.3 Soil Series Descriptions

This section is on the "official" series descriptions that are used as standards for soil series in the Sudan. There is a good start on the completion of the descriptions for the official file. About 70 to 80 soils have been described and recognized as established series. It is not known for sure how many, nor the names of soils that have been used in various reports. A program is currently under way to make a list of all soils that have been used in all of the soil survey reports. This list will be the basis of the workload that remains to be completed and the series that need revision. Following are a few comments that might be considered when ccompleting new series descriptions or revising old ones. Samples of a modern format used by the Soil Conservation Service have been given to the soil correlator.

1. The official file should first be rearranged and the soil series filed alphabetically by series name. The names of the series should always be checked for consistent and correct spelling. As an example in the Shendi and Ed Damer areas the Ed Damer series has been mapped in both areas. In one area it is a spelled Dammer and in the other Ed Damer. To those who would not know they would be two separate series.

2. The last revised date and the initials of the authors and correlator should appear in the upper right hand corner. Also it is much more helpful in locating series if the name is given on each page.

3. After the heading - Typical Profile - a list of map symbols is given. A separate list may be maintained but should be eliminated from "official" series.

4. As was mentioned previously the comments in the range of characteristics should be carefully reviewed. Roy W. Simonson, Past Director of Soil Classification and Operations of the USDA-SCS has made some excellent comments on this point. These are quoted from correspondence by Dr. Simonson in March 1969.

"Taking parts of definitions of classes in categories above the series and using those as statements of ranges in characteristics in the series description is bad both for the writer and the reader. Undesirable consequences are of several kinds.

If our field men were to go more and more to getting their ranges of characteristics for series from the definitions of families, those same men would find less and less need to make and record careful observations on soils of their survey areas. Then a man would follow the easier path to a greater and greater extent. It would permit them to decide on the basis of a profile or two how the soils of a given series should be classified at the family level. Having decided that, the men need not make as many careful observations nor record them as fully in the future. The men could instead look at additional profiles with the idea of getting them placed in the system and stop at that point in their observations. The same men could lift parts of definitions of family classes to provide statements for the range in characteristics of the individual series. This simply reflects a general principle enunciated with some table pounding by a professor during my undergraduate days when he was out of patience with his class— "Every man is as lazy as he dares to be but some have more courage than others." Unless the practice of using family class limits and ranges directly as ranges in characteristics for series in the series descriptions is discouraged, more and more of our men will take this easy route rather than try to work out the range for a given series through their own observations. There is, of course, the possibility that the range in characteristics for a given series does coincide exactly with that of the family into which the series is placed. The chances that this will happen, however, seem very small to me.

A second important danger is that readers of series descriptions will believe that our field men are actually recording observations made rather than restating family class spans and limits.

Furthermore, both readers and writers of series descriptions will eventually come to believe that the statements report facts. Repetition, especially repetition with emphasis, comes to be accepted by a large part of the audience and also by the speaker or writer. This principle is well stated in Mein Kampf and was also adequately demonstrated by the author after he wrote the book.

The intent that a series should have a range of characteristics within the span of the family into which the series is classified is part of our approach in classification. Consequently, certain limits in the permissible ranges for a series are implicit in its placement into a family. The placement of a series into a family is given in the first sentence of each standard series description. Restating the family class limits in the section on range in characteristics is therefore redundant. This also has a further disadvantage.

The statement of precise limits, unless they do rest on actual observations, is a claim to greater precision than is actually attained as general practice. Consequently, it is wiser to leave the statement of precise limits in the definition of family classes to a larger publication than the series description. In a full monograph, there is room to record the uncertainties and describe the degree of precision or exactness possible in setting spans and limits for family classes. In a series description, however, such qualifications are out of the question. Bald statements of limits must stand by themselves. They become claims to high degrees of precision."

5. In the section on competing series and their differentiae list the series alphabetically. If possible differentiate the series by using diagnostic criteria. As an example soil A has an argillic horizon and is the coarse-loamy family and has 5YR hues. Soil B is similar but is in the fine-loamy family and has 10YR hues and lacks an argillic horizon. In the soil A description soil B would be described as follows: " Soil B lacks an argillic horizon, has a fine-loamy texture control section and has 10YR hues." The section on Principal Associated Soils should also explain how those soils differ using the same format as in the competing series section.

6.4 Soil Profile Description

Comments on the descriptions of soil profile have been made in various sections of the report. However, a few additional points might be considered here. The consultant re-emphasises the importance of carefully observing all the horizons and features that are expressed in the profile. This of course takes more time, skill, and patience but the study of soils is very important not only for classification but for interpretation in use and management. After all, that is the major purpose for soil surveys, to interpret them for different kinds of uses.

1. Many of the field profile descriptions and some "official" series descriptions lacked important diagnostic characteristics that are called "additional features" in the soil survey manual. If they are present they should be noted in the description of each horizon. Some examples are:

   1.1 The width and depth of cracking.

   1.2 The relative amount and quantity of the distribution of lime.

   1.3 Description of the size, shape and amount of coarse fragments could be improved. The amount should be determined quantitatively by weighing all fragments greater than 2 mm from a weighed volume of soil or by volume displacement. In the latter method from a known volume of soil the greater than 2mm fraction is determined by measuring the amount or volume water that is displaced by the coarse fragments. To be able to do this every soil scientist or mapper should have at least one 2 mm sieve. If that is not possible at least one for each field party.

   1.4 An excellent reference for field methods is the Handbook of Soil Survey Investigations Field Procedures. A copy has been given to the soil correlator. This should become a working tool for guidelines of field techniques.

2. Most pits that were observed had been described to less than 2 meters. In fact some soils that could have been described deeper were less than 1 meter. Even though the requirements for most diagnostic criteria in soil Taxonomy is less than 1 meter, soil profiles should be described to at least 2 m if rock is not limiting the depth. Differentiae between soil series are disgnostic to a depth of 2 meters

3. The use of horizon nomenclature in profile descriptions should be used for all profiles described. The person describing the soil profile has the best opportunity to relate the processes going on by labelling the horizons. They are the best estimates or approximations of horizonation at the time the description is written. Especially noted was the lack of use of ca, cs, m, b, etc. horizon nomenclature.

4. Taxonomic diagnostic horizons should be recorded at the time the profile is described. This should be done while the soil scientist is looking at the soil profile and records his first approximations on the description form.

5. Field descriptions should be completed in an abbreviated nomenclature for speed and ease of comparing profile notes. The consultant used this technique with several members of the Administration. At a later time the narrative profile description could be written by a competent secretary (if available). A copy of the abbreviations is attached.

6.5 Soil Mapping and Survey Methods

In this section some of the problems encountered by the Soil Survey Administration will be mentioned and some observations of mapping techniques.

1. One of the common major difficulties of the soil survey teams is the the lack of adequate base material. It is possible to make soil surveys without aerial photography and it is being done now. However the technology, material, and equipment is available but not being used for up-to-date photographic coverage by the government. It takes more time and the soil boundaries are not as accurate when using line maps or schematic drawings of the projects or schemes. When location maps are drawn or drafted by the requesting group or agency they are often inaccurate, not-to-scale, and out of proportion to objects on the landscape i.e., jebels, khors, reservoirs etc.. When photography is available it is old, mostly 1950's, and often of poor quality. Also the flight lines do not always overlap leaving large gaps in the coverage, often as much as 4-7 km wide. Examples of this occurred in the S.E. Roseires and Tonj soil survey areas.

   All these conditions unnecessarily complicate and restrict the operations of the soil survey staff.

2. Most mapping in the past has been in the central clay plains. A "grid" system is used to locate and observe and record soil profile every 1 to 2 km. This system may be adequate for areas where soils occur in large homogeneous bodies. It is very inadequate and cannot be used in areas where the soils occur in complex heterogenous patterns. Refer to the discussion for stops 85-89 in Appendix 3 on this same subject. The soil scientist must be aware of changing patterns and landscapes and adjust mapping techniques to best fit the situations. This requires judgement and skill on the part of the survey leader or party chief and the mappers. All landscapes are not the same and innovations must continually be sought after to do the best work possible.

3. In line with the statements above boundaries of projects or schemes could be reconsidered. If an arbitrary boundary is drawn by the requesting agency consideration should be given to extending the survey boundaries to include a natural geographic unit. In this way soil relationships may be understood more fully, and more logical and practical landscape units be separated. Examples of natural geographic units might be to map all of a jebel instead of part of it, extend the soil boundaries to include all of a ridge, or map to a major khor or drainage or water-shed area. Also refer to the comments on the Rabak area stops 17 and 18. in Appendix 3.

4. Where possible new techniques and methods must be used to provide the needed information to all users. One technique that is now being started in the west, Kordofan Province, is the use of ERTS satellite imagery and reconnaissance soil surveys. Reconnaissance soil surveys give a quick broad understanding of large areas. They indicate where potential areas are that can be developed without many requirements and those areas that need more investigations. If need be detailed soil surveys could be made at a later time when special projects require intensive investigations. More effort should be devoted to making a reconnaissance soil survey of the Sudan, district by district and province by province. The use of available manpower can be more efficiently and effectively used by making these kinds of surveys.

6.6 Soil Survey Reports

Progress is continuing on the improvement of soil survey reports by the Soil Survey Administration. However, there are parts of the reports as currently written that could be reevaluated. Some comments on the different sections of the reports concerned primarily with classification and correlation are made here.

1. At present only the modal sites of "official" series descriptions are noted in the report if the location of the modal series is in that survey area. Many soil profiles and descriptions are given in the appendixes with no indication which particular pedon is the modal one for the survey area. An example would be as follows:

   Series A, B, C D, E, F, and G are mapped in a soil survey area. Series A and E have their type locations in the survey area and are described in detail in the report and it is indicated that these pedons are the type locations. The profile descriptions are indicated as the type locations both for the survey area and for the "official" series description. The other series B, C, D, F, and G have type locations in other areas. There are profile descriptions given in the appendix for these soils (possibly several for each series) but there is no indication which profiles are the modals for that particular survey area.

   Every soil series should have a type or modal location in each survey area. The classification and correlation of the soils of an area must be based on a representative pedon. There may be other taxonomic units that may or may not classify the same as the modal for a survey area. These taxonomic units can be described as ranges of characteristics, inclusions, taxadjuncts, or variants in the mapping unit. The range of the pedon should not include characteristics that are outside the class or category boundaries.

2. The classification and correlation tables are often confusing as currently written. The tables are commonly arranged by mapping units or phases and classification nomenclature applied to each phase. The classification of a soil is at the series level and the table should be arranged to only list the soil series and their taxonomic placements. An example would be:

TABLE OF SOIL CLASSIFICATION

SOIL SERIES	CLASSIFICATION
Es Salama	Typic Torripsamments mixed, hyperthermic
Kulud	Typic Camborthids coarse-loamy, mixed, hyperthermic

Phases should be described and included with the map units. Variants should be treated like new series and included in the classification table.

3. There are many inconsistencies, duplication of information and omission of information in the tables and the narrative descriptions. It was commonly discovered that the depths of horizons and horizon nomenclature was either omitted or inconsistent between the narrative write-up, profile description, and the laboratory data.

In view of this situation a person should be appointed to be in charge of editing all manuscripts for format, inconsistencies, errors, omissions, etc. It would be timely for a committee of the soil survey staff and FAO staff to review again the format of the soil survey reports.

6.7 Training

The formal training given by the consultant consisted of a series of 2 lectures and a seminar or workshop held at Wad Medani. The lectures were primarily oriented towards problems and difficulties observed in the field in classifying soils. The workshop consisted of a series of 6 problems in classification. After the participants had completed the assignments a review and discussion of the problems was held. Another seminar was also held one evening at Kadugli.

Most of the time in the field informal training was given on an individual or group basis while observing or describing soil profiles. Many of the profiles visited were pits that had been previously opened.

To continue a training program the Soil Survey Administration should establish annual workshops or seminars. These seminars should be working seminars where the participants are involved in conducting different parts of the session. Subjects that could be included are soil classification, improving "official" series descriptions, mapping unit descriptions, definitions of diagnostic horizons, interpreting laboratory data, definitions of horizon nomenclature, etc. Different members of the Soil Survey Staff should be involved in leading or conducting different parts of the seminar. It would also be beneficial to have guest lectures on related subjects from research stations, the University of Khartoum or from different agencies of the government.

7. FOLLOW-UP FOR FUTURE ACTION

After 4 months of field work and observations the consultant recognizes 3 major areas that would be beneficial for additional emphasis or training.

1. As mentioned in the section on soil correlation there are special problems that need attention. A tentative program is outlined below for the soil correlator, Mohamed A. Ali, to aid the Soil Survey Administration in classification, correlation, and operations.

   The consultant recommende that Mohamed A. Ali attend a series of workshops, conferences, and seminars for an intensive training period of about 6-7 weeks. This training is recommended to be held in the United States. The USDA soil conservation service already conducts annual training sessions in the fields mentioned.

   1.1 Attend the classification and correlation workshop held at one of the regional centers - 2 weeks

   1.2 Attend a final correlation conference at a regional center - 1 week

   1.3 Attend a comprehensive review held in the field in an area of the United States that represents similar soils as those in the Sudan. Possibly in the southwest or in California - 1 week

   1.4 Attend a training session at one of the regional soil survey laboratories. Courses are given in understanding laboratory techniques and methods of analysis and the interpretation of laboratory data. 1 or 2 weeks

   1.5 Complete this program by meeting and discussing soil classification, correlation and soil survey in Washington D.C. with Bill Johnson, Deputy of Soil Survey; Dr. Jack McClelland, Head of Soil Survey Operations and Classification; and Dr. Klaus Flach, Head of Soil Survey Laboratories. - 1 week

If planned ahead of time this extensive training program could be coordinated within a period of 6 to 7 weeks. Also if possible this consultant would be available as coordinator or to assist in the program in the United States and to participate in the reviews and conferences.

There is no language barrier as M. A. Ali has an excellent command of the English language. He has also studied abroad so is able to adapt to different situations without difficulties. He is the person that would benefit most from such a program and be able to apply this newly gained information to the best use in Sudan. This extensive training would give a quick comprehensive review of the correlation processes for on going soils surveys in the United States. Also it would establish personal contacts and open means of communication with those at high levels in the United States that are experienced and responsible for guidance and operations of the soil survey program. This is especially important for communication of new ideas or concepts concerning soil classification and correlation. This training should take place within the next year.

2. As mentioned in the section on soil survey reports a person should be appointed to be responsible for editing and reviewing soil survey manuscripts. This new appointee should attend a training school or series of workshops specialising in this field. In the United States programs are already established in this field. Other countries might have the same kind of programs.

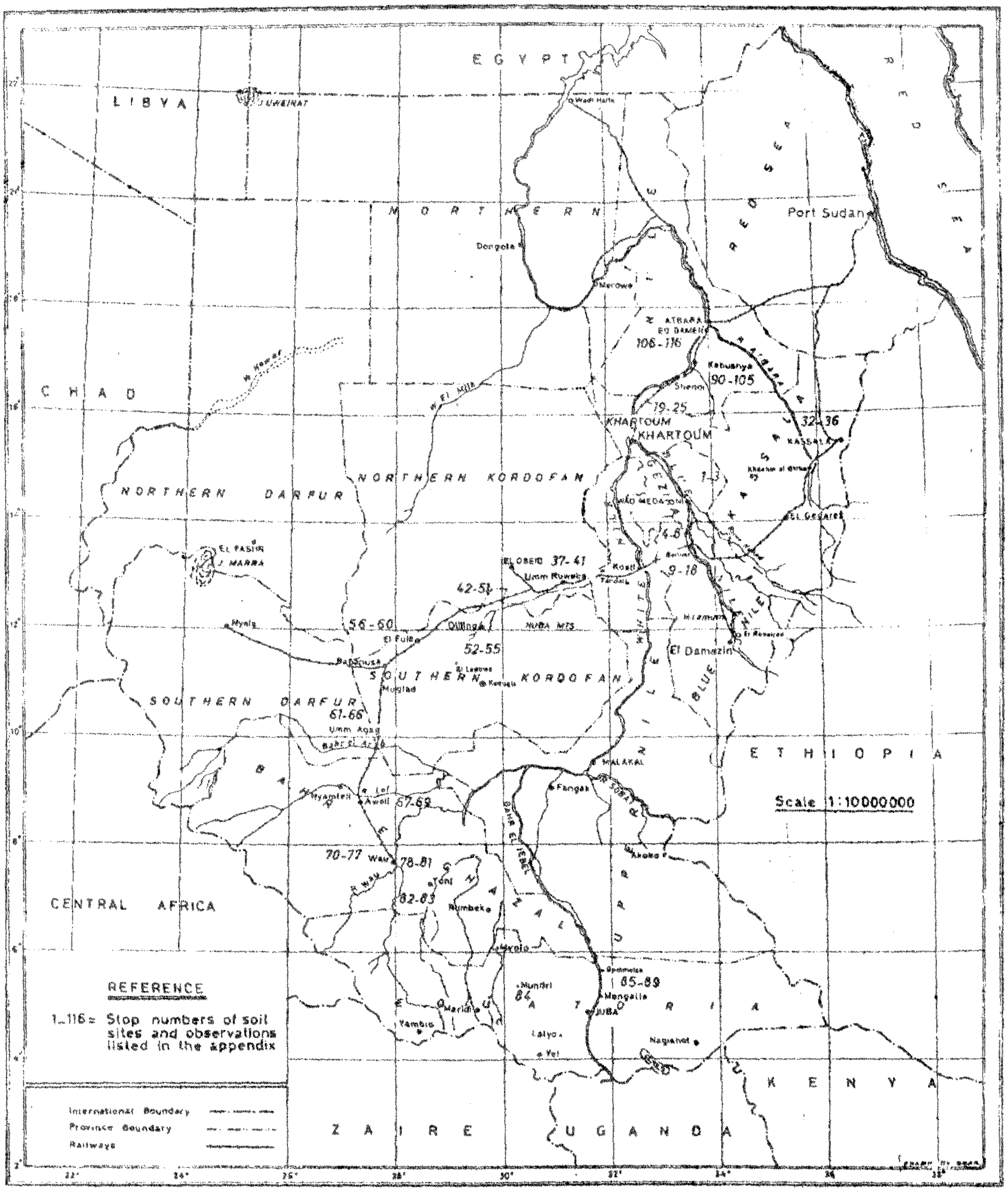
   At present in the Soil Survey Administration no single person is responsible in this field. To make the most out of these reports for both the non-technical or general uses and other scientists, a complete review should be made of these reports. This program should take place and be completed within the next year. By June 1976.

3. In the next 2 or 3 years a short review should again be made by a soil classification consultant familiar with the USDA Soil Taxonomy. This review should be about 4 to 6 weeks in duration and continue a similar program of this consultancy. At that time a person such as Dr. McClelland or Bill Johnson would be the most beneficial to both the Sudan Soil Survey Administration and to those responsible for changes in Soil Taxonomy.

APPENDIXES

APPENDIX 1

LOCATION MAP AND STOP NUMBERS



EGYPT
LIBYA
J. UWEINAT
Wadi Halfa
RED SEA
Port Sudan
NORTHERN
Dongola
Merowe
ATBARA
ED DAMER
106-116
Kabusnya
90-105
Shendi
CHAD
W. Howar
W. El Milk
19-25
KHARTOUM
KHARTOUM
32-36
KASSALA
NORTHERN KORDOFAN
NORTHERN DARFUR
1-3
WAD MEDANI
GEZIRA
El Gedaref
4-8
EL FASHIR
J. MARRA
EL OBEID 37-41
Umm Ruwaba
Kosti
9-18
42-51
Nyala
56-60
El Fula
Dilling
NUBA MTS
52-55
Babanusa
El Damazin
SOUTHERN KORDOFAN
SOUTHERN DARFUR
Muglad
61-66
Umm Agad
Bahr el Arab
WHITE NILE
BLUE NILE
MALAKAL
ETHIOPIA
Fangak
Scale 1:10000000
Nyamlell
Aweil 67-69
BAHR EL GHAZAL
BAHR EL JEBEL
70-77
Wau
78-81
R. Wau
Tonj
82-83
Rumbek
UPPER NILE
CENTRAL AFRICA
Yirol
REFERENCE
1-116 = Stop numbers of soil sites and observations listed in the appendix
Mundri
84
85-89
Mongalla
JUBA
EQUATORIA
Maridi
Yambio
Yei
Nagishot
KENYA
International Boundary
Province Boundary
Railways
ZAIRE
UGANDA
22°
24°
26°
28°
30°
32°
34°
36°
38°
2°
4°
6°
8°
10°
12°
14°
16°
18°
20°
22°

APPENDIX 2

ITINERARY

ITINERARY

DATE	PLACES, NAMES, AND SUBJECT
23-26/11/74	Departure from Santa Rosa, California, U.S.A. to FAO Rome via San Francisco, Los Angeles, and London.
26/11/74 to 3/12/74	Arrive FAO Rome. Meet with several FAO staff including Drs Dudal, Pecrot, Howard, Higgins, Nduaguba, and Dalton.
3/12/74	Departure from Rome and arrive in Khartoum.
3-5/12/74	Meet with UNDP staff in Khartoum and some Sudanese government officials.
5-7/12/74	Departure from Khartoum and arrive in Wad Medani. Meet with FAO UNDP staff and the staff of the Soil Survey Administration. Discussion on program and general outline of work to accomplish during the 4 months consultancy.
8/12/74	Field trip to Guneid with Messrs. M.A. Ali, Pacheco, Nachtergaele and Purnell. Also met with I. Baillie from Huntings.
9-10/12/74	At Wad Medani studying reports and preparing for field trips.
11-12/12/74	Field trip to Sennar area (M.A. Ali, Purnell, van der Kevie, and Osman el Tom. Also met with I. Baillie.
13/12/74	Holiday - At Wad Medani.

14-17/12/74	Field trip to Rabak area (Kenana sugar scheme survey) (Ali, van der Kevie, Purnell, Arlidge, and members of Soil Survey staff).
18-28/12/74	At Wad Medani studying soil survey reports and other publications and documents. Preparing for field trip and for lectures.
29/12/74 to 2/1/75	Field trip to N.E. Khartoum area and at Khartoum. (Ali, Adam, El Tom, Purnell, . and others of the Soil Survey staff).
3/1/75	At Wad Medani. Holiday.
4-5/1/75	At Wad Medani, lectures on soil classification, soil surveys and related subjects. Also held a workshop with problems on soil classification. Soil Survey staff, FAO staff, and others.
6-10/1/75	At Wad Medani working with Soil Survey staff on reports and preparing for Field trip.
11-12/1/75	Field trip to N.E. Khartoum (Adam and Nachtergaele).
13/1/75	Holiday.
14/1/75	At Wad Medani preparing for field trip.
15-21/1/75	Field trip to Agadi and S.E. Roseires area (Osman el Tom, van der Kevie and others of the Soil Survey staff at the survey areas).

22-27/1/75	At Wad Medani working with FAO and Soil Survey staff with satellite imagery, survey reports, reviewing literature in the Research Station's library, and preparing for field trip.
28-29/1/75	Field trip to Kassala area (Ali, van der Kevie, Pacheco).
30/1/75	To Khartoum and return to Wad Medani.
31/1/75	Holiday.
1/2/75	Preparing for field trip to the south.
2/2/75	Field trip to the south Wad Medani to Rabak (Purnell, Pacheco, M. Ali, M. Nur, Hashim).
3/2/75	Rabak to Tendelti.
4/2/75	Tendelti to El Obeid.
5/2/75	El Obeid to Dilling (Mr. Dave Parry from Huntings joined the field trip).
6/2/75	Dilling to Kadugli via the Habila Mechanized Farm (van der Kevie joined the field trip).
7/2/75	At Kadugli studied the soils at the area and visited the new substation. (Hashim remained at Kadugli).
8/2/75	Kadugli to El Fula.
9/2/75	El Fula to Babanusa. Reviewed project area of Mr. Pacheco on photo interpretation af false color and computer analysis of satellite imagery.

10-11/2/75	Babanusa to Umm Agaga area. Umm Agaga Mechanized Farming Scheme.
12/2/75	Umm Agaga to Nyamlell (Mr. Pacheco + Parry left field trip).
13/2/75	Nyamlell to Aweil (met with Klinkenberg working on the Aweil rice scheme).
14/2/75	Aweil to Wau.
15-16/2/75	At Wau to study soils of the Halima Experimental Farm and the Wau Canning Factory Farm. Met with members of Soil Survey staff and Messrs. A. Mulder, D. Hopkinson and Kooymans from the Land Development Project.
17/2/75	Wau to Tonj.
18-19/2/75	At Tonj studying the soils of the Kenaf Corporation Project. Met with members of Soil Survey Staff. Mr. van der Kevie remained to assist in the soil survey.
20/2/75	Tonj to Muolo.
21/2/75	Muolo to Juba.
22-25/2/75	At Juba met with FAO and Soil Survey staffs.
26/2/75	Juba to Mongalla (Purnell, M. Ali, M. Nur, and Moneim).
27/2/75	Mongalla to Gemmeiza sugar scheme and returned to Mongalla.
28/2/75	Mongalla to Gemmeiza and return to Juba.

1/3/75	At Juba. Made a review of the soils of the Rotum Farm Scheme. (Purnell, Ali, Khodary, Moneim, Khalid, and others of the Soil Survey staff).
2/3/75	Juba to Khartoum by B707 jet.
3/3/75	At Khartoum. Holiday.
4-8/3/75	At Wad Medani. Compiling notes and preparing for field trip to the North.
9-11/3/75	Field trip tour Wad Medani to Shendi via Khartoum (Ibrahim Buraymah).
12-14/3/75	Shendi to Ed Damer and Atbara area (met with Hassan Fadl and Mr. Ali Taha Soil Scientist of the Hudeiba Research station).
15/3/75	Ed Damer to Khartoum.
16/3/75	Khartoum to Wad Medani. Completed details for departure to Rome with UNDP and air lines.
17- 27/3/75	At Wad Medani. Preparing final report, discussions and consultations with FAO and Soil Survey staff.
28/3/75	Departure from Wad Medani to Khartoum.
29/3/75	At Khartoum completing business with UNDP for departure to FAO Rome.
30/3/75 to 2/4/75	Departure from Khartoum to Rome via Cairo and Athens.

3-6/4/75 At Rome. Final report and discussions with FAO staff.

7/4/75 Departure to Santa Rosa California, U.S.A..

APPENDIX 3

COMMENTS AND BRIEF DESCRIPTIONS OF SOILS

CONTENTS

Stops 1-3 1/ — GUNEID AREA - Guneid Sugar Cane Scheme and Proposed Extension

Stops 4-8 — SENNAR AREA - North West Sennar Survey Report

Stops 9-18 — RABAK (KOSTI) AREA - KENANA Sugar Estate Survey Report

Stops 19-25 — N.E. KHARTOUM AREA - N.E. KHARTOUM Soil Survey Report

Stops 26-31 — AGADI-S.E. ROSEIRES AREAS - AGADI Extension '74-'75 and S.E. Roseires Soil Survey

Stops 32-36 — KASSALA AREA - Upper Atbara Area Report

Stops 37-89 — FIELD TRIP TO THE WEST AND SOUTH

- Stops 37-41 — Kosti to El Obeid
- Stops 42-51 — El Obeid to Dilling and Kadugli
- Stops 52-55 — Kadugli to El Fula
- Stops 56-60 — El Fula Transect
- Stops 61-66 — Umm Agaga Area - Umm Agaga Soil Survey Report
- Stops 67-69 — Aweil - Awil Rice Scheme
- Stops 70-77 — Wau Area - Halima Experimental Farm
- Stops 78-81 — Wau Area - Wau Canning Factory Farm
- Stops 82-83 — Tonj Area - Kenaf Corporation Farm
- Stop 84 — Muolo to Juba
- Stops 85-89 — Gemmeiza Area - Gemmeiza Sugar Scheme
- Rotum Farm at Juba

Stops 90-105 — SHENDI AREA - Shendi - Wad Bau Naga Soil Survey Area

Stops 106-116 — ED DAMER AREA - Soil Survey of Ed Damer, El Zeidab, and Kelli Areas

1/ Location of stop numbers are also shown on the map in Appendix 1.

Included in Appendix 3 are comments and brief descriptions of soils seen on field trips. They are listed by area in sequential order from the first field trip to the last area visited. The stops are listed consecutively and are referred to at various places in the text and on the map in Appendix 1. Where appropriate the sample number or site number (i.e., GAA05 or site 3) for the soil survey is given in parenthesis. For more detailed descriptions and laboratory analysis one may refer to the various soil survey reports or reports of field trips by the FAO staff. Some information on Soil Taxonomy and a brief explanation of taxonomic terms may be found in Appendix 6. Definition of terms used in the brief descriptions are from the USDA Soil Survey Manual, Handbook No. 18. Abbreviations used are given in "Definitions and Abbreviations for Soil Descriptions, USDA-SCS, West Technical Service Center, Portland, Oregon, April 1974", copy attached.

Colors are for dry soil unless otherwise noted (m=moist). Other abbreviations commonly used are 1) mont. = montmorillonitic; 2) hyp. = hyperthermic; 3) isohyp. = isohyperthermic; 4) calc. = calcareous;

Stop 1 to 3 - GUNEID AREA

(Additional notes may be found in a memo from W. van der Kevie to M.F. Purnell dated 12/1/75).

Stop 1 (GAA05)

This site is mapped as Suleimi clay shallow melanic overwash phase (mapping unit 14 t). It had been dry farmed to dura. A brief description from the site is:

Horizon	Depth (cm)	Texture	Color	Other Features
A1	0-5	fgscl	10YR 4/3	calc.
B21	5-20	fgsc or fgc	10YR 4/3	calc.; 1 cm cracks 20-50 cm apart; horizon much denser.
B22	20-60	fgc	10YR 3/3 and 4/3	Calc.; few cracks 0.5 -1 cm cracks up to 100 cm apart.

				rance of being massive
Cb	60-120	fgc or sc	10YR 4/1;3/2(m)	calc.

The soil had cracks 1 cm wide at a depth of 1 m but very questionable if any slickensides or pressure faces present between 25 and 100 cm. The clay content is over 30%. It was estimated at about 30% in the surface and 40 to 50% to a depth of 1 m. This soil has an ochric epipedon, a cambic horizon, an ustic or aridic moisture regime, and enough clay to cause shrinking and swelling but not enough to qualify for a vertisol. This area is in a transitional soil temperature zone between hyp. and isohyp. and soil moisture regimes and should be investigated for further verification.

Classification:

1. If "iso" soil temperature and an ustic soil moisture regime - Vertic Ustropepts fine, mont., isohyp.
2. If hyp. soil temperature and an ustic soil moisture regime - Vertic Ustochrepts fine, mont., hyp.
3. If the soil moistue regime is aridic these soils would be - Ustertic or Vertic Haplargids.

Stop 2

This site is mapped as Suleimi clay (map unit 17) and is irrigated and planted to sugar cane. The pit was only 20 cm deep but observed by auger boring to a depth of 1 m.

The soil is dark brown (10YR 4/3), clay with some evidence of slickensides. Clay content was estimated at 50 to 60%. The melanic or dark gray layer is deeper than 90 cm and little or no gypsum above 90 cm.

Classification:

1. Typic Chromusterts fine, mont., isohyp.
2. If the soil moisture regime is aridic, these soils would be classified as Torrerts.

Stop 3

After checking the soil map this particular pit was on or very near the boundary between map unit 14 Suleimi clay, shallow melanic and Suleimi clay. However, the pit was fairly representative of Suleimi clay.

A 0-50 cm 10YR 4/2; 3/2 m; 40 to 50% clay (estimate)
AC 50-75 cm 10YR 3.5/1.5; 50 to 55% clay (estimate)
C 75-100 cm similar to 50 to 75 cm.

The site is planted to sugar cane and irrigated but many slickensides and pressure faces could be observed in the pit.

Classification:

1. Typic Chromusterts fine, mot., isohyp.
2. Same comments as stop 2.

Stops 4 to 8 - SENNAR AREA

(Additional notes may be found in a memo from W van der Kevie to M.F. Purnell dated 12/1/75).

Stop 4

The site is in a bare virgin area and appears to be an older terrace or pediment surface. The soil as described by Osman El Tom is the Hagu series:

Horizon	Depth (cm)	Texture	Color	Other Features
A11	0-2	scl	5YR 4/6; 4/4 m	
A12?	2-20	hscl	5YR 4/6	fine cracks
B21t	20-80	heavy c	5YR 4/6	fine cracks, pressure faces or clay films.
B22t	80-148	g c	5YR 4/6	

Reaction is pH 7.0 to 7.6 with a slight increase with depth. The questions in classification are:

1. Does the soil have a lithic or paralithic contact within 1.5 m?

2. Is there enough evidence that shows clay illuviation?
3. Does the clay decrease by as much as 20% of the maximum within 1.5 m?
4. Is there enough evidence of cracking and soil movement to integrade to the Vertic subgroup? This dry site has cracks 1 cm wide at 50 to 60 cm depths.

Classification:

With an ochric epipedon, argillic horizon and no paralithic contact at depths of less than 1.5 m the soil would be classified as follows:

1. If the clay content does not decrease:
   1.1 Thodic Paleustalfs fine, mont., (mixed?), isohyp.
   1.2 Vertic Paleustalfs fine, mont., (mixed?), isohyp.

2. If the clay decreases by 20% the soil would be classified as:
   2.1 Udic Rhodustalfs fine, mont. (mixed?), isohyp.
   2.2 Vertic Rhodustalfs fine, mont. (mixed?), isohyp.

There are no Vertic or Ustertic subgroups of Paleustalfs or Rhodustalfs but are implied in the Paleustalfs. A request could be submitted to provide subgroups for soils like the above.

The Hagu series was previously classified as Ultic Haplustalfs fine, illitic, isohyp.

Stop 5 (site 5)

This site is very similar to stop 4 and mapped as Hagu series but is under irrigation and planted to sugar cane. The main difference is the color which is 2.5YR 4/4, 3/6, and 4/6 having higher chromas with increasing depth. Comments on classification would be the same as stop 4.

The Hagu series needs to be reviewed using new laboratory analysis on base saturation by the method of sum of the cations. Also a further check on the lower horizons to see if the clay content is decreasing and by what amount.

Stop 6 (site 2)

The pit is in a bare field that is virgin land. It is mapped as the Dinder series. Structure was not well expressed in the pit and only had a few thin vertical cracks to about 70 cm. However, about 5 to 10 m away there were large cracks 5 to 7 cm open to the surface. The dominant structure is weak moderate subangular blocky with a distinct horizon at 20-70 cm with platy structure. There is a slight clay increase from the surface to 20 or 25 cm. There are many slickensides from about 20 cm. The soil was described by Osman El Tom.

Horizon	Depth	Texture	Color	
A11	0-3	c	10YR 4/3	sl. calc. concretions
A12	3-25	c	10YR 4/3; 3/3(m)	" "
A13	25-70	hc	10YR 3/3	" "
AC	70-120	hc	10YR 3/3	" "

The consultant observed the color of the surface 25 cm to be 10YR 4/2; 3/2 moist instead of 10YR 4/3; 3/3.

Classification:

Typic Chromusterts very fine, mont., isohyp.

Stop 7 (site 3)

The pit was almost 2 meters deep in irrigated sugar cane and mapped as Dinder series. There are no visible cracks because of the irrigation but there are many slickensides and pressure face. There are weakly expressed parallelepiped structural aggregates. Again this color was observed to be 2.5 YR 4/2 (m) approaching 10YR 4/2. Clay content is estimated at 60-65%.

Soil profile described by I. Baillie.

A11	0-36	lt.c	10YR 3/3 m	(2.5YR 4/2 m)	sl. calc.
A12	36-80	c	"	"	"
(A13)AC	80-120	c	"	"	"
(AC) C	120-170	c	"	"	"

Classification:

As described by Baillie: Typic Chromusterts
As described by consultant: Entic Chromusterts
both in the very fine, mont., isohyp. family.

The problem here is not one of classifying the pedon. The mapper must decide from observations whether or not the color values are dominately more or less than 5.5 dry or 3.5 moist. This is the criteria between the Typic and Entic subgroups. If the dominant color values are less than 5.5 dry and 3.5 moist other colors may be added as inclusions in the map unit, as a taxadjunct, or both may be mapped (Typic and Entic) and identified as a complex. The ranges of one series may not go beyond the class limits established by the criteria in Soil Taxonomy.

Stop 8 (site 1)

Very similar to stop 7 but cracking better expressed. Also in cane and irrigated. Comments are the same as for stop 7. Mapped as Dinder clay.

Stop 9 to 18 - RABAK AREA

(Additional notes may be found in a memo from W. van der Kevie to M.F. Purnell dated 12/1/75).

Stop 9 (KSP Nursery - 1)

This is the site of the nursery for the Kenana sugar scheme. A pit was observed to 140 cm and then augered to 240 cm. The color was 10YR 4/1 both moist and dry with 2.5Y 5/2 (m) mottles. The soil cracked 1 to 3 cm wide as of this date to a depth of 30 cm. The surface is slightly granular and it becomes calcareous with depth. A few very good striated slickensides above 140 cm. Alluvium from White Nile deposition.

Classification:

Entic Pellusterts very fine (?), mont., isohyp.

Stops 10 through 16 are on Blue Nile alluvium with a few fine quartzitic and sandstone pebbles on the surface. In some places the top 100 cm does not appear to be related to the deposits below. When these pits were examined (15/12/74) by the consultant the soils were still moist 15 to 20 cm below the surface. Therefore a question was raised about the depth of cracking. It was proposed to revisit the area in March of 1975 to observe the cracking pattern when the soils were at their driest state. The time was not available to do this so the question of cracks deep enough to 50 cm still remains unresolved, and needs to be observed in the future.

STOP	COLOR	CRACKING	CLASSIFICATION
10 (KSPP-1)	2.5Y and 10YR 4/2 (m)	few thin cracks to the surface. Within 2-10 m from pit 1 cm cracks at 50 cm.	Entic Chromusterts fine, mont., isohyp. 70-73% clay.
11 (KSPP-2)	2.5Y and 10YR 4/2(m)	do	do
12 (KSPA-3)	10YR 3/2 (d, m)	20-30 cm deep; 2-10 cm cracks 30-50 cm deep; only a few cracks 50-150 cm deep; 1-2 cm cracks	Typic Chromusterts very fine, mont., isohyp. 70-73% clay.
13 (site near (m) base camp in in a Khor)	2.5Y 5/2; 4/2(m)	2-5 cm cracks to 50 cm deep	Entic Chromusterts very fine, mont., isohyp.
14 (KSPA-12)	10YR 4/2; 3/2 (m)	cracks in pit few and indistinct yet within 2-4 m there are 1-5 cm cracks to 30 cm deep.	Typic Chromusterts very fine, mont., isohyp. 70-73% clay.

15 (KSPA-13)	10YR 4/2; 4/3 (m)	few fine cracks 30-50 cm deep	Entic Chromusterts very fine, mont., isohyp.
16 (KSPA-11)	10YR 4/2.5; 2.5Y 4/2 (m)	Strong surface mulch and 2-5 cm cracks down to 20 cm deep.	Entic Chromusterts very fine, mont., isohyp.

Stops 10 through 16 except 13 are all very similar and would be very difficult to map as separate series. At thetime these sites were observed in December with high moisture content it is difficult to adequately describe the cracking pattern. Vertisols should be observed and described in at least 2 of their moisture states; 1) when they are the driest just before the rainy season and 2) when they are moist throughout.

The soils in this area all have a similar profile:

0-20 cm dry and few to many cracks 1-5 cm wide

20-60 cm moist with a platy appearance with few if any cracks. Very strong wedge-shaped (Sphenoid) structural aggregates.

60-100+ cm dry or only slightly moist and few to many cracks 1-2 cm wide.

At the current stage of correlation the consultant would establish a new series that represents these soils.

Classification:

1. If at the end of the dry season the cracks are not 1 cm wide at 50 cm these soils would be classified as Vertic Ustropepts very fine, mont., isohyp. (See correspondence in Appendix 9 concerning Vertic subgroups)

2. If cracks are 1 cm wide at 50 cm they are Entic Chromusterts very fine, mont., isohyp.
   The mapping unit would have inclusions of 3/2 (m) colors or treated as a taxadjunct.

3. Stop 13 would be a separate series.

Stop 17

This stop was at a pit on a long low ridge that separates the drainage of the White and Blue Nile. There are gravel layers at varying depths on the ridge. The soil in the pit without laboratory data would classify as a Typic Rhodustalf clayey over loamy (heavy clay loam?)-skeletal, mixed, isohyp.

Stop 18

About 100 meters east of stop 17 the gravelly substratume was overlain by clay deposits of the plains. Although this ridge comprises about 40,000 feddans no soil series was mapped. They are identified as miscellaneous land types and only indicated whether or not the soils are suitable for sugar cane. It would only take slightly more time to describe the soils on these ridges and jebel pediments and classify them so they may be interpreted for many uses. See Appendix 5 for definitions of miscellaneous land types.

Stops 19 - 25 N.E. KHARTOUM AREA

Stop 19 (NEKHA-1)

This soil is mapped as Kuku series. It has a sandy clay loam surface 5 cm over Nile alluvium. The sandier surface is most likely caused by deflation. The fines are being removed by wind and water and not much clay movement is downward. Another point of discussion was that the surface is entirely wind blown deposits. If the surface material is wind deposited Kuku series should be considered as Torrerts. There are cracks below a depth of 5 cm, to about 50 cm. In the definition of Torrerts in Soil Taxonomy "their cracks may stay open throughout the year in most year, although they may be partially or largely filled with a soil mulch if the soil is moved by wind or animals".

If the soil does not meet the requirement of the Torrerts it would be classified as Typic Camborthids fine, mont., hyp. The ESP is 16-36%. The natric subgroup require 40% saturation with sodium throughout the cambic horizon. If two or more series were in the same family Kuku could be separated at the series level on the bases of sodicity.

Stop 20 (NEKHA-13)

Soils on terrace deposits from Nubian sandstone with dominately reddish brown colors in the 7.5YR and 5YR hues and mapped as the Hattab series.

A brief description:

Horizon	Depth	Texture	Est. Clay %	Clay Films
A11	0-2 cm	cs	2%	-
A12	2-6	ls	5	-
A13	6-20	ls	6	-
A3/B1	20-40	sl	10	1nbr
B21t	40-60	scl	30-35	3nbr; 1mkbr
B22t	60-140	scl	35-38	3nbr,po;1mkbr
II?B3	140-160	gc	40% clay 50-60% gravel	
II C	160	mostly gravel substratum 70-80%		

The depths as previously described were 0-5, 5-18, 18-46, 46-90, 90-100, 100-155 cm.

Classification:

The soil has an ochric epipedon, argillic horizon, and has an aridic moisture regime. It would be classified as Typic Haplargids fine-loamy, mixed, hyp. The texture control section is determined by the weighted average of the 40-90 cm B2t horizon.

The soil had previously been classified as Paleustalfic Haplargids fine-loamy, mixed, hyp. This classification was used to reflect the formation of the deep argillic horizon under another climate therefore a much older soil. This information should be identified at the series level.

Stop 21 (report site No. 14 and 15)

This site is similar to stop 20 but is mapped as Hattab shallow phase. The horizons and diagnostic features are the same but this soil has a gravelly layer within 1 meter of the surface. The gravel content is about 70 to 80% (est.).

Cl ssification:

Typic Haplargids fine-loamy over clayey skeletal, mixed, hyp.

This phase should be established as a new series if significant feddanage occurs. The series has a different family category and has much different use and management problems.

In the course of mapping these two soils - Hattab and Hattab shallow phase - are very difficult and may be identified only by borings at close intervals. To resolve this in mapping they could be mapped together as a complex and their occurrence on the landscape and their proportionate areal extent described carefully in the map unit descriptions.

Stop 22 (NEKA-16)

Site NEKHA-16 is mapped as the Idd Babiker series. It is similar to Hattab series but has mostly 10YR and 7.5YR hues and the argillic horizon is much closer to the surface and only very weakly expressed. The laboratory data that accompanies the description has enough clay increase (by about 1% clay) to qualify for an argillic horizon. Again the consultant separated in more detail horizons at the surface. The estimated clay content in the new horizons clearly had enough clay increase for an argillic.

Horizon	Depth	Texture	% Clay (est.)	Previous Description	
A11	0-3 cm	ls	4-5		
A12	3-10	slorl	10	A11	0-10
A3/B1	10-30	l	15	A12	10-30
B21t	30-60	slc	22	A13	30-60
B22t	60-100	slc	24	B2	60-120
II Cca	100-160	scl	30	B3	120-145

This soil was previously classified as Typic Camborthids fine-loamy, mixed, hyp.

Classification:

Typic Haplargids fine-loamy, mixed, hyp.

Even though both Hattab and Idd Babiker are in the same family they have enough accumulative differences to separate them at the series level. Below is a summary of these differences.

	Hattab	Idd Babiker
Color:	5YR	10YR and 7.5YR
$CaCO_3$:	no $CaCO_3$	$CaCO_3$ occurs within 1 m
Argillic:	moderate to strong B2t, occurs lower in the profile	weak B2t, occurs higher in the profile
Gravel:	Gravel within 1-2 m	No gravel within 2 m

Stop 23 (NEKHA-06)

This pit represented the Kadaro series but has a slightly higher gypsum content than the modal pedon. The soil was previously described with the following horizons:

Horizon	Depth
A1	0-5 cm
B21	5-45
B22	45-75
B3	75-125
Cca	125-165

The consultant separated the surface horizons as follows:

Horizon	Depth	
A1	0-5 cm	
B2t	5-15	strong columnar structure; also many moderately thick and some thick clay cutans or films on ped faces.
B3tca	15-30	

There is a calcic horizon at a depth of 125 cm but is not diagnostic above the series category.

Classification:

Typic Natrargids fine-loamy, mixed, hyp.

Stop 24 (NEKHA 07)

This soil is mapped as the Muwalla series. It is a complex soil s with 2 profiles developed in 2 different parent materials. The surface 16-20 cm is material from Nubian sandstone and below 20 cm the source of material is Nile deposits. At another time the party leader, Adam, and the FAO associate chemist along with the consultant revisited the area and redescribed this profile. The soil was also resampled for laboratory analysis of the redescribed pr file. For a comparison of data and the descriptions see the attached analysis.

The analytical data of the redescribed sample show significant differences with those of the first description.

e.g. 1) The average clay content of the top 10 cm was in the first description 35%, in the redescription when this layer was split up in 3 horizons the average clay content was 22% and the maximum clay was reached between 2 and 4 cm being 30%.

2) The maximum $CaCO_3$% is reached between 43-60 cm in the re-sampling (9%) while in the first description the maximum $CaCO_3$ % is 15% and occurs between 105-125 cm.

3) The electric conductivity reaches a value of 5.1 mmho/cm in the redescription, while the maximum in the first sampling was 3.6 mmho/cm.

Other examples of differences although less significant may be found in the other determinations as pH, organic carbon, CEC etc..

A possible reason for these errors may be the fact that the first described samples were analysed in Wad Medani, while the redescription was analysed in Gedaref substation. This gives an indication that regular check-ups should be made between the different stations on standard samples.

Old narrative description

I. Information on the site

a) Profile number: NEKHA07
b) Soil name: Muwalla series
c) Classification: Haplargid
d) Examination: 15.1.1974
e) Authors of description: Adam and Abbas
f) Location: See map
g) Elevation: -
h) Land form
    1) Physiographic position of site: Plain
    2) Land form of surrounding country: Flat
    3) Microtopography: Nil
i) Slope i on which profile is sited: 1% slope
j) Vegetation and or land use: Open forest of A. tortilis
k) Climate: Compare data of Khartoum Met. Stations

II. General Information on the soil

a) Parent material: Intermixing of River Nile alluvium and Nubian sandstone
b) Drainage: Moderately welld drained
c) Moisture conditions in the soil: Profile is moist below 20 cm
d) Depth of groundwater table: 30-35 metres
e) Presence of surface stones or rock outcrops: Nil
f) Evidence of erosion: Nil
g) Presence of salt or alkali: Nil
h) Human influence: Grazing and wood cutting

III. Brief General Description of the profile

Dark greyish brown sandy clay loam underlain by an olive brown sandy clay which is prismatic in structure; topsoil is noncalcareous and of a mild soil reaction while the subsoil is calcareous and of high pH.

IV. Profile Description

A11 0-10 cm Dark greyish brown (10YR 4/4) moist and dry with very few very small fine yellowish red mottles; fine sandy clay loam; strong fine and medium subangular blocky structure with platy components; slightly sticky slightly plastic wet, friable moist, slightly hard dry; many fine tubular pores; very few very small quartz pebbles embedded in the matrix; noncalcareous matrix; common very fine and few fine roots; clear smooth boundary; pH 8.0; (sample No. NEKHA07034).

A12 10-20 cm Dark greyish brown (10YR 4/4) moist and dry; sandy clay loam; weak to moderate fine and medium subangular blocky structure; slightly sticky slightly plastic wet, friable m moist, slightly hard dry; common fine tubular pores; very few small quartz gravel embedded in the matrix; noncalcareous matrix; common very fine and few medium roots, few Cyperus rotundus roots; clear smooth boundary; pH 8.0; (sample No. NEKHA07035).

B21t 20-40 cm Olive brown (2.5Y 4/4) moist with common small yellowish red and reddish brown mottles; coarse sandy clay; weak very coarse prismatic structure breaking into weak fine medium and coarse subangular blocky structure; sticky and plastic wet, friable moist; common very fine clay films; many very fine, common fine, few medium and coarse tubular pores; very few small sandstones (Fe+Mn cemented) embedded in the matrix; very few very small hard irregular whitish $CaCO_3$ nodules; noncalcareous matrix; very few very small hard irregular whitish $CaCO_3$ nodules; noncalcareous matrix; very few small artefacts; very few worm casts; very coarse and medium, few fine and very fine roots; the larger roots are horizontally growing; gradual smooth boundary; pH 8.2; (sample No. NEKHA07036).

B22t 40-65 cm Olive brown (2.5Y 4/4) moist; sandy clay; moderate fine and medium prismatic structure; sticky and plastic wet, friable moist; few very thin clay films; common very fine and fine tubular pores; very few small hard irregular whitish $CaCO_3$ nodules; few small and coarse soft whitish $CaCO_3$ aggregates; calcareous matrix; few very fine roots; gradual smooth boundary; pH 8.6 (sample No. NEKHA07037).

B23 65-105 cm Olive brown (2.5Y 4/4) moist; sandy clay; strong coarse andm medium prismatic structure; sticky and plastic wet, firm moist; patchy thin clay films on the ped faces; common vertical fissures; very few very fine tubular pores; common very small (3-4 mm) quartz gravel; very few very small hard irregular whitish $CaCO_3$ nodules; common coarse to soft whitish $CaCO_3$ aggregates on the ped faces; calcareous matrix; very few very fine roots; gradual wavy boundary; pH 9.0. (sample No. NEKHA07038).

B3 105-125 cm Olive brown (2.5Y 4/4) moist (70%) and light olive brown (2.5Y 5/4); with very few very small faint yellowish red and distinct dusky red mottles; sandy clay; massive; sticky and plastic wet, firm moist; very small pressure faces; very few very fine tubular pores; few small hard irregular $CaCO_3$ nodules; common coarse (vertically elongated) whithish $CaCO_3$ aggregates; calcareous matrix; gradually smooth boundary; pH 9.0; (sample No. NEKHA07039).

C 125-165 cm Light olive brown (2.5Y 5/4) (80%) and light grey (10YR 7/1) with very coarse faint yellowish red and few small distinct dusky red mottles; sandy clay; massive; sticky and plastic wet, firm moist; very few very fine tubular pores; common small and large grey hard irregular whitish $CaCO_3$ nodules; common small quartz gravels; calcareous matrix; pH 9.2; (sample No. NEKHA07040).

Soil Analytical Data

Location: N E Khartoum

Date of Sampling: 15 1 74

Profile No : NEKHA-7

Soil: Muwalla

Surveyor: A.I. Adam

Sample No	Horizon	Depth cm	pH Paste	pH H_2O (1:5)	pH KCl	E C mmhos cm	$CaCO_3$	Mechanical Analyses >2mm	CS	FA	Si	C	Sat. %
274	A11	0-10	7.4	8.1		0.47	0.5		17	21	27	35	45
75	A12	10-20	7.5	8.0		0.43	0.[illegible]		48	22	10	20	30
76	B21t	20-40	7.9	8.5		0.57	0.8		50	17	7	25	35
77	B22t	40-65	8.3	9.4		1.08	7.0		47	16	7	23	36
78	B23	65-105	8.7	9.7		1.21	10.0		41	15	8	26	42
79	B3	105-125	8.6	9.7		2.44	15.0		35	14	4	32	63
80	C	125-165	8.5	9.3		3.60	11.5		32	12	7	37	75

Sample No.	N %	C %	C/N	Exchangeable Cations meq/100 g Na	K	Ca	Mg	C.E.C.	Base Sat.	E.S.P.	S A R
274	0.053	0.87	16	00	0.2			33		00	0.8
75	0.009	0.14	16	00	0.7			17		00	0.5
76	0.014	0.16	11	00	0.6			21		00	2.5
77	0.007	0.19	24	1.7	0.3			22		6.7	8.7
78	0.007	0.13	18	4.5	0.2			24		17.2	10.7
79				8.1	0.2			25		27.1	21.2
80				10.5	0.2			21		38.2	25.5

Soil Analytical Data Profile No NEKHA-7 (continued)

Sample No	SOLUBLE CATIONS AND ANIONS meq/l in saturation extract								AGGREGATE STABILITY	HYDRAULIC CONDUCTIVITY	BULK DENSITY	
	Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	SO_4^{--}	HCO_3^-	CO_3^{--}			0 Bat	dry
274	1.0		2.0	1.3	0.5		1.6	00				
75	0.5		1.8	1.0	0.3		1.7	00				
76	3.1		1.8	1.2	0.3		1.5	00				
77	7.8		1.0	0.6	1.0		2.1	00				
78	8.8		0.8	0.5	4.4		3.0	0.6				
79	20.5		1.0	0.9	0.7		2.6	00				
80	33.0		2.0	1.3	17.3		1.7	00				

New Narrative Description (Profile No. NEKHA07).

I. Information on the site

a) Profile Number: NEKHA07

b) Soil name: Muwalla

c) Classification: Sapto-Natrargidic Haplargids

d) Date of examination: 11.1.1975

e) Authors of description: R T. Cook, Adam and Freddy

f) Location: See Map

g) Elevation: 350 m

h) Land form

1) Physiographic position of site: Plain

2) Land form of surrounding country: Flat

3) Microtopography: Nil

i) Slope on which profile is sited: <1% slope

j) Vegetation and/or land use: Open forest of A. tortilis

k) Climate: Compare data of Khartoum Meteor. Station

II. General Information on the Soil

a) Parent material: Inter-mixing of River Nile alluvium and weathered and transported Nubian sandstone

b) Drainage: Moderately well drained

c) Moisture conditions in the soil: Profile moist below 20 cm

d) Depth of groundwater table: 30-35 metres

e) Presence of surface stones or rock outcrops: Nil

f) Evidence of erosion: Nil

g) Presence of salt or alkali: Nil

h) Human influence: Grazing and firewood cutting

III. Brief General Description of the profile

Dark brown clay loam overwash material that underlain by dark greyish brown sandy clay loam which is columnar in structure. Topsoil is noncalcareous and of neutre soil reaction while the subsoil is calcareous and of high pH.

IV. Profile Description

A1 0-2 Dark brown (7.5YR 4/4) moist and brown (7.5YR 5/4) dry; loam; single grain; slightly sticky and plastic wet, very friable moist, soft dry; noncalcareous matrix; few very fine roots; abrupt smooth boundary; pH 8.0; sample No. NEKHA0701.

B21t 2-4 Dark brown (7.5YR 4/4) moist and brown (7.5YR 5/4) dry; clay loam; strong, medium and coarse platy structure; sticky and plastic wet, very friable moist and hard dry; common very fine tubular pores; noncalcareous matrix; few very fine roots; abrupt smooth boundary; pH 8.0; sample No. NEKHA0702.

B22t 4-9 Dark brown (7.5YR 4/4) moist and brown (7.5YR 5/4) dry; clay loam; moderate fine and medium angular blocky structure; sticky and plastic wet, very friable moist, hard dry; common fine tubular pores; noncalcareous matrix; few very fine roots; clear smooth boundary; pH 8.0; sample No. NEKHA0703.

B3 9-16 Dark brown (7.5YR 4/4) moist and dark yellowish brown (10YR 4/4) rubbed colour, and brown (7.5YR 5/4) dry; sandy clay loam; moderate coarse subangular blocky structure; sticky and plastic wet, very friable moist, slightly hard dry; common fine tubular pores; noncalcareous matrix; few medium and coarse roots; clear smooth boundary; pH 8.0; sample No. NEKHA0704.

IIA 16-28 Dark greyish brown (10YR 4/2) moist and yellowish brown (10YR 5/4) dry; sandy clay loam; moderate coarse subangular blocky structure; sticky and plastic wet, very friable moist, slightly hard dry; commonn fine tubular pores; very few small hard irregular grey $CaCO_3$ nodules, noncalcareous matrix; very few small artefacts; few medium and coarse roots; clear wavy boundary; pH 8.2; sample No. NEKHA0705.

IIB21t 28-43 Dark greyish brown (10YR 4/2) moist, and yellowish brown (10YR 5/4) dry; sandy clay loam; moderate coarse subangular blocky structure; sticky and plastic wet, friable moist and slightly hard dry; common fine clay films; common fine tubular pores; few small hard $CaCO_3$ nodules, noncalcareous matrix; few very fine roots; diffuse boundary; pH 8.2; sample No. NEKA0707.

IIB22t 43-60 Dark greyish brown (10YR 4/2) moist and yellowish brown (10YR 5/4) sandy clay; strong medium coarse columnar structure; sticky and plastic wet, firm moist, very hard dry; common fine clay films; common fine tubular pores; common fine soft $CaCO_3$ aggregates calcareous matrix; few very fine roots; gradual wavy boundary; pH 8.6; sample No. NEKHA07.

IIB23 60-80 Yellowish brown (10YR 5/4) moist and light yellowish brown (10YR 6/4) dry; sandy clay; strong medium prismatic and moderate coarse angular blocky structure; sticky and plastic wet, firm moist and very hard dry; few clay films; common fine tubular pores; common fine soft $CaCO_3$ aggregates, strongly calcareous matrix; very few very fine roots; diffuse wavy boundary; pH 8.8 sample No. NEKHA0708.

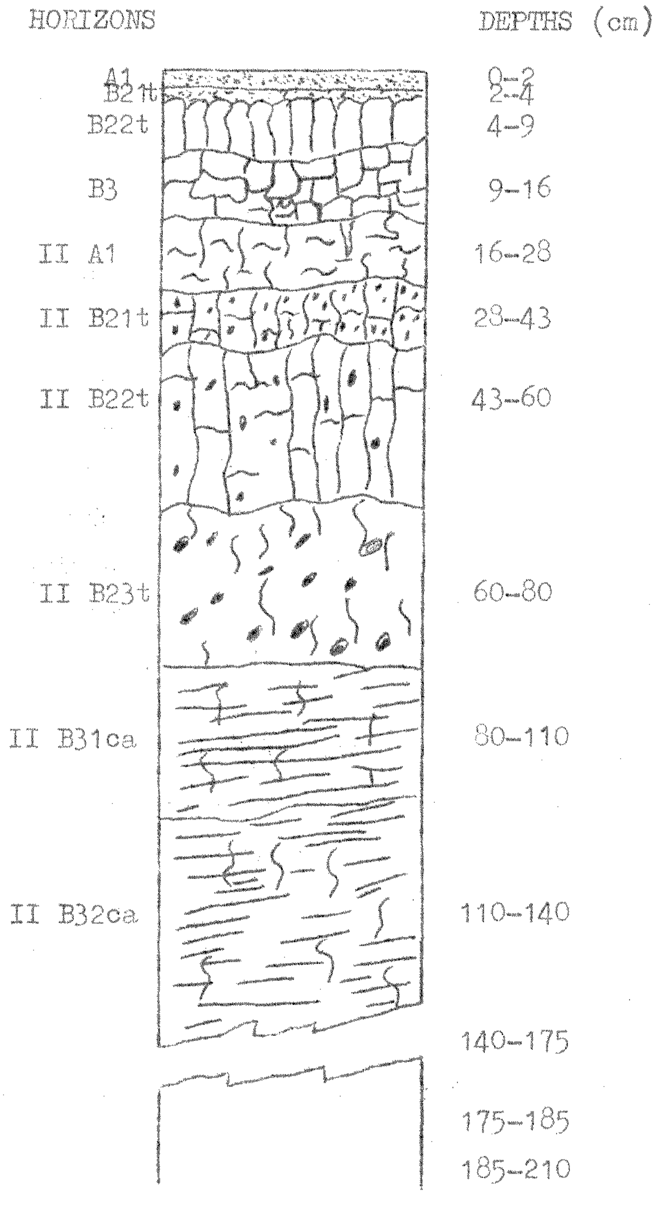
IIB31ca 80-110 Yellowish brown (10YR 5/4) moist and light yellowish brown (10YR 6/4) dry with few fine faint light brownish grey mottles; clay; strong fine prismatic and moderate fine and medium angular blocky structure; sticky and plastic wet, firm moist and very hard dry; common fine tubular pores; common soft $CaCO_3$ aggregates, calcareous matrix; gradual wavy boundary; pH 8.8; sample No. NEKHA0709.

IIB32ca 110-140 Yellowish brown (10YR 5/4) moist and dry with few fine faint brownish grey mottles; clay; strong medium prismatic and moderate medium and coarse angular blocky structure; sticky and plastic wet, firm moist and hard dry; common fine tubular pores; few small hard and soft boundary; pH 9,0; sample No. NEKHA0710.

IIB33ca 140-175 Brownish yellow (10YR 6/6) moist and yellow (10YR 7/6) dry with few fine faint brownish grey mottles; clay; massive; sticky and plastic wet, firm moist and hard dry; few fine tubular pores; common hard $CaCO_3$ nodules, strongly calcareous matrix; pH 9.0; sample No. NEKHA0711.

IIC1 175-185 Brownish yellow (10YR 6/6) moist and yellow (10YR 7/6 dry; clay; massive; sticky and plastic wet, firm moist, hard dry; common medium hard $CaCO_3$ nodules, calcareous matrix; pH 8.8; sample No. NEKHA0712.

IIC2 Auger 185-210 Dark brown (7.5YR 4/4) moist, with common medium faint yellowish red and very few distinct black mottles; clay; calcareous matrix; pH 8.6; sample No. NEKHA0713.



A schematic drawing of this redescribed profile