STATE UNIVERSITY OF GHENT

FACULTY OF SCIENCES
Laboratory of General Pedology

BODEMKUNDIGE INVENTARISSEN : KARAKTERIZERING, KWALITEIT EN EVALUATIE VAN HUN GESCHIKTHEID VOOR SPECIFIEK LANDGEBRUIK

SOIL RESOURCE INVENTORIES : CHARACTERIZATION, QUALITY AND EVALUATION OF THEIR ADEQUACY FOR SPECIFIC LAND USE

by

Balthazar M. MSANYA

A thesis submitted to the State University of Ghent, Belgium,
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Director of laboratory:
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door

Balthazar M. MSANYA

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TO THE MEMORY OF MY BELOVED FATHER

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Ghent State University, Belgium.

ABSTRACT

In many countries a lot of soil resource inventories (SRIs) particularly soil surveys have been made and are still being made. Their objectives are generally well stipulated and known, yet there are indications that these documents are not sufficiently being used both in developing and developed countries. It is against this background that the present study was started. The intention has been to look for ways of characterizing SRIs and to evaluate their adequacy for specified land uses. This way it was hoped that reasons behind the limited use of such documents could be identified and hence help to frame recommendations for future soil inventories.

The data base in this study comprises (a) a total of 176 soil survey reports (including accompanying maps) from 46 countries, (b) 70 completed questionnaires from soil surveyors representing 40 countries and (c) 94 completed questionnaires from users of soil maps and reports representing 35 countries.

Using the 176 SRIs, a general inventory of the documents was made as a first attempt to characterize them. Then indices to characterize the SRIs in terms of their cartographic attributes were developed. These indices were highly correlated with each other. Other observations on cartographic attributes indicated that (a) the concept of map linear reduction factors is not consistently used and (b) information on soil description sites is only rarely given in SRIs.

In relation to the information content of map legends and soil reports it was observed that (a) most SRIs are produced by free survey method; (b) the most commonly used attributes in soil mapping are texture, drainage, landform, topography, parent material and soil depth; (c) information on density of field observations is often lacking in SRIs and is commonly vaguely presented; (d) USDA and FAO/Unesco classification systems are the most widely used internationally; (e) most SRIs contain interpretive data and (f) information on purity of mapping units is often not given in SRIs and in many cases only partly presented.

Two methods are developd and described for estimating the utility of base maps. It was noted that many SRIs do not bear information about their compliance with specified base map accuracy standards.

With regard to general legibility of SRIs, it was observed that (a) provision of instructions on how to use the SRIs is mostly neglected and (b) glossary of specialized terminology and ranges of soil properties of mapping units are commonly not provided in the documents.

A method is developed and described for characterizing and systematically evaluating information given in map legends and soil reports about mapping units in function of specified land uses. Furthermore, a comprehensive method is also described for the assessment of the predictive adequacy of SRIs for three land uses in function of (a) cartographic attributes, (b) map legend and soil report attributes and (c) base map attributes. Guidelines outlining the assessment procedure are provided. This method was applied on 66 selected semi-detailed and detailed SRIs from 17 countries. Following strictly the stipulated criteria of adequacy it was found that only about 27 % of the documents are completely adequate for predicting performance of both corn and oil palm, and about 30 % can be considered adequate for predicting performance of Eucalyptus deglupta (forestry).

A preliminary study on the adequacy for prediction of soil erosion hazards was done on 50 selected SRIs from 18 countries. Based on the adequacy criteria per se, it was found that most of the documents could be said to be adequate for the use in question. It was also noted that (a) although information on climate is given in all documents, winds are frequently not described; (b) information on topography is normally limited by the lack of contour lines printed with soils information or the lack of contour maps appended to the soil maps and (c) information on soil permeability is often not described.

Analysis on the answers given by respondents of the questionnaire to soil surveyors shows that (a) soil surveyors to a great extent determine the nature of SRIs to be made and only occasionally do users have the opportunity to do so; (b) some terminologies and criteria used in soil survey eg. soil survey intensity, field soil mapping procedures and purity of mapping units are not conceived and used consistently; (c) most soil surveyors do not monitor utility of the SRIs they make; (d) soil maps are sometimes too complicated and (e) publicity about SRIs has not sufficiently been made.

The results from the questionnaire to users of soil maps and reports indicate among other things that (a) soil surveys are still considered very important in development projects; (b) there are problems of knowing about the existence of soil maps, yet communication media such as radio, television and newspapers have not been used significantly to ameliorate the situation; (c) major problems encountered while using soil maps and reports include poor legibility, problems of location on the maps, use of vague and in some cases complicated terminology. A revised questionnaire to users of soil maps and reports has been proposed to accomodate changes that will take it more useful as a source of information.

To put everything in a nutshell, it can be said that indeed, existing SRIs do present serious bottlenecks that need attention in future inventories. For this a series of recommendations has been suggested at various levels of the study.

Bodemkundige inventarissen : karakterizering, kwaliteit en evaluatie van hun geschiktheid voor specifiek landgebruik

Samenvatting

In talrijke landen werden en worden nog steeds een groot aantal bodemkundige inventarissen (SRIs) opgemaakt, vooral bodemkarteringen. Hun objectieven zijn gewoonlijk goed bepaald en gekend, maar toch zijn er indikaties dat ze niet voldoende worden gebezigd, zowel in ontwikkelde als in ontwikkelingslanden. Het is met deze achtergrond dat deze studie begonnen werd. De bedoeling was uit te zien naar middelen om SRIs te karakterizeren en hun geschiktheid voor specifieke bodemgebruiken te evalueren. Aldus hoopt men dat redenen voor het beperkt gebruik van deze dokumenten konden gevonden worden, en bijgevolg helpen aanbevelingen op te stellen voor toekomstige bodeminventarissen.

De data base van deze studie omvat (a) een totaal van 176 karteringsrapporten (inbegrepen begeleidende kaarten) van 46 landen, (b) 70 ingevulde vragenlijsten van bodemkarteerders uit 40 landen en (c) 94 ingevulde vragenlijsten van gebruikers van bodemkaarten en -rapporten uit 35 landen.

Gebruik makend van de 176 SRIs, werd een algemene inventaris opgesteld als eerste poging om ze te karakterizeren. Vervolgens werden indexen ontwikkeld om de SRIs te karakterizeren in termen van hun kartografische kenmerken. Deze indexen waren onderling hoog gekorreleerd.

Andere waarnemingen over kartografische eigenschappen wezen er op dat (a) het concept van lineaire kaartreduktiefaktoren niet konsekwent wordt gebruikt en (b) informatie over sites van bodembeschrijving zelden wordt gegeven in SRIs.

Met betrekking tot de informatie-inhoud van de kaartlegenden en bodemrapporten werd vastgesteld dat (a) de meeste SRIs gemaakt worden volgens de vrije karteringsmethode; (b) de meest gebruikte eigenschappen bij bodemkartering zijn : textuur, drainage, landvorm, topografie, moedermateriaal en bodemdiepte; (c) informatie over de dichtheid van de veldwaarnemingen ontbreekt dikwijls bij SRIs en wordt gewoonlijk vaag voorgesteld; (d) USDA en FAO/Unesco klassifikatie-systemen zijn internationaal het meest gebruikt; (e) de meeste SRIs bevatten verklarende gegevens en (f) informatie over de zuiverheid van de kaarteenheden wordt dikwijls niet gegeven in SRIs en in veel gevallen slechts gedeeltelijk.

Twee methoden worden ontwikkeld en beschreven om het nut van basiskaarten te schatten. Er werd vastgesteld dat veel SRIs geen informatie bevatten over hun compliantie met specifieke basiskaart-nauwkeurigheidsstandaarden.

Met betrekking tot de algemene leesbaarheid van SRIs werd vastgesteld dat (a) provisie van instrukties voor het gebruik van SRIs is meestal verwaarloosd en (b) een woordenlijst van gespecialiseerde terminologie en reeksen van bodemeigenschappen van kaarteenheden zijn gewoonlijk niet voorhanden in de dokumenten.

Een methode wordt ontwikkeld en beschreven voor de karakterisatie en systematische evaluatie-informatie in kaartlegenden en bodemrapporten over de kaarteenheden in funktie van specifiek landgebruik. Bovendien wordt een alom-

vattende methode beschreven voor de schatting van de voorspelbare geschiktheid van SRIs voor drie landgebruiken in funktie van (a) kartografische kenmerken, (b) de kaartlegende en het bodemrapport en (c) de kenmerken van de basiskaart. Richtlijnen voor de schattingswerkwijze worden gegeven. Deze methode werd toegepast op 66 geselekteerde, semi-gedetailleerde en gedetailleerde SRIs van 17 landen. Strikt de uitgestippelde kriteria voor geschiktheid volgend, bleek dat ongeveer slechts 27% van de dokumenten volledig geschikt zijn om de opbrengsten van granen en palmolie te voorspellen, en ongeveer 30% voor Eucalyptus deglupta (bosbouw).

Een preliminaire studie over de geschiktheid tot voorspelling van bodemerosiegevaar werd uitgevoerd op 50 uitgekozen SRIs van 18 landen. Steunend op geschiktheidskriteria per se, werd gevonden dat de meeste dokumenten geschikt waren voor het gebruik in kwestie. Er werd ook genoteerd, dat (a) alhoewel gegevens over het klimaat bestaan in alle dokumenten, de winden veelal niet beschreven zijn; (b) informatie over topografie normaal beperkt is bij gebrek aan hoogtelijnen gedrukt met de bodeminformatie of bij gebrek aan hoogtekaarten behorend bij de bodemkaarten en (c) informatie over bodempermeabiliteit is dikwijls niet beschreven.

De analyse van de antwoorden op de vragenlijsten voor de bodemkarteerders toont aan dat (a) bodemkarteerders grotendeels de natuur van de SRIs bepalen en dat slechts bij gelegenheid de gebruikers de mogelijkheid hebben dit te doen; (b) sommige terminologieën en kriteria gebruikt bij bodemkartering b.v. karteringsintensiteit, terreinkarteringsmethoden en zuiverheid van de kaarteenheden niet bedacht en samenhangend gebruikt zijn; (c) de meeste bodemkarteerders geen toezicht houden op het nut van de SRIs die ze maken; (d) bodemkaarten soms te ingewikkeld zijn en (e) er niet genoeg publiciteit rond de SRIs werd gemaakt.

De resultaten van de vragenlijst naar de gebruikers van bodemkaarten en -rapporten geven aan o.a. dat (a) bodemkartering steeds bekeken wordt als zeer belangrijk in ontwikkelingsprojekten; (b) er problemen zijn i.v.m. het besef van het bestaan van bodemkaarten, daar kommunikatiemedia als radio, televisie en pers niet signifikant werden gebruikt om de situatie te verbeteren; (c) grote problemen die oprezen bij het gebruik van bodemkaarten en -rapporten inhouden : slechte leesbaarheid, problemen bij het lokaliseren op de kaarten, gebruik van een vage en soms ingewikkelde terminologie. Een gereviseerde vragenlijst voor de gebruikers van bodemkaarten en -rapporten werd voorgesteld om veranderingen aan te passen, die ze nuttiger zal maken als informatiebron.

Om alles in een notedop samen te vatten, kan gezegd worden dat inderdaad bestaande SRIs ernstige knelpunten bevatten, die aandacht vragen in toekomstige inventarissen. Daartoe werd een reeks aanbevelingen voorgesteld op diverse niveaus van de studie.

Inventaires des ressources du sol : caractérisation, qualité et évaluation de leur adéquation pour l'utilisation spécifique de la terre

Résumé

Dans beaucoup de pays, bon nombre d'inventaires des ressources du sol (SRIs), surtout des cartographies, ont été réalisés et le sont encore. Leurs objectifs sont généralement bien stipulés et connus; cependant, il y a des indications que ces documents ne sont pas suffisamment utilisés, aussi bien dans des pays développés que dans ceux en voie de développement. C'est sur cet arrière-plan que cette étude a été commencée. L'intention était de chercher des façons pour caractériser les SRIs et d'évaluer leur adéquation pour des utilisations spécifiques des terres. De cette manière, on espérait que les raisons pour l'utilisation limitée de tels documents pouvaient être identifiées, de sorte qu'on pourrait formuler des recommendations pour des inventaires du sol futurs.

Les données de base dans cette étude comprennent (a) un total de 176 rapports de cartographies du sol (y compris les cartes accompagnantes) de 46 pays, (b) 70 questionnaires remplis par des cartographes du sol représentant 40 pays et (c) 94 questionnaires remplis par des utilisateurs de cartes pédologiques plus rapport représentant 35 pays.

En utilisant les 176 SRIs, un inventaire général des documents a été réalisé en tant que premier essai pour les caractériser. Ensuite, des indices pour caractériser les SRIs en termes de leurs attributs cartographiques ont été élaborés. Ces indices étaient hautement corrélatifs entr'eux. D'autres observations sur les attributs cartographiques ont indiqué que (a) le concept de facteurs de réductions linéaires de cartes n'est pas utilisé uniformément et (b) l'information sur les sites de description d'un sol n'est donnée que rarement dans les SRIs.

En relation avec le continu d'information des légendes de cartes et des rapports pédologiques, il a été observé que (a) la plupart des SRIs sont réalisés par la méthode de cartographie libre; (b) les attributs le plus souvent utilisés en cartographie des sols sont la texture, le drainage, la forme de la terre, la topographie, le matériau parental et la profondeur du sol; (c) une information sur la densité des observations du terrain manque souvent dans les SRIs et est communément présentée de façon vague; (d) les systèmes de classification de l'USDA et de la FAO/Unesco sont le plus largement utilisés sur le plan international; (e) la plupart des SRIs contiennent des données interprétatives et (f) une information sur la pureté des unités cartographiques manque souvent dans les SRIs ou n'est représentée que partiellement.

Deux méthodes sont développées et décrites pour estimer l'utilité des cartes de base. On a noté que beaucoup de SRIs ne contiennent pas d'information sur leur acquiescement à des standards spécifiques d'exactitude de la carte de base.

En ce qui concerne la lisibilité générale des SRIs, il a été observé que (a) la provision d'instructions pour l'utilisation des SRIs est le plus souvent négligée et (b) un glossaire de la terminologie spécialisée et des séries de propriétés du sol des unités cartographiques ne sont généralement pas

présents dans les documents.

Une méthode est développée et décrite pour caractériser et évaluer systématiquement l'information donnée dans les légendes de la carte et les rapports pédologiques sur les unités de cartographie en fonction d'utilisations spécifiques de la terre. En plus, une méthode compréhensive est également décrité pour l'évaluation de l'exactitude de prédiction des SRIs pour trois formes d'utilisation de la terre en fonction de (a) les attributs cartographiques, (b) ceux de la légende de la carte et du rapport pédologique et (c) ceux de la carte de base. Des directives sur le procédé d'évaluation sont pourvues. Cette méthode a été appliquée sur 66 SRIs semi-détaillés et détaillés selectionnés dans 17 pays. En suivant strictement les caractères d'adéquation stipulés on a trouvé qu'environ 27% des documents sont complètement adéquats pour prédire le rapport de blé et du palmier à huile, et environ 30% peut être considéré comme apte pour prédire le rapport d'Eucalyptus deglupta (sylviculture).

Une étude préliminaire sur l'adéquation pour prédire les dangers d'érosion du sol a été réalisée sur 50 SRIs sélectionnés dans 18 pays. Basé sur les critères d'adéquation en soi, on a trouvé que la plupart des documents pouvait être considéré comme adéquat pour l'utilisation en question. On a également noté que (a) bien qu'une information sur le climat est donnée dans tous les documents les vents ne sont souvent pas décrits; (b) l'information sur la topographie est normalement limitée, par manque de courbes de niveau imprimées avec les informations pédologiques, ou le manque de cartes d'altitude accompagnant les cartes de sols et (c) l'information sur la perméabilité du sol n'est souvent pas décrite.

L'analyse des réponses des questionnaires par des cartographes du sol démontre que (a) les cartographes déterminent pour une grande partie la nature des SRIs à réaliser et seulement occasionnellement les utilisateurs ont l'opportunité de le faire; (b) certains terminologies et critères utilisés dans la cartographie des sols, p.ex. l'intensité de la cartographie, des procédés de cartographie de terrain et la pureté des unités de cartographie, ne sont pas conçus et utilisés conséquemment; (c) la plupart des cartographes du sol ne contrôlent pas l'utilité des SRIs qu'ils élaborent; (d) les cartes des sols sont parfois trop compliquées et (e) la publicité autour des SRIs n'est pas suffisante.

Les résultats des questionnaires des utilisateurs des cartes des sols et des rapports indiquent e.a. que (a) les cartographies des sols est toujours considérée comme très importante dans les projets de développement; (b) il y a des problèmes sur le fait de savoir que des cartes des sols existent, alors que les média de communication comme la radio, la télévision et la presse n'ont pas été utilisés de façon significative pour améliorer la situation; (c) des problèmes majeurs qui se sont posés en utilisant les cartes et les rapports incluent une mauvaise lisibilité, des problèmes de localisation sur les cartes, l'utilisation d'une terminologie vague et parfois compliquée. Un questionnaire revisé pour les utilisateurs des cartes des sols et des rapports a été proposé pour accomoder des changements, qui les rendront plus utiles comme source d'information.

En résumé, on peut dire qu'en effet les SRIs présentent de sérieux "goulots" et exigent plus d'attention dans les inventaires futurs. Pour cela des séries de recommandations ont été suggérées à différents niveaux de l'étude.

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Balthazar M. MSANYA

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Chapter 1

GENERAL INTRODUCTION

11. PREAMBLE

A soil resource inventory (SRI) is defined as any document that describes the attributes and spatial distribution of soils (Forbes et al., 1982). In this context, soil surveys, land evaluations, capability surveys and land inventories are examples of soil resource inventories (SRIs). All these are important documents for development planning. A SRI is essentially composed of a SRI map and a SRI report, commonly called soil map and soil survey report respectively.

The results in a SRI are intended to be a factual basis in the development of sound programmes of land use. Land use planners and decision makers have the task of selecting the best uses for the available soil and land resources. Hence they expect SRIs to answer the basic questions of what can be done, where to be done and how it should be done. In order that these documents can answer these questions, they must at the desired level of accuracy give information pertaining to the description of the soil properties or qualities that can be used to predict the overall land performance for a particular use, and at the same time should provide a map showing the distribution of the different soils.

12. OBJECTIVES AND JUSTIFICATION OF THE STUDY

In many countries a lot of SRIs, particularly soil surveys, have been made. They are expensive and their cost increases sharply with increased detail. While there is a general agreement about the stated objectives of soil surveys, there is doubt whether sufficient use is being made of these works, especially in developing countries (Dudal, 1978); but in developed countries this situation is sometimes not much better (Msanya et al., 1987). Many feasibility studies include soil survey data, yet it often appears that they are not taken into account in the subsequent layout of development plans. In most developing countries published soil surveys have been too little used to justify their cost (Beckett and Bie, 1978). This has been attributed to various reasons including poor presentation of soil survey results, lack of communication between soil scientists and agriculturists, difficulties arising from specialized terminology, inadequate interpretation on the surveyor's side or lack of interest on the side of the planners. One of the objectives of the present study is thus to ascertain the reasons behind the limited use of SRIs. This is achieved by consulting a large and varied collection of SRIs and by use of appropriate questionnaires to SRI users.

The second objective of this study is to find ways of characterizing SRIs and evaluating their adequacy for given land use objectives. Adequacy of a SRI for a particular land use is the degree to which that document can give information crucial to the implementation of that land use. With so many SRIs having been made and still being made, questions naturally arise as to whether they are good enough. This calls for some criteria of quality as a measure of success. In the course of this study it is envisaged that deficiences in existing SRIs can be pin-pointed and suggestions can be made for improvement in future ones.

Some workers like Webster and Beckett (1968) and Burrough et al. (1971) attempted to establish ways of expressing the quality of SRIs by gauging information given by these documents on specific attributes. However, comprehensive characterization and evaluation of the adequacy of SRIs has not been done. Adequacy evaluation of SRIs is a rather recent subject which took shape during the 1977-78 Cornell University Workshops on "Soil Resource Inventories and Development Planning" which finally gave rise to the publication of the "Guidelines for Evaluating the Adequacy of Soil Resource Inventories" (Forbes et al., 1982).

In the mentioned guidelines, it is stipulated that the adequacy of a SRI for a given land use is a function of four major attributes namely (a) <u>cartographic attributes</u>, (b) <u>map legend</u> and <u>SRI report attributes</u> (c) <u>base map attributes</u> and (d) <u>ground truth</u>. Figure 1.1. is a schematic representation of the statement. The concepts and definitions related to these attributes are presented at length in chapter 4. The present study is based on the above stipulations, but also some modifications and new ideas are incorporated for the sake of simplicity, practicality and rationality.

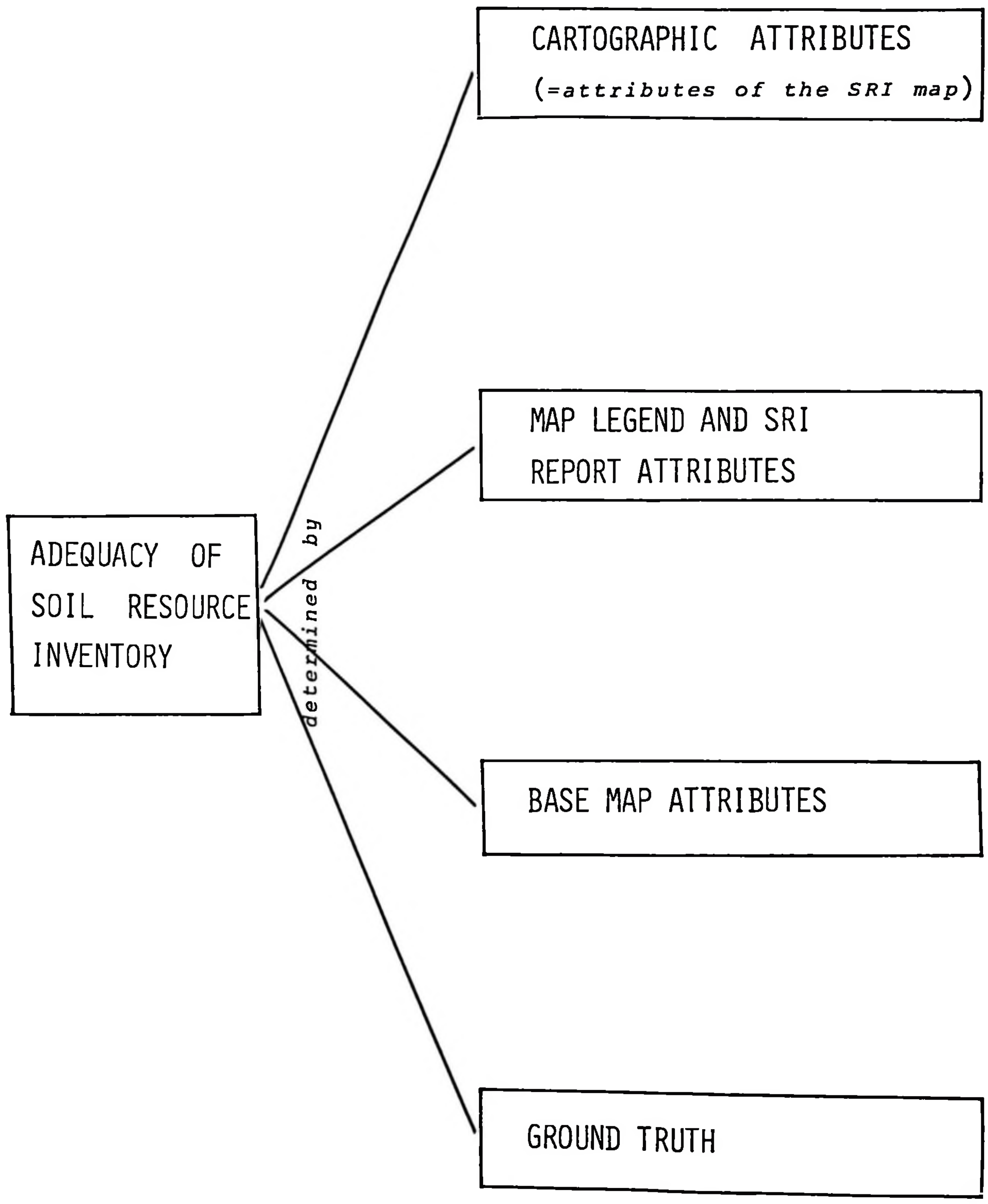
To be able to judge the adequacy of a SRI, the aforesaid attributes have to be assessed and quantified as criteria of quality. In this research a method is established using the first three attributes to evaluate the adequacy of some existing SRIs for specified land uses. Ground truth is not used in the assessment despite its importance, because of the fact that it can only be done in the field where the SRIs were made. Its assessment is almost impossible especially when dealing with many SRIs from different parts of the world. Consequently this means that those SRIs qualifying as adequate as far as the other three attributes are concerned will still need to be assessed for ground truth. For those which don't qualify need not be considered for ground truth assessment as this is a very expensive exercise which can only be justified if the documents are already adequate in terms the other attributes.

During the characterization process of SRIs different measurable attributes of these documents are established. <u>The third objective</u> of the present study is also to establish the different relationships existing between these attributes. This has been achieved through statistical analysis using a computer.

The <u>fourth objective</u> of the study is to establish and analyse the different methodologies that have been used in soil inventories. The use of a questionnaire to soil surveyors from different parts of the world has supplemented to a great extent the information that can be extracted by reading the documents.

A <u>fifth objective</u> is to establish the opinion of SRI users on the use and the role of SRIs in development projects. To achieve this, an appropriate questionnaire was designed and sent to possible SRI users from different parts of the world.

Figure 1.1. Schematic representation to show the major attributes determining the adequacy of soil resource inventories (after Forbes et al., 1982)



It is well known that developing countries are faced with lack of manpower in many fields of science, and soil survey is not an exception. In the field of soil survey, these nations have two major problems. First, they have to depend on foreign experts whom they are unable to give the right instructions as to what has to be done when making SRIs. Second, they cannot control the quality of the work done by the experts. Elaboration of a method to assess the adequacy of SRIs which is one of the major goals of this study can be very beneficial to both developing and developed countries. To the developing countries it is especially more important since even with limited qualified manpower, it is envisaged that quality of SRIs made by foreign as well as local experts could be checked and at the same time objectives for future soil inventory programmes could be laid down.

Moreover, since people who are not soil scientists are known to be among the more important audiences for whom soil inventories are made (Cline, 1981), an elaboration of a method of appraising the adequacy of SRIs is deemed necessary to enable both soil experts and non-experts to appreciate the uses which these documents can or cannot be put into.

13. STRUCTURE OF THE THESIS

The thesis comprises 7 major chapters.

Chapter 1 introduces the subject of the research.

Chapter 2 is a literature review on the basic concepts of soil surveys. It gives the information commonly expected of soil surveys and their techniques.

Chapter 3 describes the data base used in the study.

Chapter 4 presents a critical revision of current concepts and philosophies on soil resource inventories. New definitions rather uncommon in the classical soil survey literature are introduced. It gives methods that can be used to estimate the measurable attributes of SRIs. It also discusses some important results and observations on SRIs and their attributes.

Chapter 5 describes the predictive adequacy of SRIs in relation to specified land use objectives (corn production, production of tropical tree crops and forestry). Criteria are established for assessing the adequacy of SRIs. It also discusses important results and observations on SRIs and presents some conclusions.

Chapter 6 presents and discusses results of questionnaires to soil surveyors and users of soil maps and reports. It also gives recommendations related to the subject matter.

Chapter 7 gives the general conclusions and recommendations.

Chapter 2

REVIEW ON BASIC CONCEPTS OF SOIL SURVEYS

21. DEFINITION OF SOIL SURVEY

According to the Soil Survey Manual (USDA-SCS, 1974), soil survey is the application of field methods and supporting information from other sources to (a) identify, define and classify soils in a given area and (b) delineate on a soil map the areas occupied by the different soils, alone or in combination. Soil survey is not just the process of mapping discrete parcels of the landscape but rather is the whole procedure involved in the making of soil resource inventory. It therefore includes the initial planning, the field investigations, elaboration of the legend, description and sampling of the soils, analysis of the soil samples, drawing of the soil map, writing of the report and preparation of the interpretations. Figure 2.1. summarizes the main stages of soil survey.

Figure 2.1. The main stages of soil survey (Young, 1976)

Planning of survey

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Stage 1: PRE-FIELD OPERATIONS

+ Study of existing data
+ General field reconnaissance
+ Main air photo interpretation
+ Design and planning of field survey

↓

Stage 2: FIELD SURVEY

A. Soil mapping
+ Survey reconnaissance
+ Mapping
+ Representative profile description

B. Evaluation and other field activities
+ Land evaluation
+ Soil response

↓

Stage 3: POST-FIELD OPERATIONS

+ Revision of air photo interpretation
+ Laboratory analysis of soil samples
+ Data analysis
+ Presentation (map preparation and report writing)
+ Participation in project planning

Survey activities in land management

22. SOIL SURVEYS IN GENERAL

22.1. Objectives

Assessment of the properties of soils and their response to management is crucial in agriculture, forestry, rural and urban planning as well as in many engineering works. The practical purpose of soil surveys is therefore to supply adequate information for land use decision making. As Smyth (1981) put it, the objective of soil surveys is to obtain a better understanding of the spatial changes in the characteristics of the soil continuum so that soils may be used more efficiently for the benefit of mankind. Soil surveys are intended to enable more numerous, more accurate and more useful predictions to be made for specific purposes than could be made otherwise (Dent and Young, 1981).

Soil surveys can be classified in terms of their planning objectives. Table 2.1. is relating land use planning objectives with some parameters of soil survey. Depending on the type of land use objectives, Eswaran (1978) distinguished the following types of soil surveys :

a. Soil surveys for master planning identify land areas recommended for broad classes of land use such as urban development, wildlife habitat, recreation, forestry, grazing and cropping.

b. Soil surveys for project planning identify accurately the location of land use components for implementation. For example in a large area designated for irrigated agriculture, a survey for project planning should be able to identify areas unfit for irrigation, farm units with adequate soil resources, main and distribution canals to deliver water, roads etc.

c. Soil surveys for operational planning design systems of land management within tracts assigned to specific uses. They should be able to tell what, how and when management inputs are needed in given areas to obtain satisfactory results from land use.

22.2. Planning

The techniques employed in soil survey vary with its purpose and the nature of the terrain being mapped. Nevertheless, in all cases the investigations should yield (a) a soil map indicating the soils and their distribution and (b) a description of the soils specifying the conditions of soil formations and the properties of the soils which should form the basis of the economic evaluation of soils (Tyurin et al., 1965).

The planning of soil survey involves discussions of its purposes, the nature of the information required and the capacity of surveys of different kinds to supply such information (Young, 1976). To have an effective survey and a suitable mapping system applied to it, a number of decisions have to be made and recorded. The Mapping Systems Working Group (1981) suggested the following sequence of decisions as a guideline for planning a survey :

a. Determination of the major objectives (including the area, purpose, schedule and interpretations) and prime users of the survey.

Table 2.1. Objectives of survey in relation to some components of a soil survey (based on Eswaran, 1978)

Objectives	Approximate Publishing Scale of Map	Minimum Size of Mapping Unit (ha)	Approximate Cost* (US dollars per ha)
A. Master Planning			
1. National	*1/1,000,000*	*4,000*	*0.2*
2. Regional	*1/500,000*	*1,000*	*1*
3. Cultural Systems	*1/100,000*	*40*	*2*
B. Project Planning for:			
1. Land settlement schemes	*1/50,000*	*10*	*3*
2. Large scale farm units	*1/25,000*	*2.5*	*5*
3. Agricultural development projects	*1/25,000*	*2.5*	*5*
C. Operational Planning:			
1. Siting fields for management practices	*1/20,000*	*1.6*	*10*
2. Siting drainage and irrigation systems	*1/10,000*	*0.4*	*20*
3. Siting experimental plots	*1/5,000*	*0.1*	*30*
4. Siting buildings (urban areas)	*1/1,000*	*0.03*	*40*

* Costs are estimates and do not include preparation of report.
Costs vary with country and other factors and are included only to show relative magnitudes

b. From the objectives decision has to be made on the criteria to be used to differentiate soils and mapping units.

c. Determination of the smallest area in the field that must be described and mapped (minimum size field delineation) and establishment of the scale of mapping.

d. Determination of the inspection density in relation to the scale and the purpose of the survey, and allocation of a survey intensity level.

e. Estimation of the man-year requirements based on the inspection density, estimated rate of progress and total area to be mapped.

f. Calculation of costs including estimates for equipment, transport, cartography etc.

g. Determination of whether the estimated costs are acceptable. If they are, the survey should proceed. If they are not they must be revised by modifying the objectives, reducing the data to be collected, reducing the area to be surveyed, increasing the manpower or asking for more money.

h. Determination of the appropriate survey procedure, sampling design and presentation format. Decisions on kinds and number of mapping units, level of taxonomy, type of map and report to be published.

22.3. Intensity

Survey intensity or survey order as used in soil survey literature (Soil Survey Staff, 1975; Mapping Systems Working Group, 1981) refers to the amount of work done (with particular emphasis on field work) and the detail or precision of the information reported in a survey. The revised edition of the 1937 US Soil Suvey Manual (Soil Survey Staff, 1951) had earlier described different types of surveys under the headings, detailed, detailed-reconnaissance, reconnaissance, generalized, schematic and exploratory based on effort invested in plotting soil boundaries in the field, the scale of the published map, survey objectives, types of mapping units and the level of soil classification used to describe the soils.

In the fifth draft of the US revised Soil Survey Manual (Soil Survey Staff, 1975), the characteristics that differentiate survey orders include kinds of mapping units, levels of soil classification, field procedures, map scale and the minimum size field delineation. These characteristics have also been incorporated in the Soil Mapping System for Canada in the definition of Survey Intensity Level (SIL) (Valentine and Lidstone, 1985). In this system, distinction has been made between those characteristics which defined SIL (eg. number of delineations with at least one soil inspection, how boundaries were checked, number of hectares per soil inspection, spacing of traverses, means of travel etc.), and those characteristics which are associated with SIL (eg. map scale, levels of soil classification, rate of field progress and survey objectives).

Table 2.2. Terminology of soil survey intensity in relation to final mapping scale and kind of mapping units (based on FAO, 1969)

Kind of survey	*Range of Scales*	*Kind of mapping units*
Very high intensity	*Larger than 1/10,000*	*Phases of soil series; soil series; occasionally soil complexes*
High intensity	*1/10,000 to 1/25,000*	*Phases of soil series; soil complexes*
Medium intensity	*1/25,000 to 1/100,000*	*Associations of soil series; physiographic units (enclosing identified soil series)*
Low intensity	*1/100,000 to 1/250,000*	*Associations of great soil groups; occasionally individual great groups; phases of great groups. Otherwise land units of various kinds enclosing identified great soil groups*
Exploratory	*1/250,000 to 1/1,000,000*	*Land units of various kinds (preferably enclosing identified great soil groups*
Syntheses	*Smaller than 1:1,000,000*	*Great soil groups and phases of great groups (with essentially taxonomic value*

Table 2.3. Additional information on soil surveys of various intensities (Smyth, 1981)

Kind of survey	Scale	Area represented by 1 cm^2 of map	Density of observations* (0.5 obs./cm^2 of map	Approx. Average rate of progress** per 20-day month	Accuracy of boundaries
Very high intensity	1/5,000 to 1/10,000	0.25 ha 1.0 ha	1/0.5 ha 1/2 ha	500 ha 800 ha	Position of all boundaries checked throughout length on the ground
High intensity	1/20,000 to 1/25,000	4.0 ha 6.25 ha	1/8 ha 1/12.5 ha	1,250 ha 1,500 ha	Position of almost all boundaries checked throughout length on the ground
Medium intensity	1/50,000	25.0 ha	1/50 ha	75 km^2	Some boundaries checked; most inferred
Low intensity	1/100,000	1 km^2	1/2 km^2	200 km^2	Almost all boundaries are inferred

* Density of observations : figures represent the density of all soil observations averaged over the entire area of the map (accectable density usually ranges between 0.25 and 1.0 observations/sq. cm on this basis).

** Rate of progress : figures given represent an approximate average from the wide range of progress rates experienced in actual surveys.

Table 2.4. Survey intensity guidelines (Mapping Sytems Working Group, 1981)

Level	Definitive Characteristics		Associated Characteristics			
	Procedure Intensity	Method of Field Checking	Range of (and usual) Publication Scale	Appropriate Levels of Soil Taxonomy (usually phases of ......)	Approximate Rates of Progress Per Surveyor, for 20 Day Month*	Typical Survey Objectives
1	At least one soil inspection in every delineation. Boundaries checked in the field along entire length in open country, or over 30% in woodland (1-5)**	Traverses primarily on foot less than 0.5 km apart. Profile descriptions and samples for all soils.	1:14,000 or larger (1:5,000)	Series	50-1000 ha	Information for very many purposes down to the level of small farms, small stream catchments, conservation areas and urban subdivisions.
2	At least one soil inspection in over 90% of delineations. Boundaries checked in the field along most of their length in open country, or less than 10% in Woodland (2-30)	Traverses on foot and by vehicle about 2 km apart. Profile descriptions and samples for all major named soils.	1:5,000 to 1:40,000 (1:20,000)	Series or family	500-6,000 ha	Information for many purposes down to the level of local planning for groups of farms, stream catchments, large urban subdivisions or small national parks.
3	At least one soil inspection in most (60-80%) delineations. Boundaries checked in the field at intervals but mainly extrapolated from aerial photographs (20-200)	Some traverses on foot, many by vehicle up to 4 km apart. Profile descriptions for all major named soils, samples from the majority of soils.	1:30,000 to 1:130,000 (1:50,000)	Series, family or subgroup	20-200 km^2	Information for limited number of purposes to level of farming areas, county planning, major stream catchments and large national parks.
4	At least one soil inspection in 30-60% of delineations. Nearly all boundaries extrapolated from aerial photographs (100-1,000)	Traverses mainly by surface vehicle up to 8 km apart. Helicopter used in some areas. Profile descriptions for all major named soils, samples from the majority of soils.	1:50,000 to 1:300,000 (1:100,000)	Family or Subgroup	75-500 km^2	Information for relatively few purposes to level of large agricultural areas, regional and provincial plans, major river catchments.
5	At least one soil inspection in less than 30% of delineations. All boundaries extrapolated from aerial photographs (1,000-20,000)	Traverses entirely by vehicle up to 20 km apart. Helicopter or fixed wing aircraft essential in some areas. Profile descriptions for any major named soils, samples from the minority of soils.	1:100,000 or smaller (1:250,000)	Subgroups, great groups or orders	250-800 km^2	Information for few general purposes for broad regional or provincial plans.

* Rates of progress includes legend development, checking, correlation and soil description as well as the mapping itself.

** Approximate number of hectares represented by one ground inspection.

The figures in this table must be treated as guidelines only for a number of reasons. Firstly, they have been established from our best estimates of how certain surveys have been done in the past. We have few surveys for which this type of information has been carefully recorded. Secondly, they are average figures which may be inappropriate in particular projects; for example, where access is particularly easy or soil boundaries are very obvious. Thirdly, they hide some peculiar anomalies. For example, although a level 2 survey may have at least one inspection in 90% of its delineations the average number of inspections in those delineations may be as few as two. On the other hand in a level 4 survey where only 30-60% of the delineations have at least one inspection these delineations may have 10 or 20 inspections each because they tend to be bigger than those of level 2 surveys and, with access over the whole map being difficult, we spend more time in those areas we can reach.

Soil surveys are also classified according to their survey intensities. The terminology on different intensities of survey and map scales is enormous but understandardized. FAO (1969), Smyth (1981) and the Mapping Systems Working Group (1981) have proposed guidelines for survey intensity in relation with other parameter of soil survey (cf. respectively tables 2.2., 2.3. and 2.4.).

Since most of the information presented in a soil survey map or report is collected in the field, more intensive surveys which describe soils in detail require more field work. This means that the number of times that the soil is inspected in a particular area is a crucial yardstick of work in a soil survey. According to the Mapping Systems Working Group (1981), an inspection is any recorded check of soil attributes made in the field. Its location is known and extrapolations can be made from it to describe a mapping unit or delineation. The number of observations per unit area of map is related to the number of observations per unit area surveyed (Bie and Beckett, 1970), and this relation depends upon the ratio of field and publication scales. The Dutch workers recommend 4 - 9 observations per square cm of map (Steur, 1961; Buringh et al., 1962; Vink, 1963) whereas according to Boulaine (1966) the French recommend 4 observations per square cm of map. However, the density of observations in the field can be decreased if soil boundaries coincide closely with observable landscape or vegetation patterns. According to Aubert and Tavernier (1972), for scales greater than 1/200,000, one should approximate a minimum of 1 observation per square cm of published map.

22.4. <u>Costs</u>

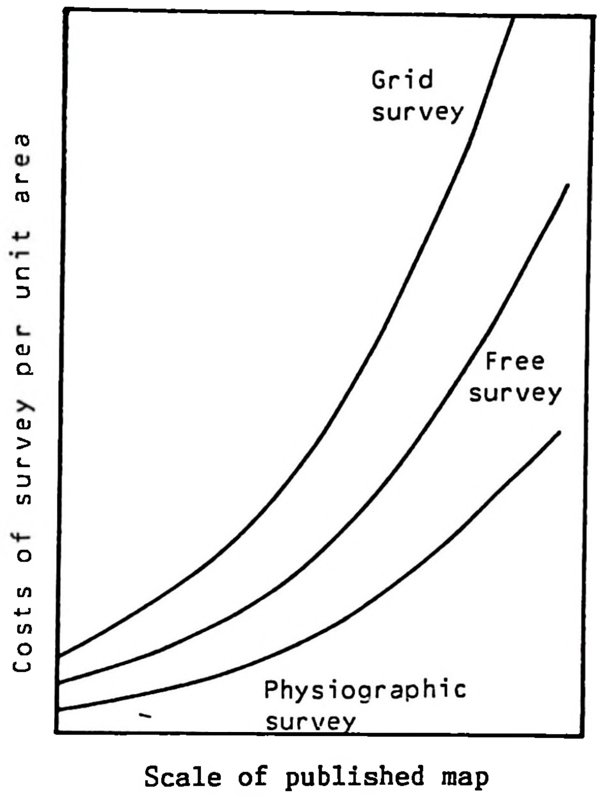
It is generally assumed that the cost per unit area of producing a soil map depends on the intricacy of the pattern of the soils which are to be distinguished, on the nature of the soil mapping units, on the survey procedures used, and on logistics or other practical problems composed by the terrain (Burrough et al., 1971). The variable cost, per unit area mapped, of making a soil map for a particular region, can be resolved into field costs and laboratory costs (Beckett, 1968). The latter comprise mostly the time and effort of air photo interpretation and putting the field data into the standard format of the manuscript map. Cartographic and clerical costs are almost constant per unit area of map and hence decrease in proportion to the square of map scale when expressed as costs per unit area mapped.

Beckett (1968) has shown that for any one area and mapping procedure, field costs tend to be proportional to the number of soil observations made and the number of observations per unit area mapped is proportional to the square of the map scale. He also found that at map scales where both procedures are possible, the field costs per unit area mapped are less for physiographic mapping, which has fewer ground observations, than for free survey. Costs for free survey are less than for those for grid survey (Burrough et al., 1971). Figure 2.2. summarizes these relationships.

The contribution of air photo interpretation (API) to physiographic survey is higher than to free survey and much higher than to grid survey. Moreover, it is argued that the contribution of API falls off sharply at map scales larger than 1/25,000 mainly because the mapping units to be differentiated at larger scales often lack clear photo contrasts (Goosen, 1967). At medium to small scales it is of considerable economy to plot boundaries by API. In fact according to Veenenbos (1957), survey costs can be reduced to 10 % at

1/300,000, or to 33 % at 1/50,000 by using API.

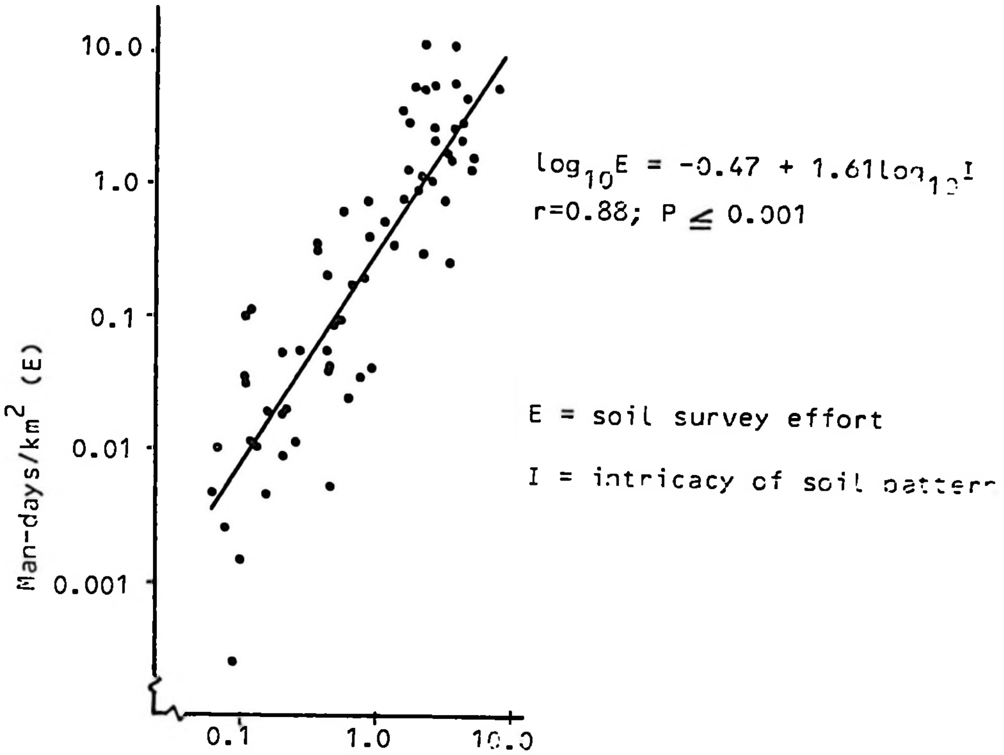
Figure 2.2. Relationships between costs, type of survey and scale of published map (Beckett, 1968)



Costs of soil surveys are also related to the salary of the surveyor. A map of soil series by grid survey is more expensive than a map of the same units, based upon the same density of observation by the same surveyor, by free survey (Burrough et al., 1971). However, a series map by grid survey by a scientific assistant is cheaper than a series map based on the same density of soil observations by free survey by a scientific officer. This is due to the fact that the salary of the latter is much higher than that of the former surveyor.

The whole effort of professional soil surveyors in organizing, conducting and writing up their surveys has been termed survey effort by Bie and Beckett (1971). This excludes assistance of labourers, or of laboratory and clerical staff, cartographers and editors. It is generally agreed that survey effort or cost increases with the intricacy of the soil pattern to be mapped (Krupsky, 1962). Bie and Beckett (1971) have demonstrated this relationship (cf. figure 2.3.). Intricacy was estimated as the average number of soil boundary intercepts per km of linear traverse on the ground based on measurements made on soil maps using a linear traverse of known length.

Figure 2.3. Soil survey effort in relation to the intricacy of the mapped soil pattern based on 66 Australian soil surveys (Bie and Beckett, 1971)



The scale of a soil map is often adjusted to the intricacy of the soil boundaries to be mapped and thus many workers relate survey effort or cost to map scale. The relationship between effort and map scale is shown in figure 2.4. After a review of many soil surveys, Bie and Beckett (1970 & 1971) and Beckett and Bie (1978) established simple relationships between survey effort or intricacy and map scale (cf. an example in fig. 2.5.).

As pointed out by Dent and Young (1981), survey cost is also affected by the following factors :

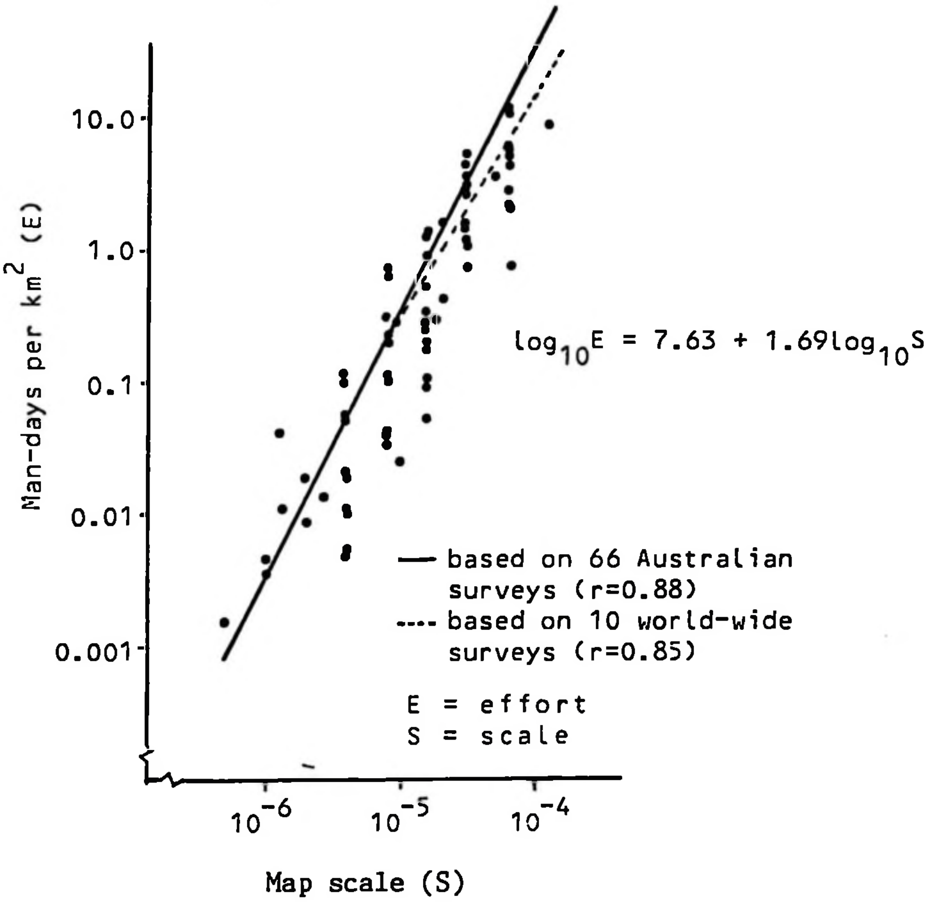
a. Whether the survey is local or distant, ie. whether near established survey offices, an air journey away, or overseas.

b. Whether it is part of an on-going programme or started afresh. National survey programmes achieve economies through keeping a constant flow of work.

c. The extent of ancillary field investigations, such as hydraulic conductivity test, and the sophistication of laboratory support.

d. Who does it. Consultant firms have to charge true costs, including cover for slack spells between jobs. However, government organizations, besides having continuity of work, may as a matter of policy include an element of subsidy.

Figure 2.4. Soil survey effort in relation to map scale (Bie and Beckett, 1971)

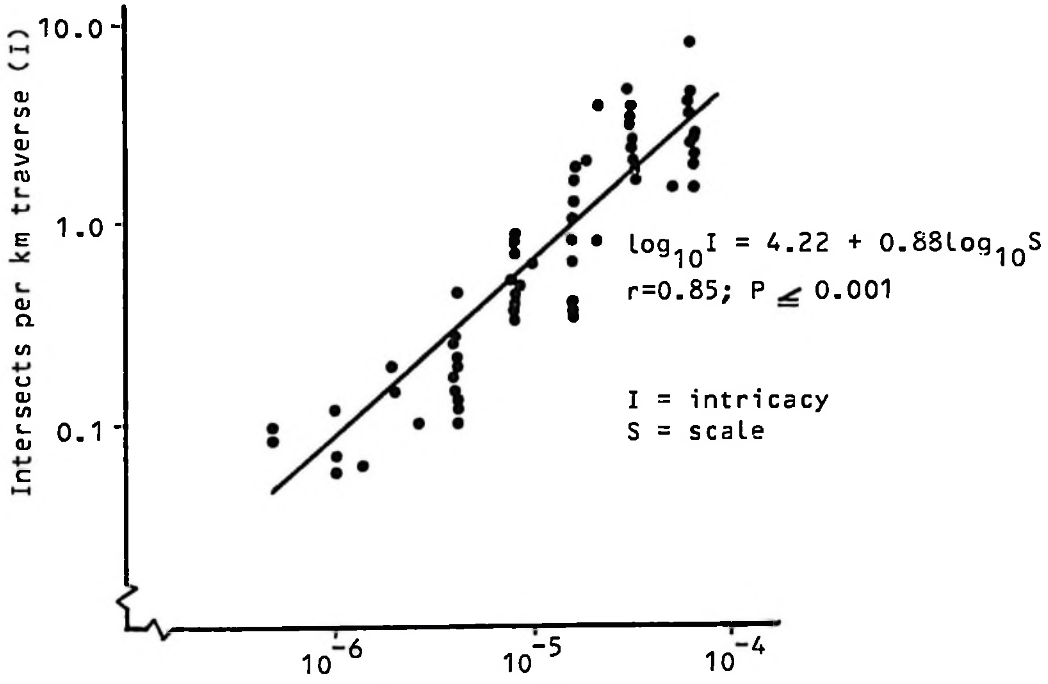


22.5. <u>Quality</u>

Soil surveys have been made and are still being made by different people in different places and by different methods. Naturally therefore, the existing soil surveys are bound to vary in quality. A good soil survey is one which is both practical in its purpose and scientific in its construction (Steele, 1967). Quality of a soil survey is the extent to which its final products ie. soil map and soil report meet the user's expectations.

As Beckett (1968) put it, a soil map is a good one if we can make both precise and accurate statements about the properties of the mapped soil units. The extent to which a soil map enables a user to make more precise statements about the soil conditions is referred to as the predictive ability of the map (Young, 1976). The statements will be precise only when the intra-unit variability is low. Soils vary considerably over the landscape but soil maps users want mapping units which are as homogeneous as possible.

Figure 2.5. The intricacy of mapped soil pattern in relation to map scale (Bie and Beckett, 1971)



Webster and Beckett (1968) expressed statistically maps users' expectations. They stipulated that there is a desire to have maximum reduction in the within-class variance compared with the variance within the classes of previous published maps or within the area unclassified if no previous map exists. They suggested the use of the intra-class correlation defined with reference to some property of interest. The intra-class correlation is conventionally expressed as follows :

$$\rho i = \sigma^2 A/\sigma^2 A + \sigma^2$$

where ρi is the intra-class correlation, σ^2 is the within-class variance and $\sigma^2 A$ is the between-class variance. From this expression it is clear that if each class (ie. mapping unit) were absolutely uniform, then σ^2 would be equal to zero and ρi has its maximum value of 1. This perfection in reality does not exist. On the other hand, if the difference between classes are not significant, then $\sigma^2 A$ and ρi are not significantly greater than 0 and this means that the map has not achieved anything. A good map is one with high value of ρi and its success would be greater for the property with the largest ρi.

It has been pointed out that neither ρi nor any other measure of the reduction in variance interest users as they are mainly concerned with predicting soil conditions from the maps. However, for the statistical assessment of utility, the user's interest would be related to the within-class variance (σ^2) which should be as small as possible as it measures the homogeneity of mapping units.

23. MAPS

23.1. Base maps for soil surveys

A base map in soil survey is any cartographic material on which soil information can be plotted (Soil Resource Inventory Study Group, 1978). A difference is made between the field base map (field sheet) and the actual base map to which soil boundaries are translated for publication. Field sheets are the working documents used during the field survey, and these could be maps or aerial photographs. For most purposes, vertical aerial photos are the best field sheets because they show all the topographic detail that is needed for navigation and location of boundaries. In this discussion only the actual base maps to which soil boudaries are translated for publication will be dealt with.

The base map should be sufficiently detailed to enable soil boundaries to be placed accurately in relation to streams, roads, buildings and any other relevant features (Dent and Young, 1981). A soil maps has little value if it is difficult to trace these boundaries owing to meagre base information. Therefore, in soil surveys it is very important to make a careful selection of base maps from the available cartographic material.

The quality of cartographic base material is not only important in determining the accuracy of plotted soil boundaries but it also affects soil identification and rate of progress during survey, the methods and costs of map construction and the quality of the published map.

There are different types of base maps used in soil surveys. This subject is well discussed in the US Soil Survey Manual (Soil Survey Staff, 1977) and also well documented by the Soil Resource Inventory Study Group (1978). The following are the most widely used base maps for soil survey :

Conventional aerial photos

Aerial photos are occasionally used for map publication of soil maps of small areas where one or two photos cover the whole area. The more common ones are black and white aerial photos. The disadvantages of aerial photos are related to distortions due to tilt, relief, and lack of contour lines.

Conventional aerial photos are also used as a base for other kinds of base maps. The most important examples include :

Aerial mosaics

These are produced by assembling individual aerial photos. Basically there are two types of mosaics, namely, controlled and uncontrolled mosaics. In controlled mosaics there is adjustment of points to ground, a feature which is lacking in uncontrolled mosaics. Controlled aerial mosaics have higher accuracy than conventional aerial photos and uncontrolled mosaics. However, they are more expensive.

Photobase maps

These are prepared from high altitude photographs. Fewer photographs are required to cover an area when compared to conventional aerial photographs.

Photomaps

These are aerial mosaics where marginal information and descriptive data have been added.

Orthophotomaps

These are also produced from conventional aerial photos, but displacements due to tilt and relief are controlled. They are very accurate and the most expensive base maps. However, the costs of production of the final maps may be less.

Topographic maps

The production of this type of base maps is also based on conventional aerial photographs, but they show both horizontal and vertical information. Unlike the photographic base maps discussed above, topographic maps are schematic in the sense that they use lines, symbols and colors to represent land areas and cultural features. Information about roads, streams and vegetation is usually shown on these maps. They are useful for measuring distances and directions and are usually well adapted for soil survey. Another principal advantage of topographic maps is that selected information can be more clearly plotted and extraneous or confusing information can be eliminated. However, the disadvantage is the lack of some ground information, such as isolated trees, fences, etc. which are recognized in aerial photographs.

Planimetric maps

These maps give the horizontal location of cultural features at a fixed scale. They don't provide vertical information, and are only satisfactory for some soil surveys. The lack of contour lines is the disadvantage of these maps for soil surveys.

23.2. Types of mapping

In term of field soil mapping, soil surveys may be classified as free surveys, grid surveys and physiographic surveys. occasionally, there are also surveys which invariably combine the three procedures of mapping. In free survey, soil observation sites are not regularly spaced but are chosen as representative of an area identified on the basis of landforms, vegetation, land use etc. as seen on the ground or on aerial photos. Moreover, additional sites are selected concurrently with survey as the soil pattern becomes clear. The term free survey was originally proposed by Steur (1961) and Buringh et al. (1962).

In grid survey the observation sites are regularly spaced on a pre-determined rectangular grid. According to Steur (1961), grid mapping is the simplest and also the most laborious procedure. The prodedure is meant to set out a series of parallel traverse lines and take soil observations at fixed intervals along them. It is more common at the intensive scales than in the less detailed surveys; and proves to be necessary in surveys of uncleared forests since one can only find out where he is by cutting trace lines through the undergrowth and measuring along these from a base line. Grid surveys are also deemed necessary in flat alluvial plains of dry regions which appear uniform on air photos while they have agriculturally significant variations in soil texture and salinity.

Most free surveys and many grid surveys are general-purpose in type, recording all observable soil features and mapping soil series or other soil type classes (Young, 1976). Free survey procedures tend to be used where there is some external expression of soil boundaries (or most of them), though not sufficiently consistent for mapping by air photo interpretation (Burrough et al., 1971). Grid surveys may alternatively be special-purpose in type, recording only those soil properties relevant to a previously determinded land use type.

In physiographic mapping, boundaries are drawn with little or no ground check, on the external properties of soil or landscape, as perceived on air photographs or by special sensors working on narrow wavebands in or out of the visible range (Beckett, 1968). In this procedure, field observations are intended not to locate boundaries but to identify the soils of the areas within the boundaries thus drawn. In so far as the precision of the mapped soil units is concerned, physiographic mapping may be equivalent to, or superior than free mapping at small map scale. However, as map scale increases, the precision of physiographic soil units is unlikely to increase beyond a certain point unless the sampling density is increased to such an extent that the procedure is not anymore cheaper than free survey.

23.3. Soil Maps

By definition a soil map is a cartographic generalization of field observations which attempts to condense a relatively large quantity of data into an easily usable form and to record the surveyor's own extrapolations from his field data to unrecorded sites (Beckett and Bie, 1978). A distinction is normally made between a primary map which is based on the field work planned to produce it, and a secondary map which is compiled from previous surveys, and/or from information originally collected for other purposes.

Users have two main requirements of soil maps :

a) To locate their area of interest (eg. farm, field etc.) and find out which soil unit or units occur; and then read their characteristics in the text. To fulfil this requirement, the maps must be at a scale which shows areas of interest at the desired level of detail and at the same time base information must be sufficient to locate precisely the mapping units on the ground.

b) To see overall distributions of soils; this is of major importance to land use planners. This is best achieved by good use of colors. A general-purpose soil map is considered as a pool of information from which many special interpretations can be made. An interpretive map on the other hand, is made for one specific purpose. Due to the relatively short life of interpretations, it is advisable that the basic soil map and its derived interpretive maps should be presented separately.

Information presented on soil maps is complementary to the one in the soil survey report (text). Moreover, the purpose of the map legend is to make the maps as self-contained as possible because often times maps are used without reference to the survey report. This is especially true when the maps are being used in the field. Soil maps provide the most convenient source of information on soil survey findings and to a large extent, the soil survey report serves to answer queries that cannot be explained on the maps themselves.

For further reading related to characteristics of soil maps and what is expected of them, the reader is referred to the works of Tyurin et al. (1965), Smyth (1970), Boulaine (1980) and Dent and Young (1981).

23.4. Accuracy and precision in soil mapping

According to the Mapping Systems Working Group (1981), the terms accuracy and precision do not mean the same thing. Accuracy in soil mapping refers to the closeness with which the information conveyed in the soil map, legend and report conforms to the actual or true soil conditions in the field. Accuracy is closely related to the density of field observations; and as the scale of a map increases, the number of field checks per unit area should also increase. The term reliability is synonymous to accuracy.

On the other hand, precision in soil mapping is the closeness with which individual pedons from one soil (or individual exposures and sites within a mapping unit) resemble one another. Precision is an expression of the range of characteristics of a soil or mapping unit and reflects the specific or the general nature of the soil map. Precision is also referred to as the **level of detail**.

Different formulae have been proposed (eg. Beckett, 1967; Webster and Beckett, 1968; Burrough, 1969; Beckett and Burrough, 1971; Legros, 1973 & 1978) for the estimation of precision of soil mapping as a measure of quality of soil survey. A soil mapping is considered good for a given property if the variations corresponding to this property and which arise from different profiles of the same unit are smaller when compared to variations of the same nature observed in the total number of profiles of the map. This is quantified by the following formula :

$$RV = \frac{\text{variance within the soil units}}{\text{total variance over mapped area}}$$

where RV is the relative variance which can vary form 0 (for mapping units which are prefectly homogeneous) to 1 (for totally unreliable soil maps. The quantity 1 - RV is then a measure of the quality of the soil map. Depending on the soil property under consideration, the scale and the density of observations, the authors found that values of 1 - RV lie between 0.20 and 0.95. The value given by 1 - RV is also called the **predictive accuracy** of the soil map (Dent and Young, 1981).

The cost of information increases with its precision and specificity, in soil science as anywhere else (Beckett, 1981). In a survey area, the precision of the mapped soil or land units increases with maps scale, probably up to a ceiling in the case of free and physiographic survey (Beckett, 1968). For general-purpose soil surveys based on series or similar units, a maximum value for 1 - RV is reached, beyond which there is little or no further improvement in predictive accuracy with increase in scale. Figure 2.6. gives a qualitative impression of the relationship between precision and publication scale for different types of soil survey.

Figure 2.6. Relationship between precision and map scale for different types of survey (Beckett, 1968)

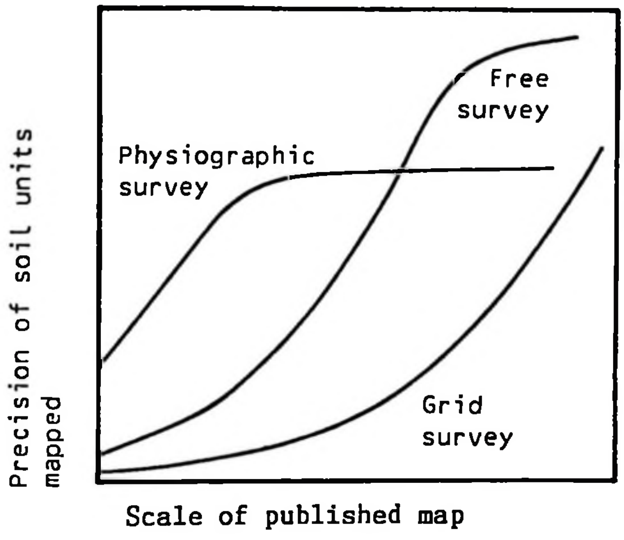
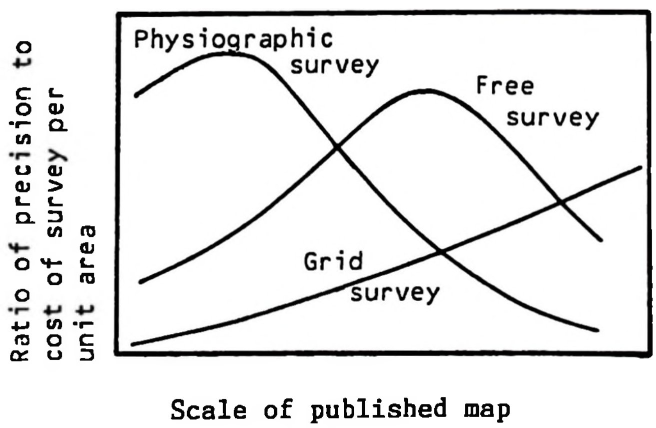


Figure 2.7. Relationship between ratio of precision to cost of survey/unit area and map scale for different types of survey (Beckett, 1968)



The ratio precision/cost of mapping per unit area mapped is referred to as the cost-effectiveness of the soil survey. In a survey area, the cost-effectiveness depends on maps scale and survey procedure. Figure 2.7. presents a plot of this ratio versus map scale.

Much as we can talk of the accuracy of soil maps, it is also worthwhile discussing the limitations of soil mapping and its techniques. Soil mapping is based on predictions which are verified by field mapping. The relationships existing between soils and landscape allow the soil surveyor to predict soil boundaries. However, not all soil boundaries can be predicted as the spatial pattern of distribution is a function of many factors interacting in different ways. The factors of soil formation eg. climate, parent material and relief, each posseses a characteristic spatial distribution (Dent and Young, 1981). Variability of soil properties over short distances within small or apparently uniform areas is of profound significance to soil survey, since it limits the attainable accuracy of soil maps. Sometimes incompleteness of soil taxonomy is a factor contributing to reduced accuracy of soil maps. Many times the techniques at the surveyor's disposal do not allow accurate mapping (Cline, 1977). Commonly, mapping techniques, time and money determine the amount of inclusions in mapping units.

24. LEGEND

24.1. Definition

According to Tyurin et al. (1965), the term legend signifies a list of the notation symbols used on the soil map, grouped according to a certain system. The information in a soil map and its report is contained in the definition of the mapping units which collectively form the mapping legend. A mapping unit is a collection of map delineations or land areas (represented by these delineations) which are designated by the same name. It represents real and mappable portions of the soil landscape that together have attributes varying within more or less narrow limits determined by the intensity of the survey and its objectives (Hopkins and Smith, 1982). A mapping unit contains predominantly one or more than one soil or nonsoil mapping individual, plus a certain proportion of unnamed and undescribed inclusions.

24.2. Kinds of mapping units

Different types of soil mapping units are used in soil surveys to accomodate different complexities of soil patterns on the landscape to best meet the purposes of the survey. The use of different kinds of mapping units allows a soil survey to better meet the needs of users requiring different degrees of detail.

The following are the different types of mapping units as described by the US National Soils Handbook (USDA-SCS, 1983) and other sources.

Consociations

These are mapping units in which about 75 % or more of the polypedons fit within the range of the taxon or the kind of miscellaneous area that provides the name for the mapping unit or fit in similar taxa or miscellaneous areas. The total amount of dissimilar inclusions generally does not exceed about 25 % and limiting inclusions should not exceed 15 % and moreover no one dissimilar soil may make up more than 10 % of the mapping unit. Consociations may be used in any soil survey regardless of scale or level of taxonomic or cartographic generalization.

Complexes

These are mapping units which consist of areas of two or more kinds of soils (taxa) or miscellaneous areas which are in a regularly repeating pattern so intricate that they cannot be delineated separately at the scale of mapping selected for the survey area. Individual areas of each soil are too small to be shown at mapping scales of about 1/24,000. Dissimilar inclusions should not be more than 25 % and limiting dissimilar soils should not exceed about 15 %.

Associations

These are mapping units which consist of areas of two or more kinds of soils (taxa) or miscellaneous areas. The major components are generally associated in a regularly repeating pattern and are individually large enough to be separated cartographically on soil survey maps. The kinds of soil used to name the association are usually dissimilar soils but may be similar. No single dissimilar inclusion is to constitute more than the least extensive of the major components, and the total amount of inclusions that are dissimilar to any of the major components should not exceed about 25 % for detailed surveys or about 35 % for small scale maps.

Phases

These are used to create groupings useful in predictions about use and management of soils. Phases can be used to subdivide taxonomic classes at any categorical level of the soil classification system. Characteristics of the soil or a combination of characteristics, such as texture, salinity and soil water, may be used as differentiating criteria for phases. When phases are used, critical information about the soil not implied in the taxa names is provided.

Undifferentiated groups

These are mapping units consisting of two or more taxonomic components which are treated as one because use and management are the same or very similar for common uses. The taxonomic components are often previously identified consociations or phases of consocations.

Variants

These are soils clearly outside the ranges of defined series,* too extensive to be correlated as mapping inclusions but not extensive enough to warrant a new series to be formed. They are potential new series. A mapping unit that is named for a variant of a series is distinguished by the term Variant immediately following the name of the most closely related established soil series.

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* soil series is defined in section 24.3.

Taxadjuncts

These are soils that have properties outside the range of recognized soil series. These properties differ from recognized soil series to such a small degree that the soils are identified as those series without qualification for naming mapping units. Taxadjuncts are outside the limits of any recognized series, but they are similar enough in morphology and behaviour to the soils of the series for which they are named and that little or nothing would be gained by establishing a new series.

Soil catena (not described in the US National Soils Handbook)

The original definition of a catena was "a regular repetition of a certain sequence of soil profiles in association with a certain topography (Milne, 1935)". He had noted that in areas where the topography consisted of a repetition of similar crests and hollows, the soil sequences down the slope were also repeated, and this succession is what he termed catena. Catena is a compound mapping unit as it contains more than one kind of soil.

Although the concept of catena could be applicable to soils of many climatic regions, it was originally designed for mapping soils in East Africa where soil catenas are well displayed. Based on the original definition, some workers (eg. Watson, 1965) pointed out the limitation of the concept if catenas would be restricted to topographic sequences developed on one parent material only. It has been argued that a restriction would greatly limit the applicability of catenas as mapping units apart from the fact that there are also great difficulties in determining the parent material in some cases (Young, 1976).

Catena has therefore been redefined by other workers to suit different systems of soil classification and mapping (Russell, 1961). The catena is said to be a valuable mapping unit in reconnaissance soil surveys because mapping of soil boundaries within a catena need not necessarily be carried out (Watson, 1965). However, care should be taken as it could be too broad to be used in certain conditions.

24.3. The role of soil classification

According to De Bakker (1970) soil classification serves two major purposes :

a. Theoretical or scientific purposes, which emphasize the origin of soils and their relationships, and

b. Purposes of practical importance, which are aimed at the application in agriculture or other technological uses of soils. For these kinds of purposes soil survey is an essential link to the practical application.

Basically, a soil classification system organizes knowledge about sets of soil properties and concepts. It identifies sets of properties and groups them into taxonomic classes. As oultined in the US National Soils Handbook (USDA-SCS, 1983), the national soil classification system is used to provide :

a. A means of remembering selected properties of soils, because the names of the higher categories of the system are connotative to those familiar with the nomenclature.

b. A means for understanding the relationships among soils within a given area and among soils in different areas.

c. A means of projecting experience with a kind of soil in one area to a similar kind of soil in another area.

d. Names that can be used as reference terms to identify soil mappping units.

Classification, at the same time as bringing order, seeks to establish relationships and in this way widens and deepens the knowlegde of the subject under study (Zonneveld, 1959).

Literature review indicates that one of the prime objectives of soil classification is to serve as a base for soil survey (Manil, 1956; Stobbe, 1962; Cline, 1963; Smith, 1963; Northcote, 1965; Kovda et al., 1967; Avery, 1973; Beinroth, 1978; Mapping Systems Working Group, 1981). Soil classification provides a vocabulary to describe the mapping units of the legend to a soil maps.

In general, the terminology contained in a soil classification system is used without further ado for map legends (Schelling, 1970). The national soil classification system of the US ie. Soil Taxonomy for example has special and unique characteristics particularly the classes of the lowest category that are sufficiently homogeneous to be regrouped to provide many interpretive groupings required for the purpose of soil surveys. In this classification sytem (Soil Survey Staff, 1975), the term soil series is used to denote (a) a taxonomic class; (b) a pedon that satisfies certain class criteria; (c) a polypedon that satisfies certain class criteria; (d) a certain delineated soil body of a soil map, consequently incorporating inclusions of unlike pedons, and (e) a certain unit of the mapping legend, a class of delineated soil bodies.

The soil series is the lowest category of the US Soil Taxonomy. By definition it is a group of soils that have profiles that are almost alike, except for differences in texture of the surface layer or the underlying material. All the soils of a soil series have horizons that are similar in compostion, thickness and arrangement. A subdivision of a soil series based on features that affect its use and management has been termed a phase. The common reference term used to name soil mapping units. Soil series are the most homogeneous classes of US Soil Taxonomy.

Mulcahy and Humphries (1967) differentiated two major kinds of soil classification. A special classification is one devised for a particular purpose, or for a limited number of purposes. Special classifications are based on a small number of characters, although this is not their essential feature. Such classifications have also been referred to as extrinsic, meaning that they are made with reference to some external criteria. On the other hand, general or intrinsic classifications attempt to order all available information about a population without reference to external criteria.

Soil surveys based on general soil classifications are the most useful in the case of under-developed areas where there is little agronomic experience, but information about the soils and environmental factors will determine the range of possible users. Special classifications are by definition limited in use to cases where objectives can be adequately defined. In many occasions, a choice between general and special classifications is not open; each has a distinct area of application, the recognition of which will lead to more efficient use of both.

24.4. Elaboration of soil mapping legend

Mapping units are established by examining the range of soils and/or nonsoils that represent a real segment of the soil landscape whose size and properties are relevant to the objectives of the survey (Mapping Systems Working Group, 1981). According to these authors, mapping unit separations should be made where the rate of change in soil properties is greatest (allowing the greatest predictability and precision of extrapolated lines). Moreover, these mapping units should also have the following properties :

a. Individual portions of them (delineations) should normally be repetitive.

b. The level of taxonomy should be chosen which best characterizes the aggregate of sites within the mapping unit.

c. Their individual delineations on the map should cover an area not smaller than 0.5 sq. cm (other workers eg. Forbes et al, 1982, consider the smallest readable map area to be 0.4 sq. cm).

d. They should represent as much as possible at the given scale, systematic and predictable changes of soil properties across the landscape, and ideally should reflect groupings of related properties.

e. They should have the smallest number of inclusions and unidentified features as much as possible.

f. Insofar as possible, at any given scale, the range of properties of the mapping unit should allow the entire unit to be treated the same for the kinds of management indicated by the purpose of the survey.

According to the structural composition of mapping units, there are five kinds of mapping legends. Langohr (1981) described at length the features used in the elaboration of mapping legends. The following text is mostly based on his work. The different types of mapping legends identified include, single soil property legend, multiple soil properties legend, soil kind/species legend, soil classification legend and nonsoil property legend. These legends differ mainly in their composition and the kind and the number of criteria used in their construction. The choice of one or the other of these legends or a combination of them, is a function of various factors including the scale of the survey.

Single soil property legend

This is based on only one soil feature/attribute eg. the pH of the upper 25 cm of the soil or the texture of the upper 20 cm of soil. Other characteristics of the legend :
(a) It needs very little reconnaissance survey, (b) It allows a quick drawing of the soil map, (c) It allows the use of nonspecialists, such as well trained labourers for the survey, (d) It has very low potential for future new interpretations and (e) It allows to draw a map which is very easy to read.

Multiple soil properties legend

This is based on several but mostly less than 12 independent soil properties. An example of this is the legend of the Belgian National Soil Map in which three letters (designating respectively texture of the upper 25 cm of soil, drainage and horizon sequence) form the basis of mapping units. Such kind of legend symbol is also called a formula. Other characteristics of the legend :
(a) It needs some reconnaissance survey in order to select the features and phases (subdivisions) that will be looked for, (b) It permits to make a relatively fast survey, (c) It needs an intermediate level of specialization for the surveyors; generally well trained labourers or technicians, (d) It has some potential for new interpretations linked to the number and kind of mapped features, (e) It permits to draw a map which is still very easy to read, (f) It may give problems in the editing of the report because it gives an impractically high number of units and excessive categorical detail, (g) It lacks hierarchy and avoids the problem of classification, and (h) It is not flexible and not open for further additions because of limited space for writing the symbol.

Soil kind/species legend

This is a comprehensive type of legend in which the soil is described in the same way as it is done for plant and animal species. Soil kinds are conceived as natural entities with rather narrow range in variation of properties and which can be used for a broad range of interpretations. The soil receives a name which is mostly the name of the village, river, or forest situated near the area where the particular soil kind was first described. By pronouncing the soil kind using any of the aforementioned reference names, automatically all the properties of the soil are included.

This kind of legend is commonly used throughout the world especially where survey organizations try to apply the survey techniques of the US Department of Agriculture. The USDA series is an example of a soil kind. Other characteristics of the soil kind legend : (a) It requires a relatively long lasting reconnaissance survey as all the soil kinds should be described, (b) It requires highly qualified surveyors (experienced soil scientists), (c) It requires much more time for survey when compared to other kinds of legend, (d) Maps based on the soil kind legend have the highest potential for future new interpretations, (e) It is more suited to detailed surveys (scales $\geq$ 1/25,000) as its use at scales smaller than this gives rise to either high amounts of inclusions or it may be necessary to use mostly complexes and associations as mapping units.

Soil classification legend

This type of legend is rather commonly used throughout the world. The mapping units are defined on the basis of a soil classification system (or soil taxonomy if several hierarchical level exist). The characteristics of this type of mapping legend will depend on three situations ie.

a. If the decision is to apply an existing soil classification system or

b. If the decision is to apply an existing soil classification system but with a necessity to check first if it has to be modified in function of the soils of the area to be mapped or

c. If the decision is to use a soil classification which is completely adapted to the soils of the area.

Taking the third situation as an example, the following are the most important characteristics of the soil classification legend : (a) It requires a lot of attention during the reconnaissance survey as the complete classification legend has to be built up during this period, (b) It takes relatively short time for the survey itself but the reconnaissance survey may last quite some time because of the need to construct the soil classification on the basis of the soils of the area, (c) It requires soil scientists with good experience in soil survey and classification, (d) It's potential for new interpretations will depend on the degree of detail (or level of hierarchy) of the soil classification. In many cases this potential is not higher than for a detailed multiple soil properties legend.

Nonsoil property legend

This kind of mapping legend is built up of nonsoil properties whose variations are thought to reflect differences at the level of the soils. Landscape units, vegetation types and land use types are examples of mapping units of such a legend. The Australian Land System of survey uses landscape units as mapping units. In this system a unit corresponds to an area, or groups of areas, throughout which is a recurring pattern of topography, soils and vegetation (Christian and Stewart, 1968).

The land systems method is mostly employed in reconnaissance surveys with mapping scales of 1/1,000,000 to 1/250,000. The method becomes less useful at larger scales, although the extent to which it might still be employed at semi-detailed and detailed scales has not systematically been investigated (Young, 1976). Its main advantage is the speed and cheapness with which large areas can be covered at the reconnaissance scale. This acrues from the economies of delineating boundaries by air photo interpretation and confining field survey to a form of stratified sampling of the areas so delineated. Moreover, some areas such as mountains can be eliminated from field survey entirely.

It should be remarked that the use by soil surveyors of nonsoil disciplines for delimiting soil mapping units must be done with much care as it is not uncommon that certain terms can be used completely in a wrong sense. The consultation and close collaboration with specialists of the respective disciplines is therefore highly recommended.

25. SOIL SURVEY REPORT

The soil survey report (memoir) acts in a supporting role supplying information that cannot be conveniently included on the soil map. It forms the descriptive and in many cases interpretive part of soil resource inventories. Recognizing the supporting role of the text and the need for easy cross-reference, a soil survey report should present both factual and interpretive descriptions of the soils in the same units which are used on the various maps.

According to Beckett and Bie (1978), the soil survey report accompanying a soil map serves four purposes :

i. It provides a general orientation on the physical and economic geography of its area.

ii. (a) It defines and discusses the soil classes in terms of which the mapping units are described; and (b) it describes the mapping units, with any necessary aids to help the user to distinguish and locate the components of compound units.

iii. It discusses and provides land capability ratings for the soil classes described and mapped.

iv. It provides a data store of miscellaneous information on the soils of its area, indexed according to soil class or mapping unit.

For more comprehensive documentation on the principles guiding the preparation of soil survey reports, the reader should consult the works of Smyth (1970) and Dent and Young (1981).

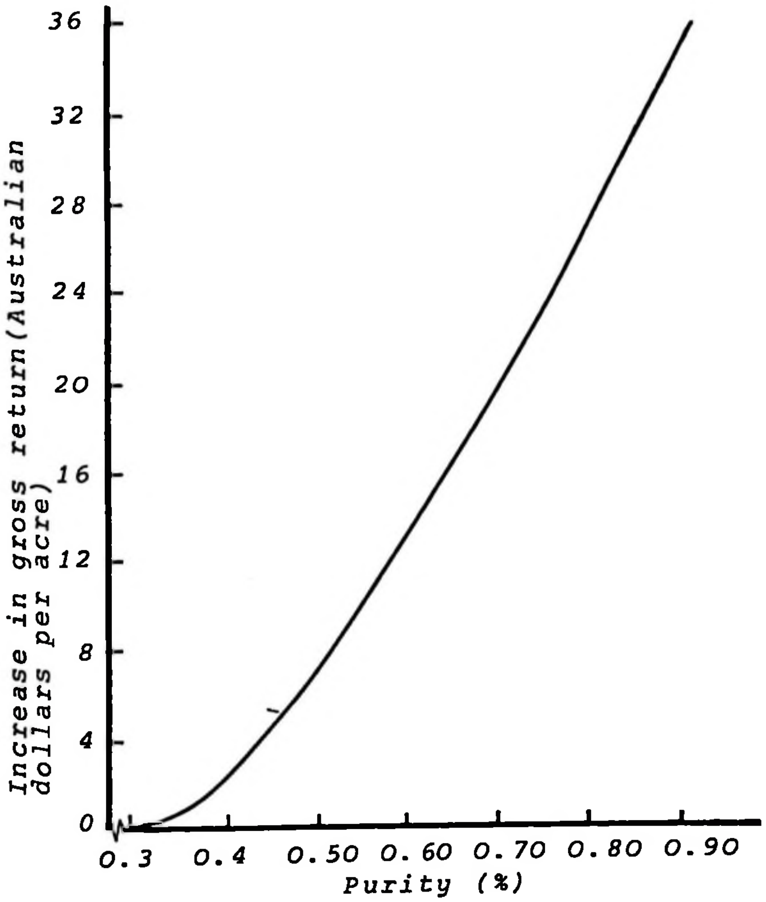
26. BENEFITS AND APPLICATION OF SOIL RESOURCE INVENTORIES

26.1. Economic benefits

One basis of calculating the economic benefit of a soil survey is to compare the profitability from different management systems on each of a number of mapping units (Dent and Young, 1981). A farmer (or any other user of land) achieves greatest net return by using each soil for the crop and management which gives maximum return (Bie et al., 1973). To achieve this, it requires both a soil map and the knowledge of the best management for each mapped unit.

A soil map indicates the boundaries between soils requiring different management for optimum returns. Bie et al. (1973) demonstrated that the benefits from a soil survey increase with the purity of the soil units mapped (cf. figure 2.8.). Naturally also, the cost of soil survey will increase sharply by increasing the purity (Beckett and Burrough, 1971) as in so doing, the detail and hence effort spent on the survey is increased. Purity of a mapping unit is defined as the proportion of the mapping unit area which is actually occupied by the soils named in the legend and/or report description.

Figure 2.8. Relationship between economic benefit and purity of mapping units (Bie et al., 1973)



Before commissioning a soil survey, it is necessary to decide in how much detail the surveyor should attempt to separate the soils. It is necessary to recognize the stage beyond which the costs of yet more detailed soil survey are unlikely to exceed the benefits to be expected from mapping units of greater purity. A method for calculating the potential economic benefit from a soil map of a given standard of accuracy has been proposed (Bie et al., 1973).

It is sometimes felt that the costs of soil survey are not justified by the returns (Young, 1976 and Dent and Young, 1981). This can be true when no use at all is made of the soil survey results, a circumstance which is not uncommon. As reported by Hills (1979), officials in some countries are known to regard soil surveys as just costly formality that must be gone through for the sake of securing financial assistance.

If the results are put into use, the value of soil surveys can be enormous. As explained by Dent and Young (1981), the absolute cost of soil surveys may seem high when taken out of context, but it is low in relation to total cost of farming, establishing a forestry plantation or a land development project and very low indeed in comparison with major engineering works such as dam. The authors report that in USA and Australia, studies have demonstated benefit-cost ratios of the order of 40 : 1 or 50 : 1.

26.2. Interpretations of soil resource inventories

Most soil surveys are carried out for practical agricultural purposes, and this is especially true for surveys related to large and intermediate scale maps (Aubert and Tavernier, 1972). Most users of soil maps are not usually interested in the soil map itself but rather in its applications. Since they are mostly not conversant with soil science, they find it difficult to interpret a soil map, owing to its complicated nature and the specialized terminology of its legend. According to Vink and van Zuilen (1974), both two problems are unavoidable in soil survey sensu stricto, where the soil as a natural product of the soil forming factors (climate, parent material, relief, vegetation, time and man), has to be mapped and described within its natural landscape. As a solution to these problems, most soil survey memoirs give a description of the agricultural and in some cases non-agricultural uses of the different soils, often also of their potential uses. To make interpretations even easier, it is necessary also to make easily understandable soil survey interpretation maps, that will provide the user with a sufficiently complete and overall picture. These maps should preferably be discussed in the memoir and added as appendices.

Soil survey interpretations are predictions of soil performance under stated conditions (Steele, 1967). The predictions begin with observations and measurements of performance of a few representative soils, but must always be extended in the form of estimates to cover other kinds of soil and other kinds and combinations of management. The more reliable and abundant the data, the more reliable are the predictions.

Interpretations are essential for adequate utilization of soil maps. Even if soil reports contain all the information most users of map will need, not all users are interested in the same things (Aubert and Tavernier, 1972); thus each person should be able to easily find the data which are necessary to solve specific problems. The authors stress also on other reasons for the need for interpretations : first, all crops do not have the same requirements for producing optimum yields; and second, the classification systems may be based on criteria which do not match specific crop requirements. While a certain soil property may be important for separating soils in a mapping legend, it may not necessarily have a major influence on the development of certain crops.

Interpretive maps are most efficient when they are produced at a scale compatible with the intended use. The larger the scale, the more detailed the classifications normally are, and the more precise the statements that can be made about the capability of the soils. This implies that large scale maps usually provide better interpretations for specific crop requirements and fertility assessment than small scale maps.

Overdal (1981) cautioned about the reliability of making interpretations. As he explains, there are two major aspects of reliability which have to be considered. One is related to the soundness of the soil map itself and the supporting documents. Geographically reliable interpretations are not possible if the map itself is inaccurate or lacks sufficient information. The second aspect concerns the knowledge of the use for which an interpretation is made. To evaluate a soil for the production of a given crop for example, the soil scientist needs to know what the soil requirements of this crop are, and what the farming system is under which this crop is to be grown. A close cooperation with agronomists, foresters, engineers, and others is necessary to set up sound criteria for interpretation of soil surveys.

Soil survey capability groupings

In capability classification, soils are placed in capability classes according to their potential to support certain types of land uses. Subclasses may be established on the basis of the limiting factors that are to be corrected in order to obtain maximum productivity. Several systems of capability classification have been developed and utilized (eg. Aubert and Fournier, 1954, Riquier, 1954, and Sys and Frankart, 1971 for Africa; Klingebiel and Montigomery, 1961 in Latin America and Steele et al., 1954 in the Caribbeans). Where irrigation projects are concerned, the most widely used system of assessment is that of the U.S. Bureau of Reclamation (1953) which classifies land in terms of its suitability for irrigation.

As a rule, in capability classification the interpretations of soil data are made based on general land use objectives, such as cropland, grassland and forests. In most cases, only one management level is considered.

Soil suitability classification

According to Vink and van Zuilen (1974), soil suitability is the degree to which a soil according to its properties meets the requirements for a particular type of land use. In detailed soil surveys, the suitability of soils for certain agricultural crops, grasses, or forest species may be deduced from experiments that are conducted on key soils, or by rating soil properties with regard to specific crop requirements. The suitability is determined for well defined crops or rotations such as industrial crops, food crops, cereals, legumes, forest species, horticultural crops, oil palm, rubber, coffee and cocoa.

Most suitability groupings for specific crops are based on soil characteristics and plant requirements and may emphasize factors such as drainage, permeability and acidity. Good examples of suitability classifications have been documented by Vink and van Zuilen (1974), Sys (1980) and Kraanen (1982).

According to Vink and van Zuilen (1974), the principal factors determining soil suitability include, yield of crops, the consistency of yields under the climatic variations occuring from one year to another, the quality of the product, the cost of production and the soil pattern.

General applications of soil survey information

The actual and potential users of soil survey include farmers, agricultural advisory staff, research workers, foresters, planning agencies, development organizations, engineers and private investors. There are numerous applications of soil survey information; the following are among the most common ones :

a. Agricultural development

Soil maps and their interpretations are frequently used in agricultural extension work and education. Since arable farming is the kind of land use to which soil survey is most frequently directed, it might be expected that the main users would be farmers. Yet, in practice this is not the case. Many farmers make little or no use of soil surveys either because they already know their soils very well or they are not capable of using such documents.

Generally, the principal users of soil surveys in many countries are staff of the agricultural extension who offer advisory service to farmers. In the Netherlands, some good examples of application of soil inventories for agricultural extention and farm management, soil improvement etc. have been documented (Van Dam, 1973 and Haans, 1978). In Britain they have what is called ADAS (Agricultural Development and Advisory Service) which offers advisory service to farmers (Dent and Young, 1981).

b. Forestry applications

In most countries, forestry is a major use of rural land. It has many analogies with the needs of arable farming, as tree species also vary in their soil preferences like crops. Hence soil maps and their interpretations are used as a basis for forestry management. In some countries efforts are being made to increase forested area using forest suitability maps already established (Van Goor, 1971).

c. Rural development and reconstruction

The changing pattern of agriculture in some countries (the trend towards larger holdings, reduction in labour, greater dependence on machinery etc.) has necessitated the reconstruction of agrarian districts where the existing structure hinders efficient farming (Haans, 1978). This land consolidation involves the re-allotment of parcels, modernization of water management, the construction of new roads all of which requiring soil information. Soil survey information is intensively used in such projects.

d. Research applications

Soil surveys serve as a base for research not only in the field of agriculture, but also in non-agricultural disciplines. In agriculture, this applies to the two most common forms of applied research i.e. fertilizer response and crop variety trials to establish their relationships with different soils. Likewise in forestry, relationships between different tree species can also be established using information from soil surveys. In archaelogy, soil surveys have proved very useful as information on artefacts and settlement traces is also plotted on soil maps (Dekker and De Weerd, 1973).

e. Land use planning and urban development

The construction of residential areas and industrial sites, construction of roads and highways calls for big changes in land use. Soil maps are frequently used as data base for these plans. The unprecedented growth of urban communities expanding to new areas has resulted in requests for soil information concerning this kind of land use (Lindsay et al., 1973).

Although the use of soil surveys by engineers is relatively new, it is rapidly expanding. Their objectives include road alignment and foundations, building foundations and disposal of sewage and other wastes. Beatty and Bouma (1973) have documented about the use of soil surveys for the selection of sites for disposal of liquid household wastes. There is now enormous evidence to demonstrate that engineering parameters (eg. shear and compressive strength, plasticity, shrink-swell characteristics, corrosivity to steel and concrete) are significantly related to soil types (Dent and Young, 1981). Soil surveys therefore provide basis for stratified sampling of the landscape, so greatly reducing the quantity and cost of engineering tests. The use of soil surveys in foundation engineering has been well documented by Aitchison (1973); and their application in highway engineering is reported by Allemeier (1973).

Soil maps are also used for ecological planning. Examples in the Netherlands have been reported by Haans (1978), whereby landscape/ecology survey for physical planning at national level was based on a soil map.

Soil survey information is also crucial in the laying of pipelines. In this regard, the experience in the Netherlands (Haans, 1978) shows that use of soil surveys helps a lot in avoiding weak and wet soils; and more importantly, better decisions can be made regarding the timing of the work, machinery to be used etc.

Chapter 3

DATA BASE

31. SOIL MAPS AND REPORTS

The study required a big collection of soil maps and reports from all over the world.

1. The International Soil Museum (now called the International Soil Reference and Information Centre - ISRIC) in Wageningen, the Netherlands, provided a compiled list of addresses of different soil survey institutions world-wide.

2. The United States Department of Agriculture (USDA) provided a list of published soil surveys of the United States containing addresses of the different state conservationists.

3. The Department of Scientific and Industrial Research (DSIR) of the New Zealand Soil Bureau supplied a publication list of soil surveys of New Zealand.

4. Centre National de Recherches Agronomiques (CNRA) of France supplied a list of published soil surveys of France, which included also addresses of the regional centres of soil information.

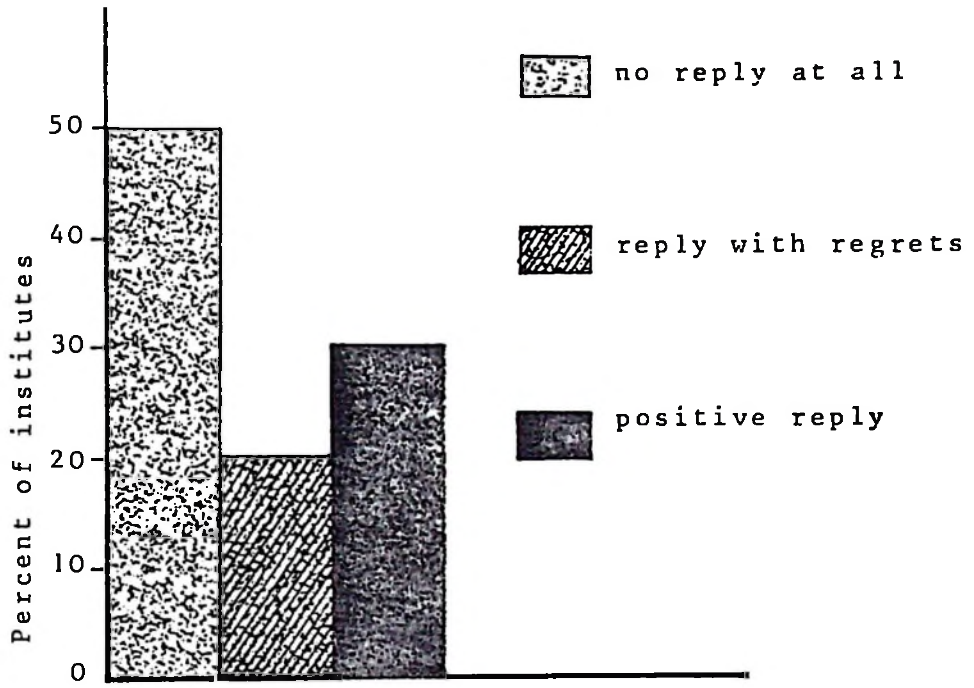
5. Office de la Recherche Scientifique et Technique Outre-Mer (ORSTROM) of France provided a list of their publications of soil surveys of various francophone countries of Africa.

6. The Netherlands Soil Survey Institute (STIBOKA) supplied a list of published soil surveys of the Netherlands.

7. The Land Resources Development Centre (LRDC) of Britain provided a publication List of land resource surveys of various developing countries.

Requests were made in writing to 44 soil survey institutions for both general and detailed soil maps and their reports . The results were not very encouraging (cf. figure 3.1.). Twenty-two institutions (50 %) did not reply to the request despite the fact that it was clearly indicated in the letter of request that our department was prepared to pay for the documents. Nine instituions (20 %) replied expressing regrets that they could not supply the documents because of unavailability. Only 13 institutions (30 %) replied expressing the possibility of supplying the documents. In total only 52 documents were guaranteed. As these were considered too few for the whole study, alternative sources were sought. Physical and personal contacts with different institutions, libraries and indiviuals in several countries proved fruitful in securing more documents. finally 176 documents from 46 countries were collected for the study. Table 3.1. shows their distribution over the various countries while table 3.2. gives the publication scales of the documents. Appendix 1 is a list of the documents.

Figure 3.1. Frequency distribution of responses to request of soil maps and reports



32. QUESTIONNAIRES TO SOIL SURVEYORS AND TO USERS OF SOIL MAPS AND REPORTS

Two questionnaires were designed aimed at getting some crucial information regarding soil surveys and their products. For further consultation the reader is referred to appendices 9 and 10. In both two questionnaires, frequency classes of answering were suggested as a guideline to the possible respondents. These qualitative classes correspond roughly to quantitative definitions as follows :

A = always = 100 % of the cases
B = frequently = more than 50 % of the cases
C = commonly = less than 20 of the cases
N = never = 0 % of the cases

33. GENERAL INVENTORY OF THE DOCUMENTS

For each SRI a general description was made which included also information on cartographic attributes, legend and soil report attributes and base map attributes. The guideline to this excercise is attached as appendix 2.

Table 3.1. Sources of the soil resource inventories used in the study

Source	No. of SRIs	% of SRIs	
AFRICA			29.55
Burundi	5	2.84	
Cameroon	7	3.98	
Ghana	4	2.27	
Ivory Coast	1	0.57	
Kenya	8	4.55	
Morocco	1	0.57	
Nigeria	5	2.84	
Senegal	1	0.57	
Sierra Leone	1	0.57	
Swaziland	2	1.14	
Tanzania	10	5.68	
Zaire	2	1.14	
Zambia	5	2.84	
ASIA			7.39
Indonesia	1	0.57	
Malaysia	3	1.70	
Papua New Guinea	2	1.14	
Sri Lanka	1	0.57	
South Korea	1	0.57	
Thailand	5	2.84	
AUSTRALIA	2		1.14
CARIBBEAN ISLANDS			4.55
Barbados	1	0.57	
Cayman Islands	1	0.57	
Dominica	1	0.57	
Jamaica	3	1.70	
Montserrat	1	0.57	
Trinidad	1	0.57	
EUROPE			19.32
Belgium	4	2.27	
Britain	6	3.41	
France	13	7.39	
Ireland	1	0.57	
Italy	3	1.70	
Malta	1	0.57	
Netherlands	2	1.14	
San Marino	1	0.57	
Turkey	2	1.14	
West Germany	1	0.57	
FAR EAST			1.14
Iraq	1	0.57	
Syria	1	0.57	
NEW ZEALAND	16		9.09
NORTH AMERICA			18.75
Canada	5	2.84	
USA	28	15.91	
SOUTH AND CENTRAL AMERICA			9.09
Argentina	1	0.57	
Colombia	1	0.57	
Mexico	1	0.57	
Peru	12	6.82	
Surinam	1	0.57	
	176 SRIs		100%

NB. No. of countries = 46

Table 3.2. Publication scales of the studied soil resource inventories *

Map scale	Number of SRIs and (%)	Map scale	Number of SRIs and (%)
1/2,000	2 (1.14)	1/30,000	1 (0.57)
1/2,400	1 (0.57)	1/31,680	2 (1.14)
1/2,500	1 (0.57)	1/32,000	4 (2.27)
1/5,000	6 (3.41)	1/40,000	3 (1.70)
1/8,000	1 (0.57)	1/50,000	25 (14.20)
1/9,000	1 (0.57)	1/62,500	1 (0.57)
1/10,000	8 (4.55)	1/63,360	4 (2.27)
1/12,500	2 (1.14)	1/100,000	27 (15.34)
1/13,500	1 (0.57)	1/125,000	2 (1.14)
1/15,000	4 (2.27)	1/126,720	3 (1.70)
1/15,840	17 (9.66)	1/200,000	5 (2.84)
1/20,000	16 (9.09)	1/250,000	5 (2.84)
1/22,000	1 (0.57)	1/500,000	2 (1.14)
1/24,000	6 (3.41)	1/506,880	1 (0.57)
1/25,000	20 (11.36)	1/1,000,000	4 (2.27)

* based on 176 documents

Chapter 4

REVISION AND TESTING OF CONCEPTS AND DEFINITIONS OF SRI ATTRIBUTES

As outlined in the introductory chapter, the adequacy of soil resource inventories for given land uses is a function of their (a) cartographic attributes, (b) legend and soil report attributes, (c) base map quality and (d) ground truth. In the current chapter, concepts and definitions related to these attributes will be introduced with the intention of establishing indices of characterizing SRIs and at a later stage establishing ways to estimate the adequacy of these documents for given land use objectives.

The definitions and concepts that will be given in this chapter are mostly derived and/or based on the 1977-78 Cornell Workshop on Soil Resource Inventories (SRIs) and Development Planning (SRI Study Group, 1978 and Forbes et al., 1982) and on my ideas and modifications (Msanya, 1984) which are introduced for reasons of practicality, rationality and simplicity.

41. CARTOGRAPHIC ATTRIBUTES

41.1. Concepts and definitions

1. Cartographic attributes of a SRI are the attributes of the SRI map itself, and which determine its overall legibility. A map is a representational and conceptual model in a framework provided by the human being's struggle to communicate to others something of the nature of the real world (Board, 1967). Maps are primarily instruments for arranging, storing, transmitting and analysing information about the spatial distribution of attributes (Varnes, 1974).

Legibility (Le) of a map is the ease with which the map user can read the information recorded on it. The cartographic attributes are important in so far as they affect the legibility of the map. A legible map presents information in a direct, clear and perhaps pleasing or artistic manner (Eswaran et al., 1981). A SRI map must legibly present the smallest land area of interest to the SRI user. The factors determining the overall legibility of a SRI will be discussed in section 45. The term land here is meant the entire complex of surface and near surface attributes of the solid portions of the surface of the earth, which are significant to man; water bodies occuring within land masses being included (SCSA, 1982).

Scale of a map

2. Map scale is the ratio of distances on the map to corresponding distances on the land. The scale is qualitatively described by the size of the sheet that would be needed to represent a given land area. Table 4.1. relates map scales to land distances and areas.

The scale of a map can be expressed in two ways, either in figures or in words, for example 1/100,000 and "one centimetre to a kilometre" are merely alternative means of expressing the same thing. It is best to have the scale of a SRI map expressed in both ways. Scale written in words may provide a

Table 4.1. The relationship between map scales and land measurements represented on maps.

Map scale	Land distance in metres represented by 1 cm on map	Map area in cm^2 representing 1 ha on land
1/2,500	25	16
1/5,000	50	4
1/10,000	100	1
1/15,840 (4 inches to 1 mile)	158.4	0.3986
1/20,000	200	0.25
1/25,000	250	0.16
1/31,680 (2 inches to 1 mile)	316.8	0.0996
1/50,000	500	0.04
1/63,360 (1 inch to 1 mile)	633.6	0.0249
1/100,000	1,000	0.01
1/126,720 (0.5 inch to 1 mile)	1,267.2	0.0062
1/150,000	1,500	0.0044
1/200,000	2,000	0.0025

useful yardstick with which to judge the implications of scale at times when a fraction conveys little information. For example, the scale 1/253,440 appears complicated but when expressed as "1/4 inch to 1 mile", puts the average map user much more clearly into the picture.

3. Though the fraction is more indicative of the meaning of scale, the scale in figures is commonly encountered written as ratio; for example 1/10,000 would be written as 1:10,000. It is worthwhile to note that the latter is merely a more convenient way of writing the former. Whether written as a fraction or a ratio, this means of expressing the scale is called the representative fraction (RpFr) of the map. The scale of the published SRI is normally called publication scale (PSc).

4. When calculations involving scale have to be made, confusion may arise especially from the scale written as a ratio and for this reason another term, the scale factor (ScFa) is hereby defined. The scale factor is the number which must be used in all calculations concerning scale, and can be defined as either the denominator of the scale written as a fraction or the second part of the scale written as a ratio (Dickinson, 1969); for example for maps of scales 1/40,000 and 1:75,000 the scale factors are 40,000 and 75,000 respectively.

The adequacy of a map scale depends on the degree of accuracy required by the map user to locate himself on the map, keeping legibility at reasonable levels. As it was indicated in chapter 2, the scale is very much related to the accuracy of the map.

Minimum legible delineation (Forbes et al., 1982)

5. A delineation (De) is the undivided portion of a map sheet inside a continuous boundary line. It is different from a mapping unit (§24.1.) because it represents a real portion of the soil landscape. A map delineation has location while a mapping unit does not have. A mapping unit is an amalgamation of all the properties of its map delineations.

6. Minimum legible delineation area (MiLeDeAr) is the smallest legible map area. It is the smallest delineation that should appear on the map. MiLeDeAr is independent of map scale, and is conventionally defined to be roughly a circular area of 0.4 cm2. Smaller delineations are considered illegible for two reasons : (1) There is not enough room inside such delineations to legibly write the mapping unit symbol, and (2) the proportion of the delineations covered by the bounding lines becomes significant. In the Mapping System for Canada (Mapping Systems Working Group, 1981), MiLeDeAr is considered as 0.5 cm2.

Minimum legible land area (Forbes et al., 1982 modified)

7. The minimum legible land area (MiLeLaAr) is the smallest land area that can be represented legibly on a map at a given scale, and is therefore the land area represented by the minimum legible delineation area. In units of hectares, the MiLeLaAr is given by the following formula considering that the MiLeDeAr is a circular area of 0.4 cm2 :

$$\text{MiLeLaAr}_{(ha)} = (1/\text{RpFr})^2 \;/\; (2.5 \times 10^8)$$

where RpFr is the representative fraction (§ 41.1.3) of the map. MiLeLaAr should be less than or equal to the smallest area of interest for a given land use. MiLeLaAr values for maps of different scales are given in table 4.2.

Delineation areal density (Msanya, 1984)

8. The number of outlined areas (delineations) per unit area in sq. cm. of a map is what is referred here as the delineation areal density (DeArDn). It is an expression of the sizes of the delineations on a map; and the greater the number of delineations the smaller is their sizes and the lesser the map legibility. I proposed to call this parameter areal density to distinguish it from linear density defined below.

Delineation linear density (Msanya, 1984)

9. Delineation linear density (DeLnDn) is the number of delineation intersects per cm traverse on a map. It can be converted into delineation boundary intersects per km traverse on the land which defines the number of delineation boundaries one is expected to cross by traversing 1 km straight line on the land. Delineation linear density is an expression of mapping intensity and like delineation areal density, it has a relationship with map legibility. The greater the DeLnDn, the lesser the legibility.

Table 4.2. Minimum legible land areas for some map scales.

Map scale	*MiLeLaAr in hectares*
1/2,000	*0.02*
1/2,500	*0.025*
1/5,000	*0.1*
1/8,000	*0.26*
1/10,000	*0.4*
1/15,000	*0.9*
1/15,840	*1.0*
1/20,000	*1.6*
1/24,000	*2.3*
1/25,000	*2.5*
1/30,000	*3.6*
1/31,680	*4.01*
1/40,000	*6.4*
1/50,000	*10*
1/62,500	*15.63*
1/63,360	*16.06*
1/100,000	*40*
1/200,000	*160*
1/250,000	*250*
1/500,000	*1,000*
1/1,000,000	*4,000*

Average delineation area, map texture and average land area (Forbes et al., 1982 modified; Msanya, 1984).

10. The average delineation area (AvDeAr) of a portion of a map with uniform map texture is the arithmetic mean of the sizes of the delineations in that portion of the map. By map texture here it is meant the pattern and sizes of delineations which determine the legibility of the map. Average delineation area is given by the formula :

$$\underset{\text{(sq. cm.)}}{\text{AvDeAr}} = 1/\text{DeArDn}$$

where DeArDn is the delineation areal density (§41.1.8). AvDeAr is measured in sq. cm of map but can also be converted into units of land area.

Average land area (AvLaAr) is given by the formula :

$$AvLaAr_{(ha)} = AvDeAr \times (1/RpFr)^2 \times 10^{-8}$$

where RpFr is the representative fraction of the map (§41.1.3). For maps with more than one map texture, determination of AvDeAr will involve the delineation density of the portion of the maps with most dense texture since it is the one most limiting to legibility.

Smallest delineation area (SRI Study Group, 1978 draft modified)

11. The smallest delineation area (SmDeAr) is the smallest area actually delineated on a particular map: On many maps it is very common for the SmDeAr to be smaller than the minimum legible delineation area. When on a map there are many delineations which are smaller than the MiLeDeAr, legibility may be seriously impaired. The occurence of very small delineations on a soil map may be an indication of the detail attempted by the soil surveyor to be shown, or of soil variability, or may be incidental observations. Hence there is no consistent interpretation of SmDeAr from one survey to another.

The SmDeAr can be expressed in sq. cm of map surface and can also be converted into land units of area. Figure 4.1. shows the smallest delineation areas of two SRI maps of different scales.

Mapping intensity (MaIt) and delineation legibility quotient (SRI Study Group, 1978 draft modified; Msanya, 1984)

12. Some parts of soil survey areas may be mapped more intensively than others. Such a survey is called multi-intensity survey (cf. figure 4.2.a.). The other type of survey is the one in which on average the whole survey area receives the same mapping intensity (implying mono-delineation density) and thus referred to as mono-intensity (cf. figure 4.2.b.). The incidence of multi-delineation density on a map does not always indicate different mapping intensities on the survey area. It may simply be an indication of the natural distribution of the soils.

In multi-intensity maps the delineation densities in the different intensity areas may be described separately. However, for reasons of map legibility the delineation density of the most intensively mapped area is the most critical especially when this area forms a big proportion of the whole mapped area; and thus should be given more consideration.

13. Since the minimum legible delineation area has been conventionally set at a size of 0.4 sq. cm, the maximum number of delineations per sq. cm of map (delineation areal density) = 1/0.4 = 2.5. By definition delineation legibility quotient (DeLeQ) is the ratio of the number of delineations on a map per sq. cm to 2.5.

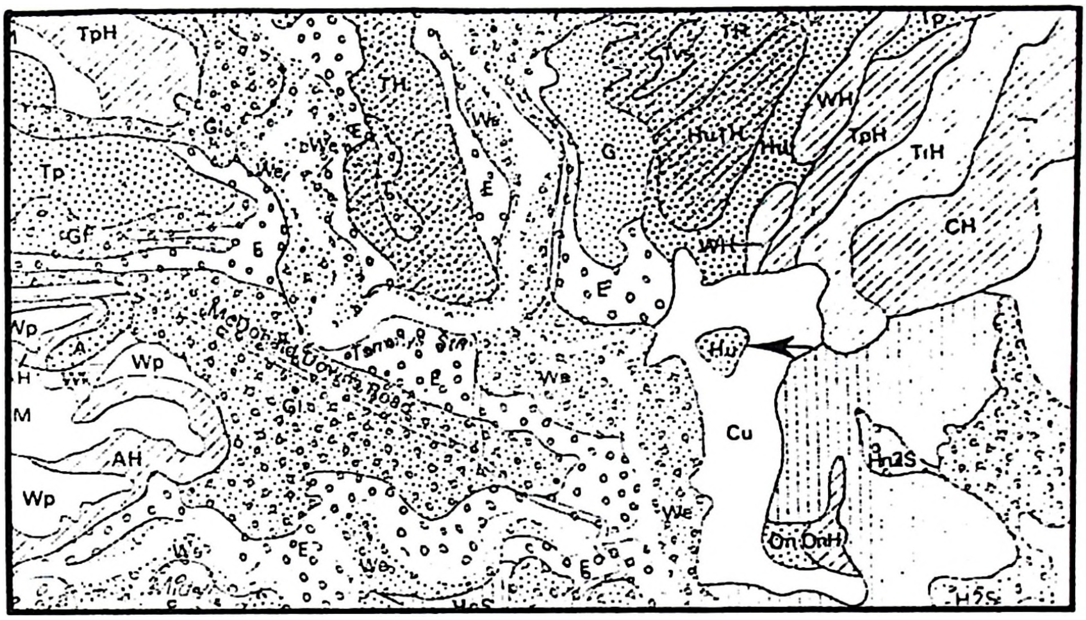
$$DeLeQ = DeArDn/2.5 \times 100$$

where DeArDn = delineation areal density; and since DeArDn = 1/AvDeAr and 2.5 = 1/MiLeDeAr, then

$$DeLeQ = MiLeDeAr/AvDeAr \times 100.$$

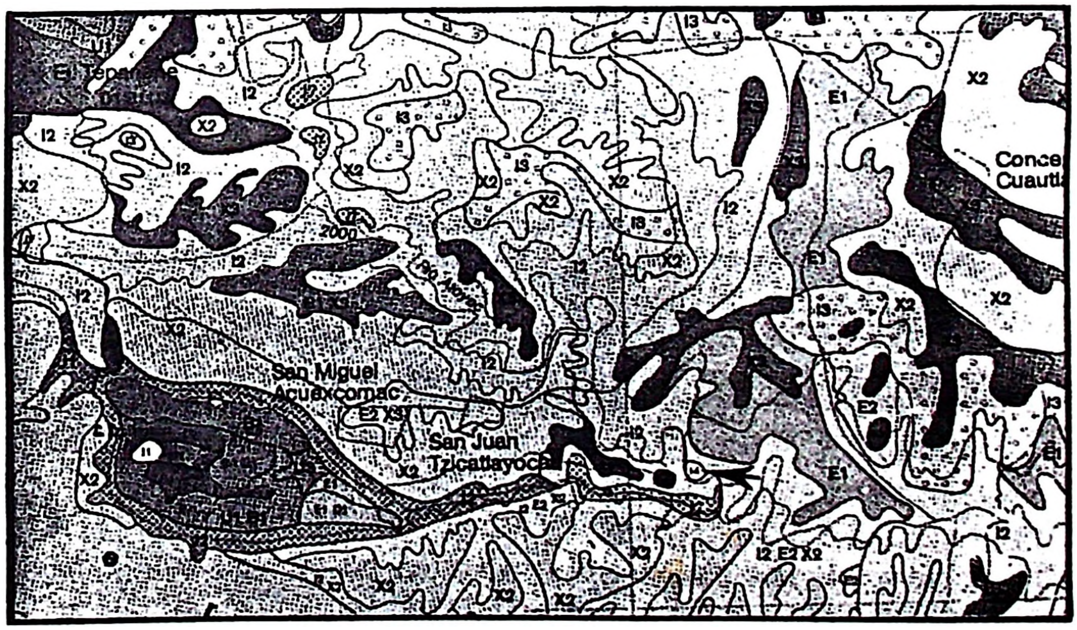
Figure 4.1. Parts of maps showing the smallest delineation area (SmDeAr) for large-scale map (A) and small-scale map (B).

A



Scale 1/31,680 Extracted from Griffiths (1978)

B



Scale 1/100,000 Extracted from Werner (1978)

NB. Arrow points at SmDeAr

Figure 4.2. Parts of soil maps showing different types of mapping intensity.

a. Multi-intensity

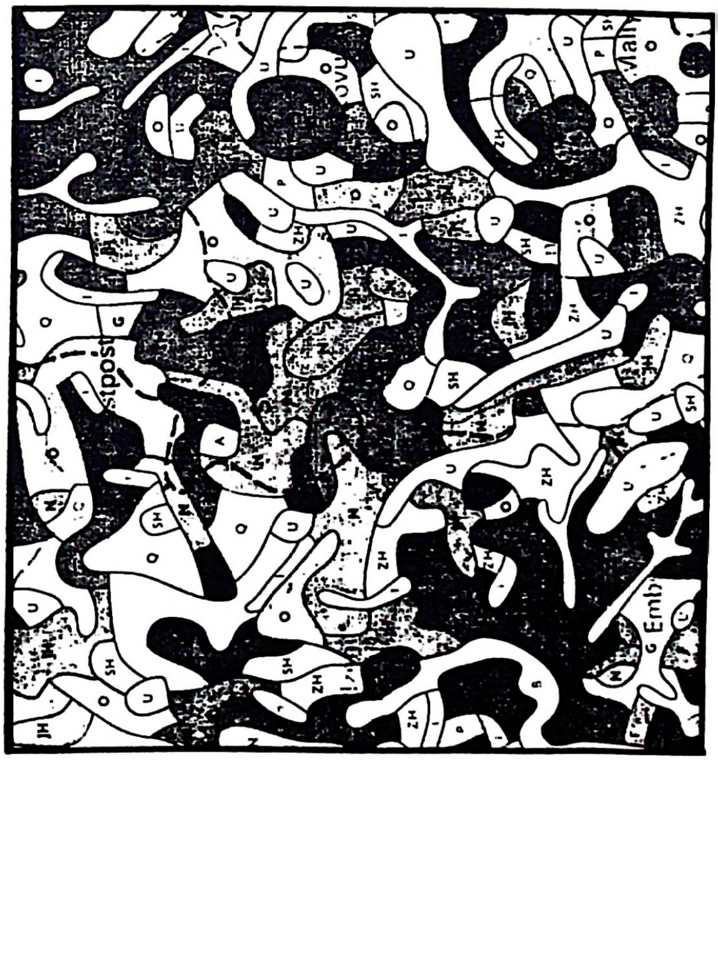
B

A

Extracted from FAO (1971)

NB. The dotted line AB separates two regions, one on the left with high density of delineations and the other on the right with relatively lower density of delineations.

b. Mono-intensity



Extracted from Murdoch (1968)

Delineation legibility quotient is a measure of the complexity or simplicity of a map; thus for comparison purposes it is normally expressed in percentage by multiplying the above ratio with 100. In the mapping system for Canada (Mapping Systems Working Group, 1981), delineation legibility quotient has been called map delineation density.

Average legible reduction factor (Forbes et al.,1982 modified)

14. The average legible reduction factor (AvLeRdFa) of a SRI map is defined as the factor by which the scale of that map can be reduced before the average delineation area becomes equal to the minimum legible delineation area. It is given by the formula :

$$AvLeRdFa = \sqrt{AvDeAr/MiLeDeAr} = \sqrt{(1/MiLeDeAr) \times AvDeAr} = \sqrt{2.5 \times AvDeAr}$$

An AvLeRdFa of 2.0 is considered optimal for legibility (Forbes et al., 1982). As its value decreases, the map texture becomes finer and the legibility decreases. When the AvLeRdFa is 2.0, the corresponding average delineation area is 1.6 sq. cm which is four times the size of the minimum legible delineation area. This delineation size of 1.6 sq. cm is referred to as the optimal legible delineation area (OLeDeAr) of the map.

Average legible scale (SRI Study Group, 1978 draft modified)

15. The average legible scale (AvLeSc) is the smallest scale to which a map can be reduced before the average delineation area becomes smaller than the minimum legible delineation area. It is given by the formula :

$$AvLeSc = RpFr \times (1/AvLeRdFa) \text{ or } = 1 / (ScFa \times AvLeRdFa$$

where RpFr and ScFa are respectively the representative fraction and scale factor of the map, and AvLeRdFa is the average legible reduction factor (§ 41.1.14).

Average legibility index (Msanya, 1984)

16. I have defined the average legibility index (AvLeId) as the difference between the scale factor (§41.1.4) of the average legible scale (§41.1.15) and that of the publication scale (§41.1.3) of a map. For comparison purposes this difference is expressed as a percentage of the scale factor of the AvLeSc. Hence it is given as follows :

$$AvLeId = \frac{ScFa_{(AvLeSc)} - ScFa_{(PSc)}}{ScFa_{(AvLeSc)}} \times 100$$

It was envisaged that AvLeId could be used to discriminate between easily readable maps and those which cannot easily be read. The greater the value the higher the legibility. Average legibility index is part of the overall legibility which does not only depend on map textural elements but also on locational aspects of soil maps. An AvLeId value of 50 is the minimum requirement for legibility (Msanya, 1984). SRI maps with AvLeId of less than 50 were observed to be difficult to read because their delineations are too small.

Maximum location accuracy (MaxLoAc)

17. The scale of a map affects the accuracy with which points on the ground can be represented. Davis et al., (1981) stipulated that a well defined ground point can be plotted to an accuracy of at best 0.25 mm on a map sheet; meaning that there is an inherent uncertainty in the ground position of the point, equal to this 0.25 mm scaled up to the ground distance. Therefore the maximum location accuracy can be given as follows :

$$MaxLoAc_{(\text{in metres})} = ScFa_{(PSc)} \times 0.25 \times 10^{-3} \quad \text{where } ScFa_{(PSc)}$$

is the scale factor of the publication scale of the map. For adequacy, the MaxLoAc should be less or equal to the accuracy with which ground points must be located. Table 4.3. presents the maximum location accuracy at different map scales.

Color pattern (SRI Study Group, 1978)

18. In colored soil maps, the choice of colors or patterns to represent delineations is critical. Colors which are too dark may obliterate substantially ground control or important non-soil features which are essential in locating soil areas. Colors or color patterns should be used in a manner that enhances legibility. Not too many different colors may be used. Maps with more than about 16 colors will probably be confusing or illegible (Forbes et al., 1982).

Complexity of map delineations

19. Cox (1927) developed a measure of roundness, whereby roundness was defined as the sphericity of a three-dimensional body or the circularity of a two-dimensional figure. Here it will be referred to as the delineation boundary roundness (DeBoRo). This index is an expression of the complexity of a figure and is equal to $4\pi A/p2$, where A is the area of the plane figure and p its perimeter. More recently, Piech (1980) employed the reciprocal of this index to measure the complexity of a population of map delineations. This was termed complexity index and in this study delineation boundary complexity (DeBoCo). It is given by the folllowing formula :

$$DeBoCo = 1/(4\pi A/p^2) = p^2/4\pi A$$

For a perfectly circular delineation, the complexity index has a value of 1.0, whereas for any other figure, the value exceeds 1.0. The higher the value the greater the complexity of the delineation. Complexity of map delineations is normally not a problem on its own. However, when coupled with very small delineation sizes it may limit accuracy. Very small irregularly shaped delineations tend to detract from legibility.

Table 4.3. Maximum location accuracy at various scales encountered in the study.

Map scale	*MaxLoAc in meters*
1/2,000	0.5
1/2,400	0.6
1/2,500	0.625
1/5,000	1.25
1/8,000	2.0
1/9,000	2.25
1/10,000	2.5
1/12,500	3.125
1/15,000	3.75
1/15,840	3.96
1/20,000	5.0
1/22,000	5.5
1/24,000	6.0
1/25,000	6.25
1/30,000	7.5
1/31,680	7.92
1/32,000	8.0
1/40,000	10.0
1/50,000	12.5
1/62,500	15.625
1/63,360	15.84
1/100,000	25.0
1/200,000	50.0
1/250,000	62.5
1/500,000	125.0
1/1,000,000	250.0

41.2. <u>Methods of estimating cartographic attributes</u>

The procedures employed in this exercise are mostly derived from Forbes et al. (1982). Some modifications and additions were made for the sake of practicality. The original approximation was applied on 59 SRIs the results of which are presented in another paper (Msanya, 1984). The current exercise has utilized a maximum of 176 SRIs except for smallest size delineation and complexity indices.

<u>Delineation areal density and average delineation area</u>

1. Transparent overlay with circles of radii 2.5 and 3.5 cm and a square with 20 cm on a side, was used. DeArDn (§41.1.8) and AvDeAr (§41.1.10) were estimated for portions of a map with a given map texture by randomly sampling the map area with the' circles or the square whose areas are known (cf.figure 4.3.) and converting the count of delineations in several of these

areas by empirical formulae, to areal density and the size of an average delineation. Starting with the small circle, the overlay, in the case of multi-intensity pp maps, was placed on the map on the portion with the finest map texture (critical for legibility), otherwise the whole map area is used during sampling. The number of delineations or portions of delineations that are within the circle are then counted. If a delineation came into the circle more than once, each of the occurrences is counted separately. This procedure is repeated for a total of five circle counts. The five counts are added and if the sum is less than 30 the sample size is considered too small, and the procedure is repeated using the circle of 3.5 cm radius. If the sum is still less than 30, the procedure is repeated with the 20x20 - cm square, but in this case taking only one count.

To obtain the delineation areal density from the sample counts, one of the following formulae is used depending on the overlay used when sampling :

a) 2.5 - cm radius circle : (sum of 5 counts)/142 - 0.1
b) 3.5 - cm radius circle : (sum of 5 counts)/192 - 0.1
c) 20x20 cm square : (1 count)/400

The average delineation area is calculated as the reciprocal of the delineation areal density.

2. <u>Delineation linear density</u>

For the determination of delineation linear density (DeLnDn) I proposed the following method : the 10 cm long line drawn on the transparent overlay (cf. figure 4.3.) was used. The overlay is placed 10 x at random on the portion of soil map with the finest map texture (in the case of multi-intensity maps) and the number of intersections of soil boundaries with this line are counted. The average score is obtained by dividing the sum by 10. To obtain the number of soil boundary intersections per map cm (DeLnDn) this figure is again divided by 10.

<u>Smallest delineation areas and their perimeters</u>

3. The smallest delineation areas (§41.1.11) were identified for each of 155 SRI maps which were already available at the time of analysis (cf. appendix 3). The areas and perimeters of these delineations were measured using a computer model HP-85 of Hewlett-Packard Co. with basic language.

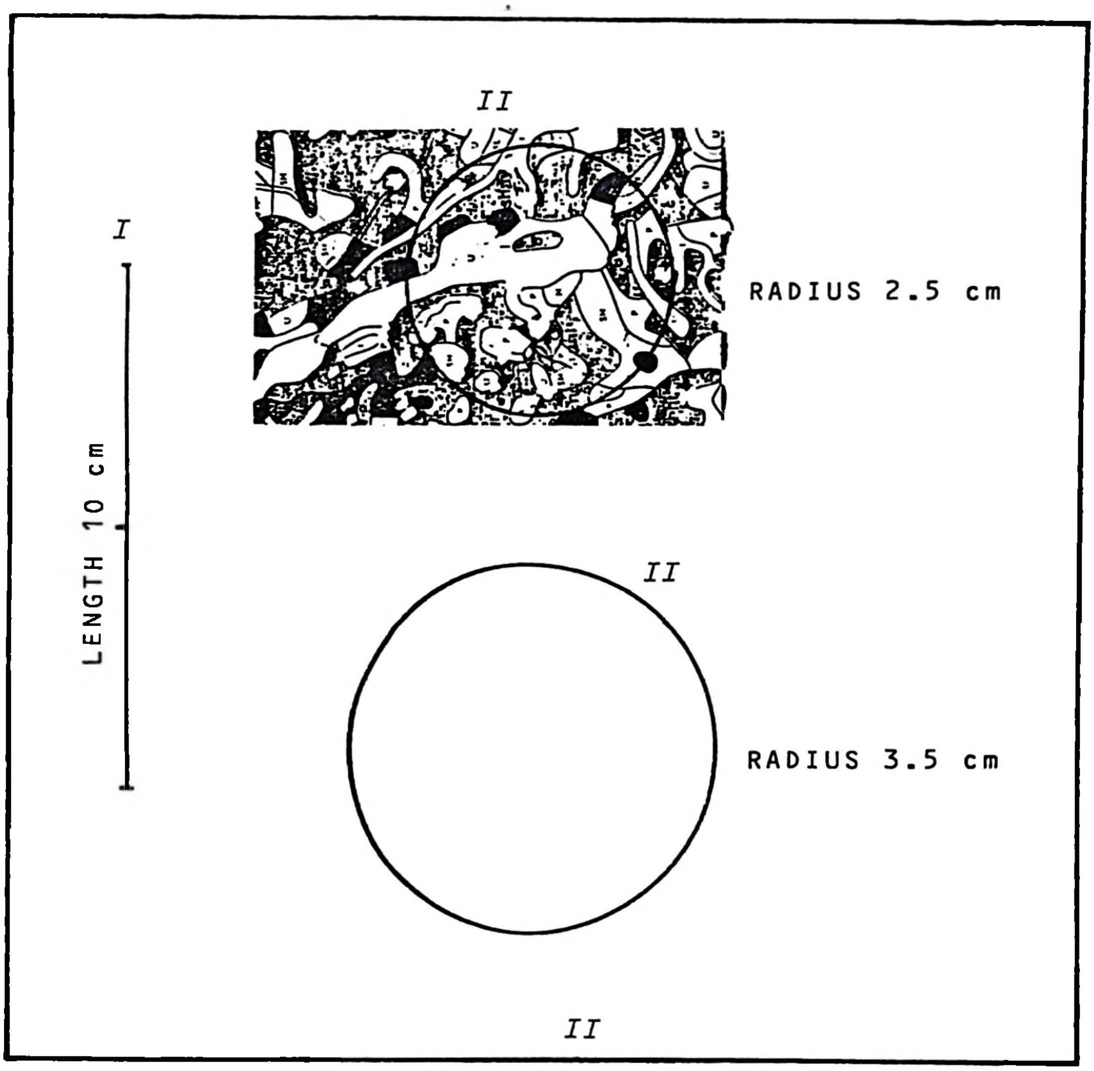
<u>Complexity indices of map delineations</u>

4. The data on the smallest delineation areas were used to compute the complexity indices of such delineations using the formula given in §41.1.19.

5. The type of <u>mapping intensity</u> (MaIt) was determined visually by examining the pattern and sizes of delineations on the maps.

6. The data on <u>minimum legible delineation area</u>, <u>average landarea</u>, <u>delineation legibility quotient</u>, <u>average legible reduction factor</u>, <u>average legible scale</u>, <u>average legibility index</u>, and <u>maximum location accuracy</u> were calculated using the formulae given in the preceeding text (§41.1).

Figure 4.3. I : Line for estimating delineation linear density;
II : Circular and square test areas for estimating delineation areal density and average delineation area.



20 cm x 20 cm

NB. Dimensions reduced
to 70 percent

41.3. <u>Results and discussion</u>

Before we can use the attributes defined and described above to characterize SRIs and to evaluate their adequacy it is felt necessary to test their consistency within SRIs of the same scale. Test on their coefficients of variation and correlation among these attributes have been made.

Similarity/variability of cartographic attributes

1. Table 4.4. shows the % correlation coefficients of some cartographic attributes at different map scales. Except for smallest delineation area (SmDeAr), the other attributes have quite similar coefficients within different SRI maps of the same scale as shown by relatively low values of CV (the highest being 35.1). This means that whereas delineation areal density (DeArDn), delineation linear density (DeLnDn), delineation legibility quotient (DeLeQ), average legible reduction factor (AvLeRdFa) and average legibility index (AvLeId) are very much consistently related to map scale, the smallest delineation area (SmDeAr) is not.

   It was interesting to note that the newly introduced parameters ie. DeLnDn and AvLeId are quite similar within SRI maps of the same scale. This implies that they are consistent enough to be used in the characterization of soil resource inventories.

Table 4.4. Similarity/variability of some cartographic attributes.

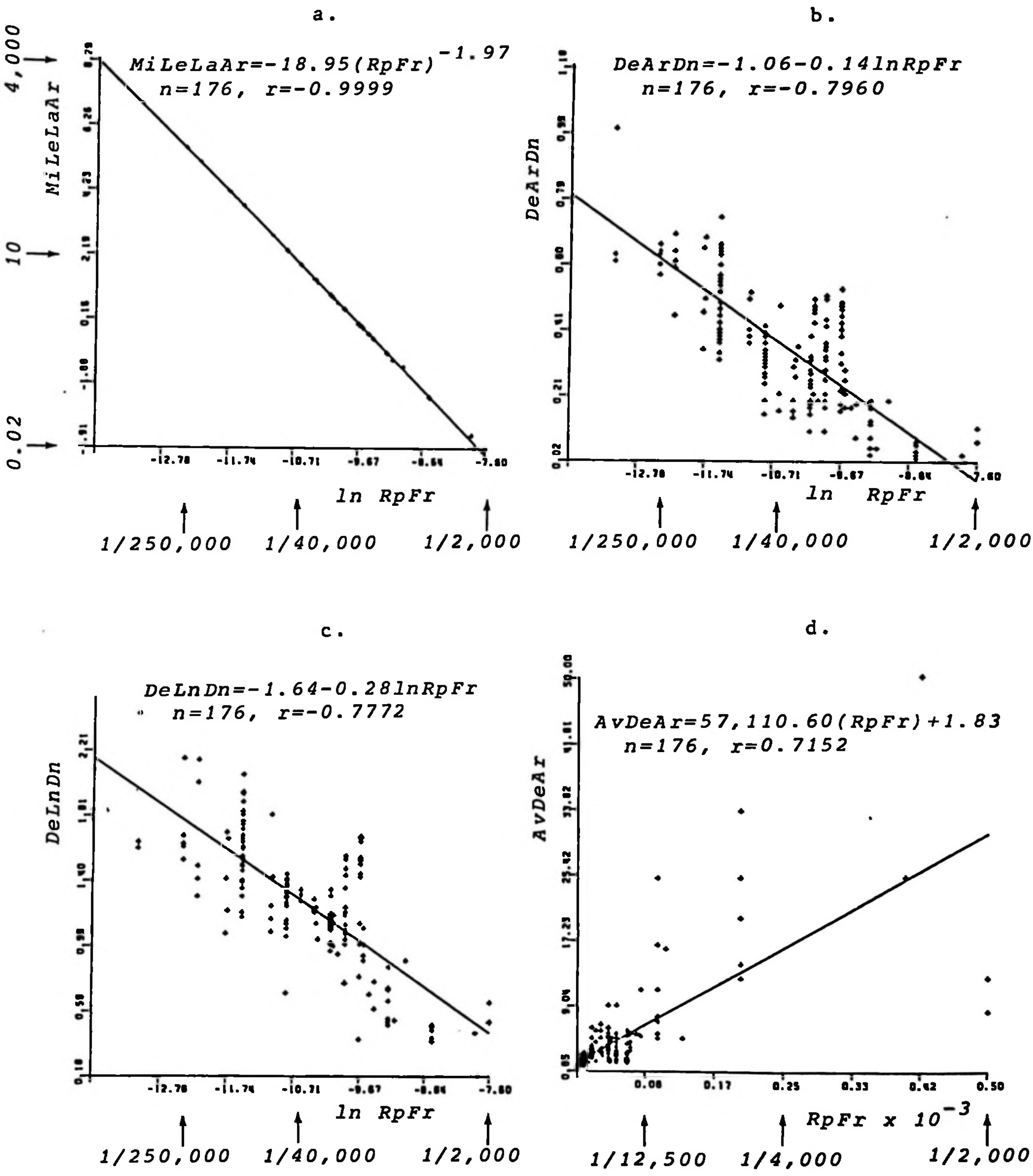
Map scale	*Percent coefficient of variation (CV)*					
	DeArDn	*DeLnDn*	*SmDeAr*	*DeLeQ*	*AvLeRdFa*	*AvLeId*
1/15,840	*27.7 (17)*	*25.9 (17)*	*182.6 (17)*	*27.6 (17)*	*19.1 (17)*	*10.1 (17)*
1/20,000	*35.1 (16)*	*20.9 (16)*	*83.1 (15)*	*35.0 (16)*	*22.5 (16)*	*10.3 (16)*
1/25,000	*30.8 (20)*	*7.8 (20)*	*59.1 (15)*	*31.2 (20)*	*15.3 (20)*	*6.5 (20)*
1/50,000	*19.2 (25)*	*12.5 (25)*	*49.7 (18)*	*19.2 (25)*	*12.0 (25)*	*5.8 (25)*
1/100,000	*22.1 (27)*	*14.5 (27)*	*65.0 (23)*	*21.8 (27)*	*11.7 (27)*	*9.2 (27)*

NB. ( ) the number of SRIs

Correlation among cartographic attributes

2. The measured cartographic attributes were correlated using a computer model Regent 200 of Applied Digital Data Systems Inc. (ADDS) using Fortran language. The relationships and the regression equations are presented in figure 4.4. It can be said that the attributes under consideration are highly correlated as shown by the high values of regression coefficients (reference being made to the r values given in appendix 4). This further confirms the suitablility of these attributes for characterizing soil resource inventories.

Figure 4.4. Inter-relationships among cartographic attributes.



NB. ln=natural
logarithm

Figure 4.4. cont.

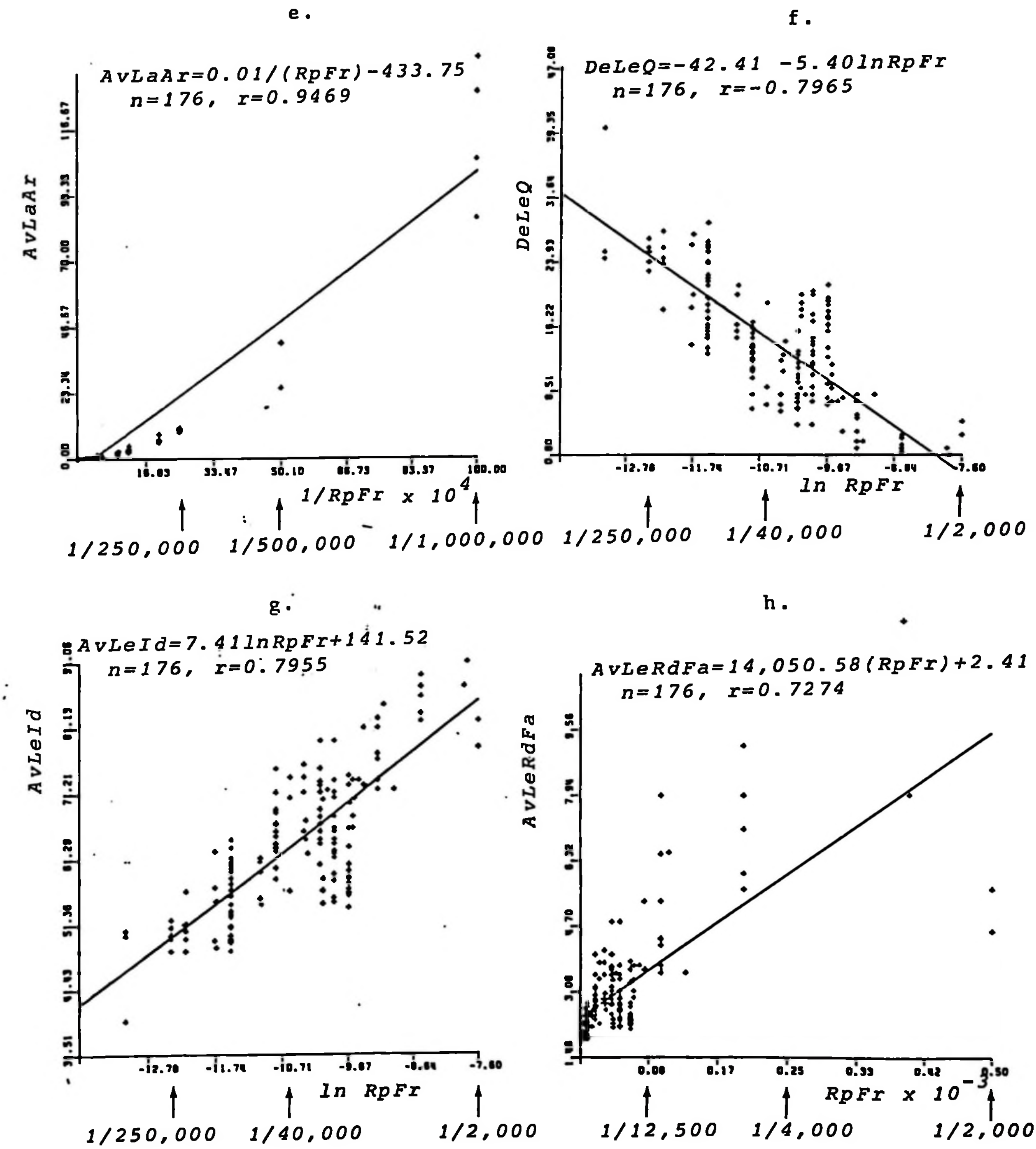


Figure 4.4. cont.

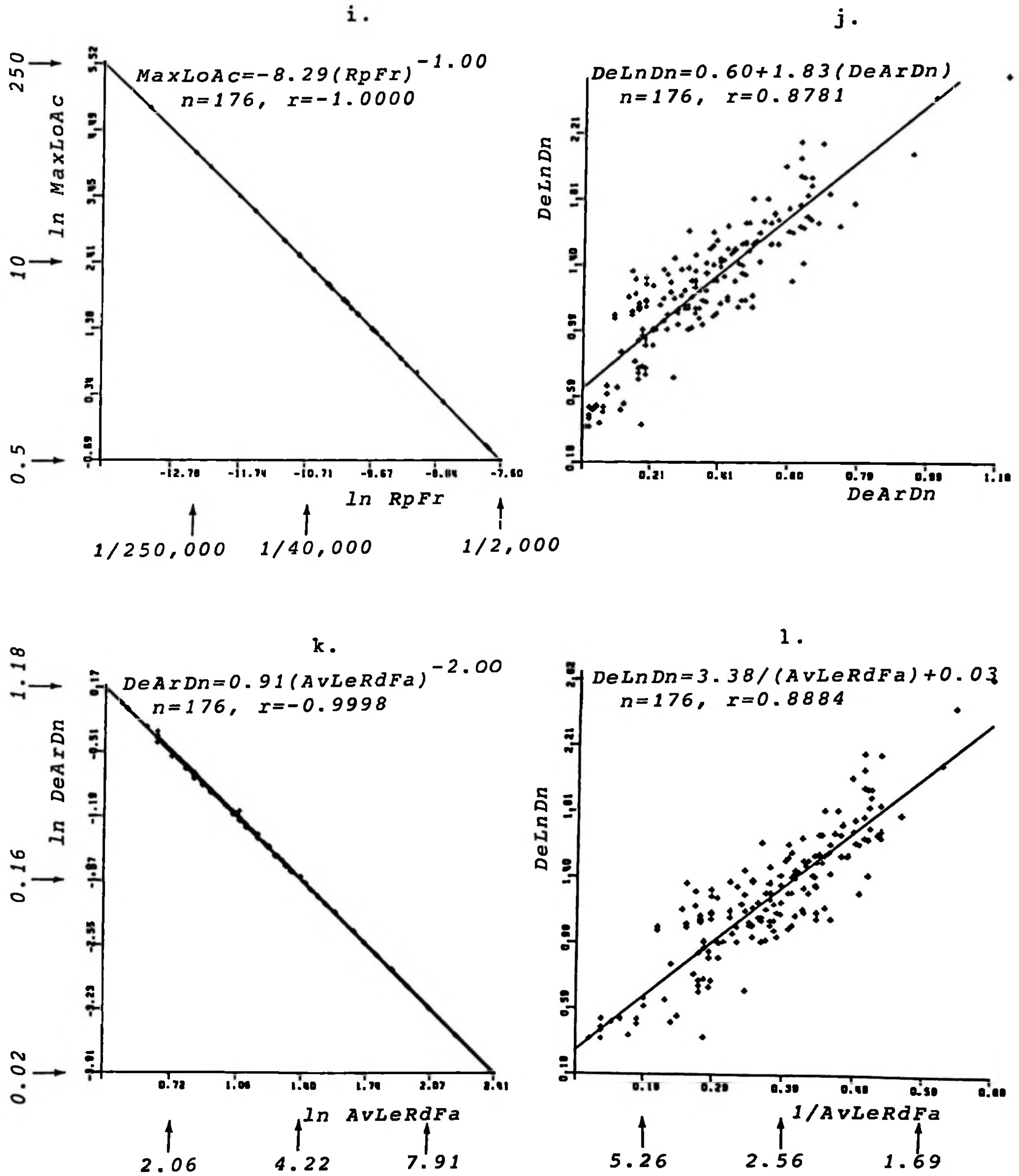


Figure 4.4. cont.

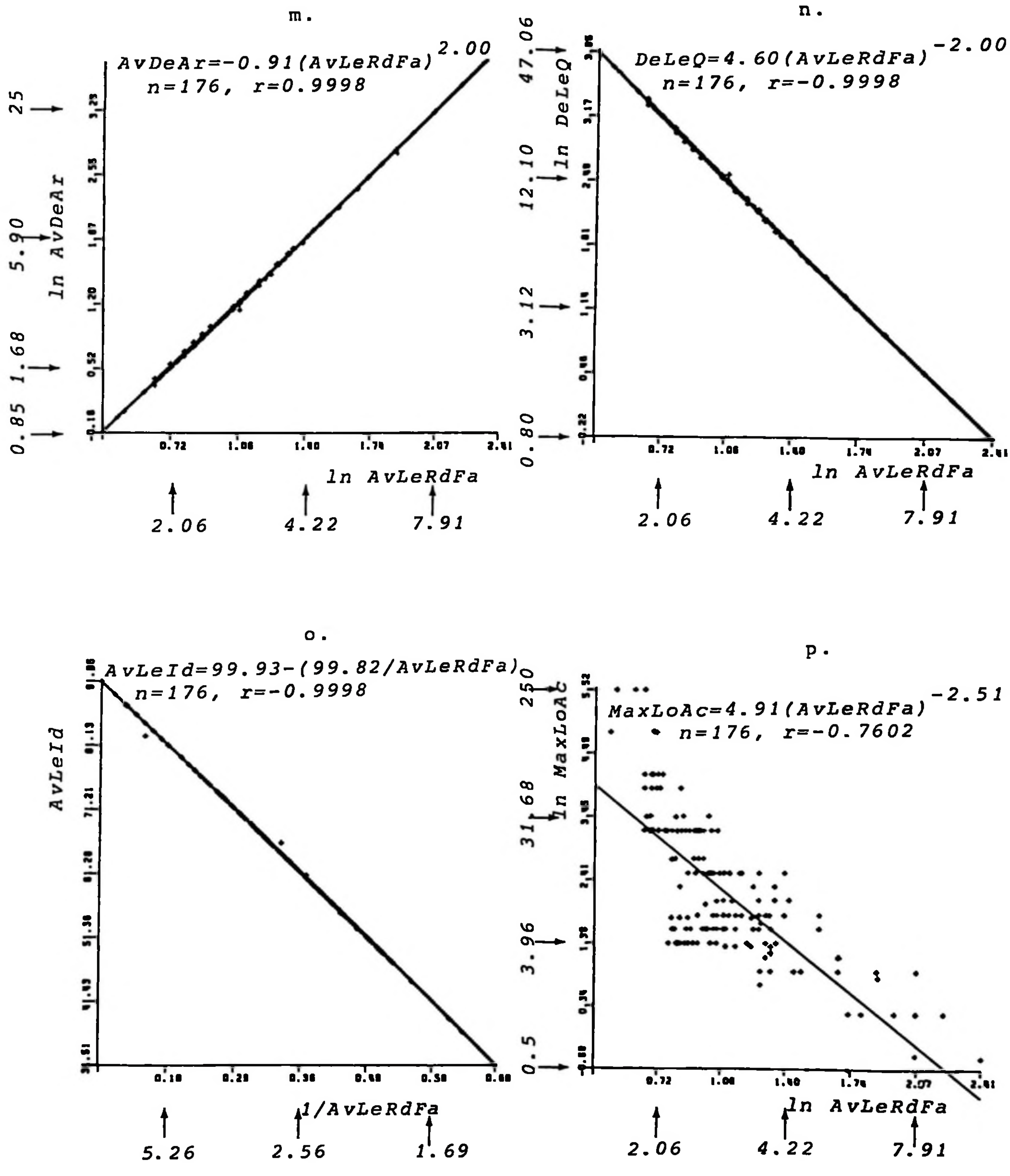


Figure 4.4. cont.

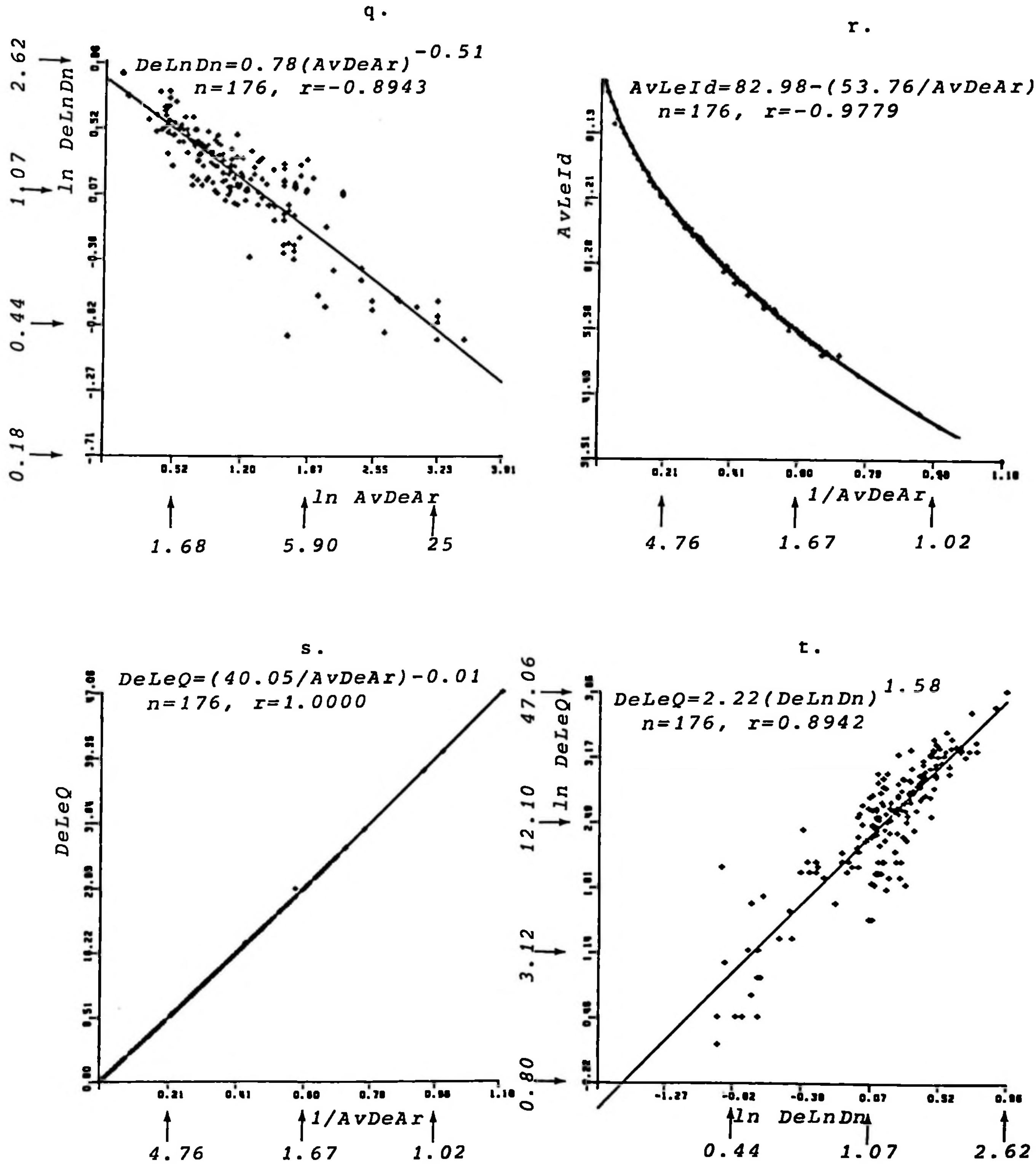


Figure 4.4. cont.

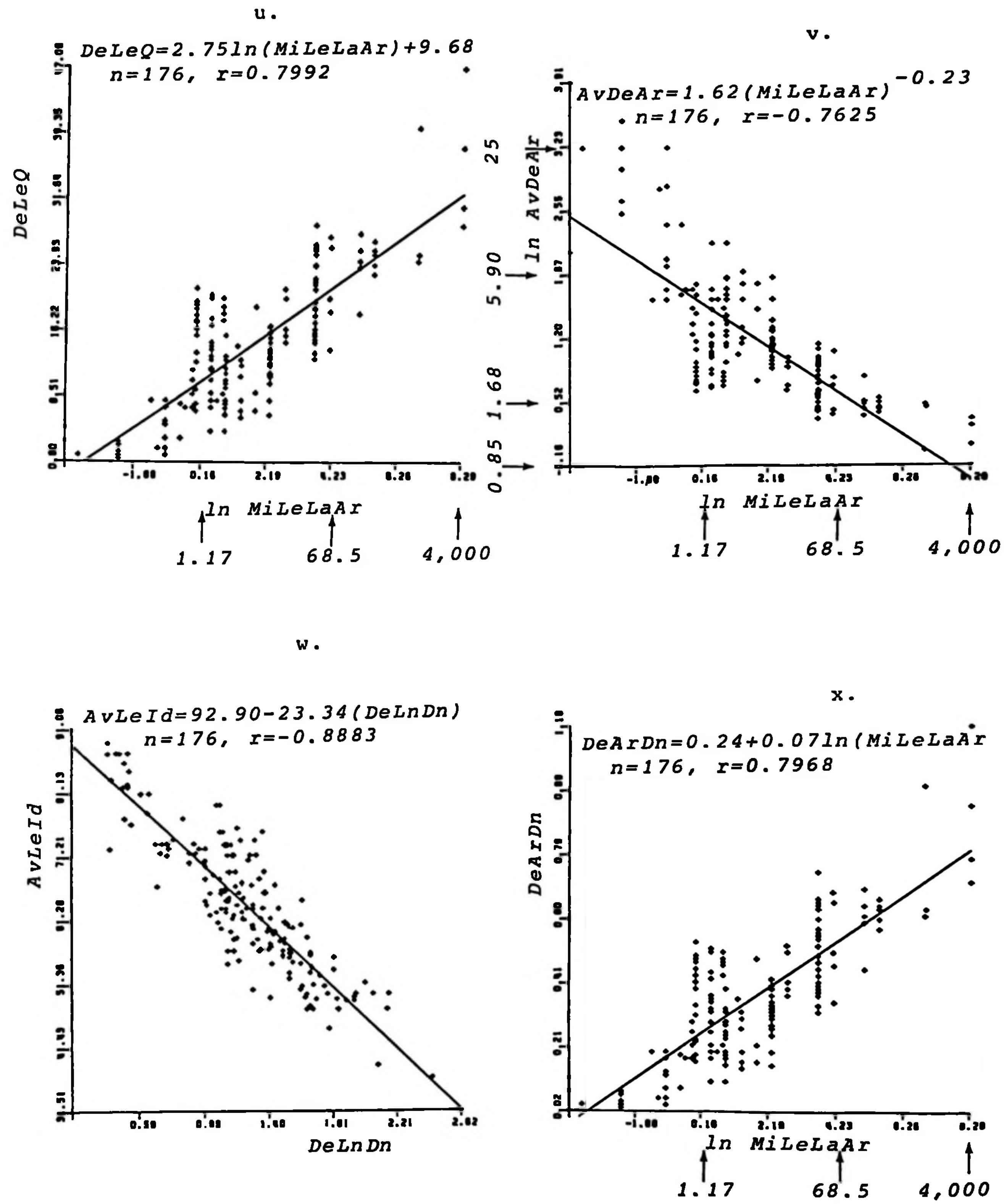
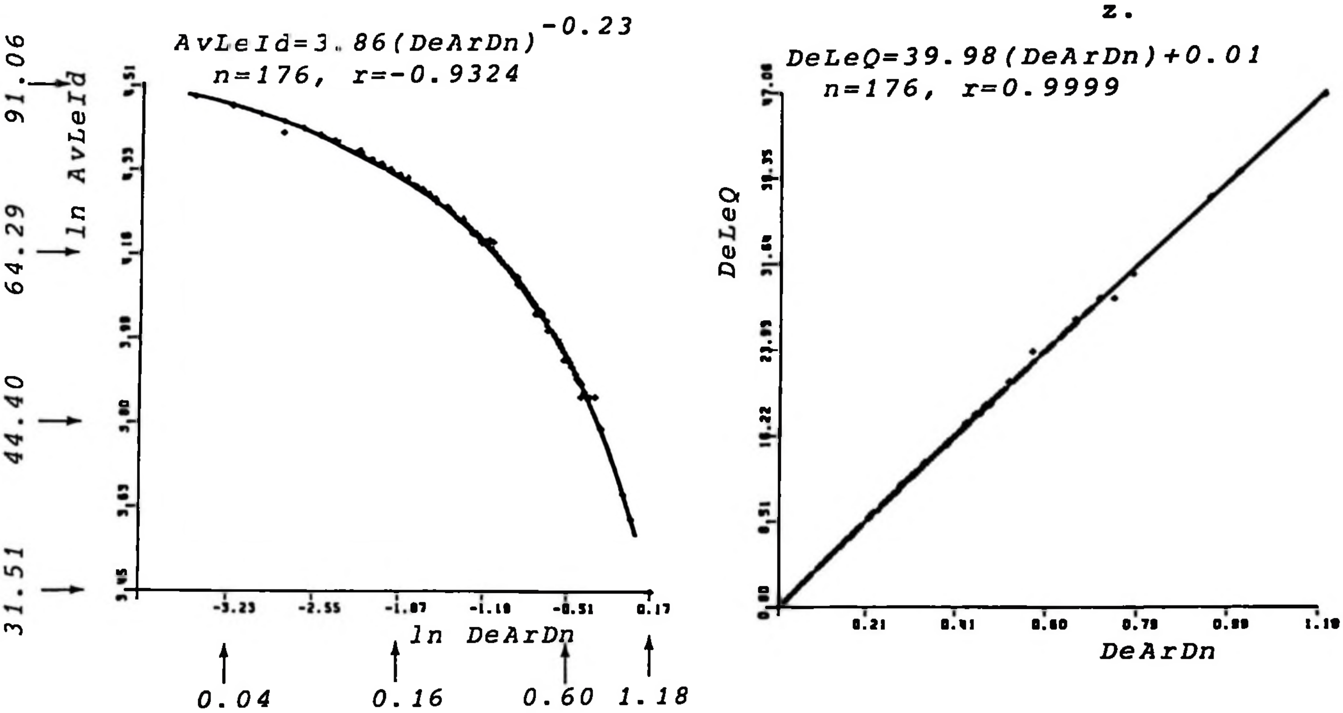


Figure 4.4. cont.

y. z.



Other observations

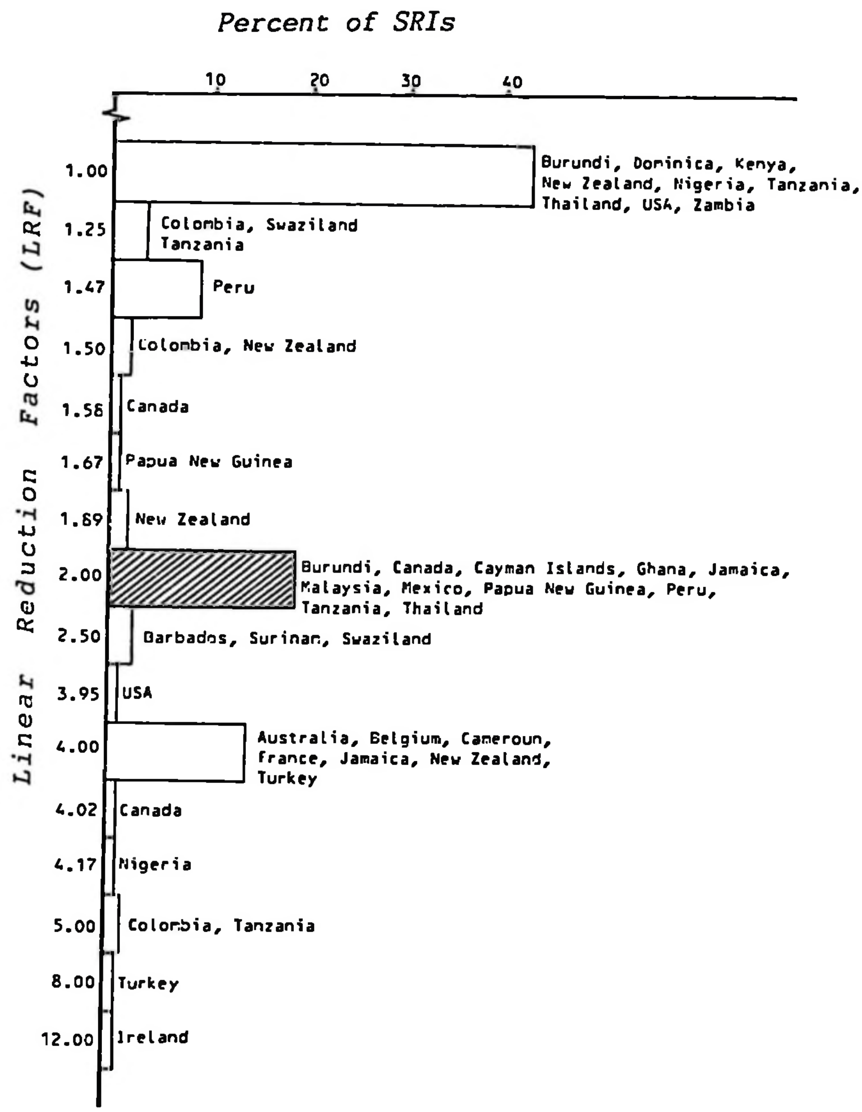
Relationship between publication scales and field scales of soil maps

3. In literature (eg. Beckett, 1981) it is commonly stressed that the scale of the base map in soil survey (field scale) should be twice the publication scale. This means that the linear reduction factor (LnRdFa) should normally be 2. However, the data in figure 4.5. indicate that in different countries and even in the same country the reduction factors are widely variable (1.00 - 12.00). Only in about 18 % of the studied SRIs the linear reduction factors have a value of 2. It appears that the ratios in practice are simply dictated by the scales of the available base maps.

When a map is reduced, any errors present in the original map will be reduced too (Dickinson, 1969). With severe reductions some of the information on the original map will almost certainly have to be sacrificed because of lack of space on the smaller scale; detail may increasingly have to be shown by conventional signs thereby reducing legibility. However, big reduction factors do not always present problems as generally stipulated in soil survey literature. This is with particular reference to a situation where a small scale map is made using a detailed field map. For example the Belgian soil association map at a scale of 1/500,000 (Maréchal et Tavernier, 1971) which was elaborated by clustering information from a detailed field map at a scale of 1/5,000 presents unique and desirable features. Based on the accuracy of the original field map, the soil boundaries presented on the soil association map are also very accurate.

When the reduction factor is too small, this implies greater costs of publication. The reduction factor of 2 advocated in soil survey literature is a compromise which puts into consideration both the factor of economy and the legibility of the published map.

Figure 4.5. Linear reduction factors of some soil maps from 27 countries *



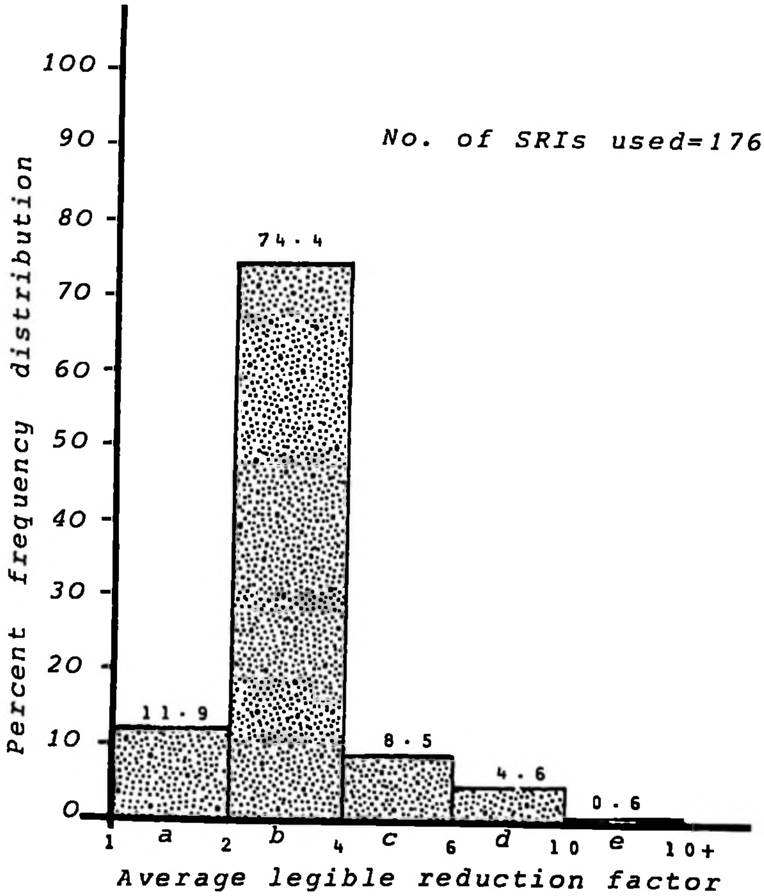
** based on 124 SRIs in which the information could be deduced*

<u>Classification of SRI maps based on the average legible reduction factors</u>

4. Soil maps can be classified on the basis of their average legible reduction factors. Eswaran et al. (1981) distinguished the following classes of map texture based on these factors.

CLASS	AVERAGE LEGIBLE REDUCTION FACTOR (Index of maximum reduction after Eswaran et al., 1981)
a. Very fine textured	$1 \leq$ AvLeRdFa < 2
b. Fine textured	$2 \leq$ AvLeRdFa < 4
c. Medium textured	$4 \leq$ AvLeRdFa < 6
d. Coarse textured	$6 \leq$ AvLeRdFa < 10
	AvLeRdFa ≥ 10

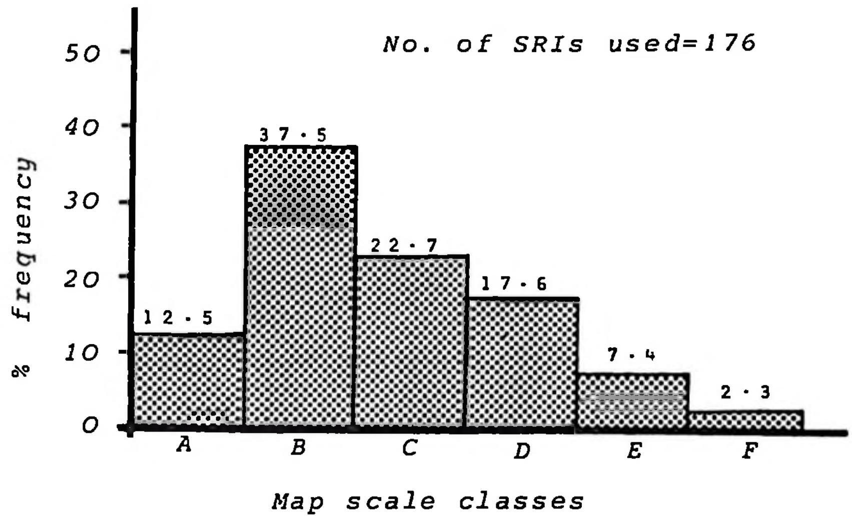
Figure 4.6. Distribution of the studied SRI maps in function of their average legible reduction factors.



Using this classification, the frequency distribution of the various classes of the studied SRI maps was calculated and is presented in figure 4.6. About 74 % of the maps belonged to the fine textured class; about 12 % were very fine textured, about 9 % medium textured and about 5 % coarse textured. Less than 1 % of the maps were very coarse textured. As shown in figure 4.4.h., AvLeRdFa increases with increasing scale of SRI map.

It is worthwhile to point out the fact that the use of the term "map texture" in this kind of classification is misleading because map texture (§41.1.10) was defined as the pattern and sizes of delineations. In this classification, delineation pattern is in no way used or implied since only the average legible reduction factors (§41.1.14) are used. The most plausible way of describing map texture would be probably by combining the average legible reduction factor and the delineation boundary complexity (§41.1.19).

Figure 4.7. Classification of the studied SRI maps in function of maps scales.



Classification of SRI maps based on scale

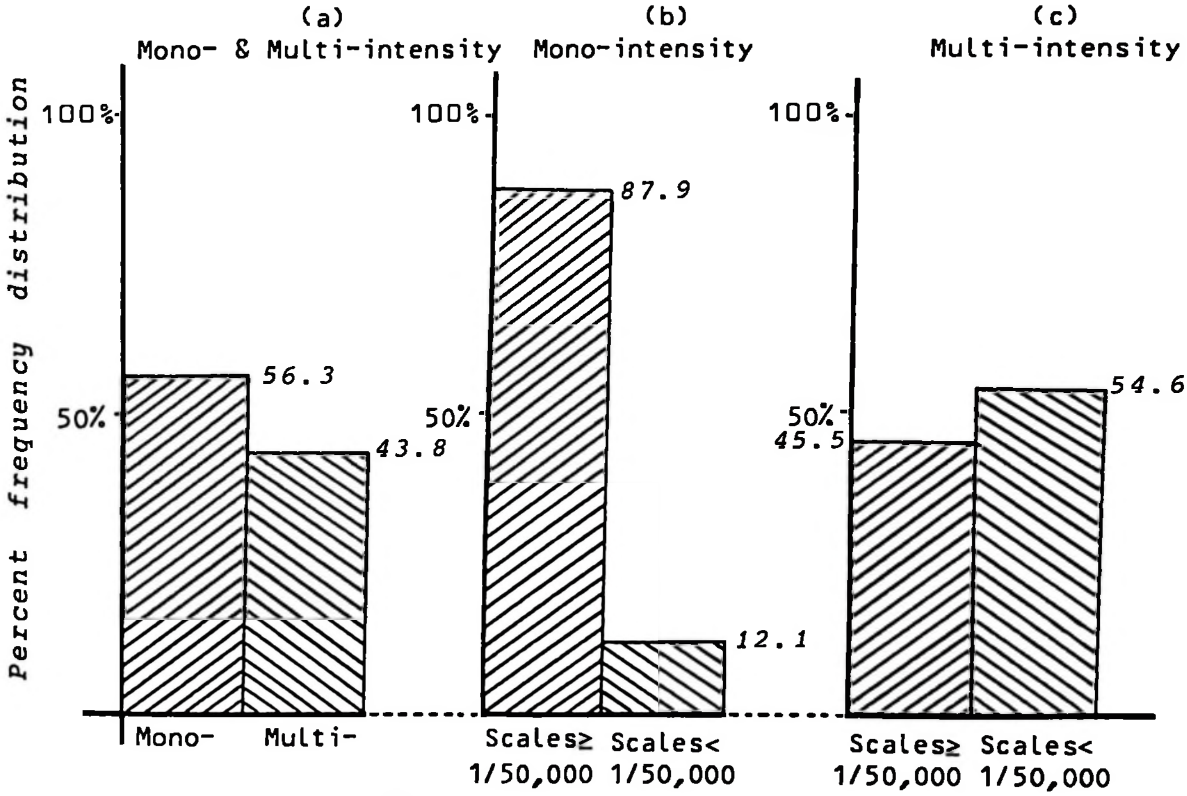
5. Eswaran et al. (1981) did also propose a classification of soil maps based on their publication scales. The following map scale classes are distinguished :

CLASSES	MAP SCALES
A. Ultradetailed	>1/13,000
B. Mesodetailed	1/13,000 - 1/26,000
C. Macrodetailed	1/26,000 - 1/65,000
D. Meso-reconnaissance	1/65,000 - 1/130,000
E. Macro-reconnaissance	1/130,000 - 1/650,000
F. Exploratory	1/650,000 - 1/2,500,000

The above classification has been applied to the studied SRIs and the frequency distribution of the various map scale classes are presented in figure 4.7. A great portion (about 38 %) of the SRIs are mesodetailed, followed by macrodetailed which form about 23 %. About 13 % are ultradetailed. Meso- and macro-reconnaissance SRIs form respectively about 18 % and 7 %. Exploratory SRIs form the smallest portion (about 2 %).

The classification given above does not make much sense because it mixes map scale with the concept of survey intensity (determined by density of field observations). The two are not necessarily related although in literature it is often advocated like that. Experience in the present study has shown that soil surveyors do not in many cases adhere to the rules and the limits in both survey intensity and map scale may change and the two are not in many cases related. Moreover, the information on density of field observations is often missing or vague in SRIs (§ 42.3.3) and one doubts the importance different soil surveyors attach to this parameter. Another confusion arises from the fact that some very small scale maps could be very accurate (see §41.3.3) due to the accuracy of the original field map used for their elaboration. It is doubtful if it is right to call such maps macro-reconnaissance simply because the scale is 1/500,000.

Figure 4.8. Types of mapping intensity for the SRIs as defined by the types of delineation density on the maps *



* based on the 176 SRIs

<u>Delineation density and mapping intensity of the SRIs</u>

6. As stated earlier (§41.1.12), some soil maps may show the same density of delineations which probably corresponds to the same field survey intensity (mono-intensity), while others show different delineation densities which probably represent different field survey intensities (multi-intensity). With the assumption that mono-delineation density on a map corresponds to mono-intensity survey and multi-delineation density a multi-intensity survey, frequency distribution of the two types of survey intensity was determined for the studied SRIs. The results are presented in figure 4.8.a. Mono-intensity maps were more than multi-intensity ones by 12.5 %. Further analyses of the two types of mapping intensity (figures 4.8.b. and 4.8.c.) reveals that about 88 % of the mono-intensity maps were of detailed scale (≥ 1/50,000), and that about 55 % of the multi-intensity ones were maps of scales < 1/50,000.

Without ruling out the possibility that natural soil conditions play a role in controlling mapping intensity, a further explanation of the above observation can also be given, ie. when mapping soils, the degree of generalizing information is higher in the case of small scale than in detailed mapping. This means that in the former case possibilities of having more than one mapping intensity are higher than in the latter. This could explain partly why most of the studied multi-intensity maps were of small scale, while on the other hand most of the mono-intensity maps were of large scale.

A combined classification of SRIs embracing average legible reduction factor, map scale and type of mapping intensity is given for each of the studied SRI in appendix 3. A SRI with for example a notation bDmu has a fine textured meso-reconnaissance multi-intensity map, whereas a SRI with an aBmo notation has a very fine textured mesodetailed mono-intensity map.

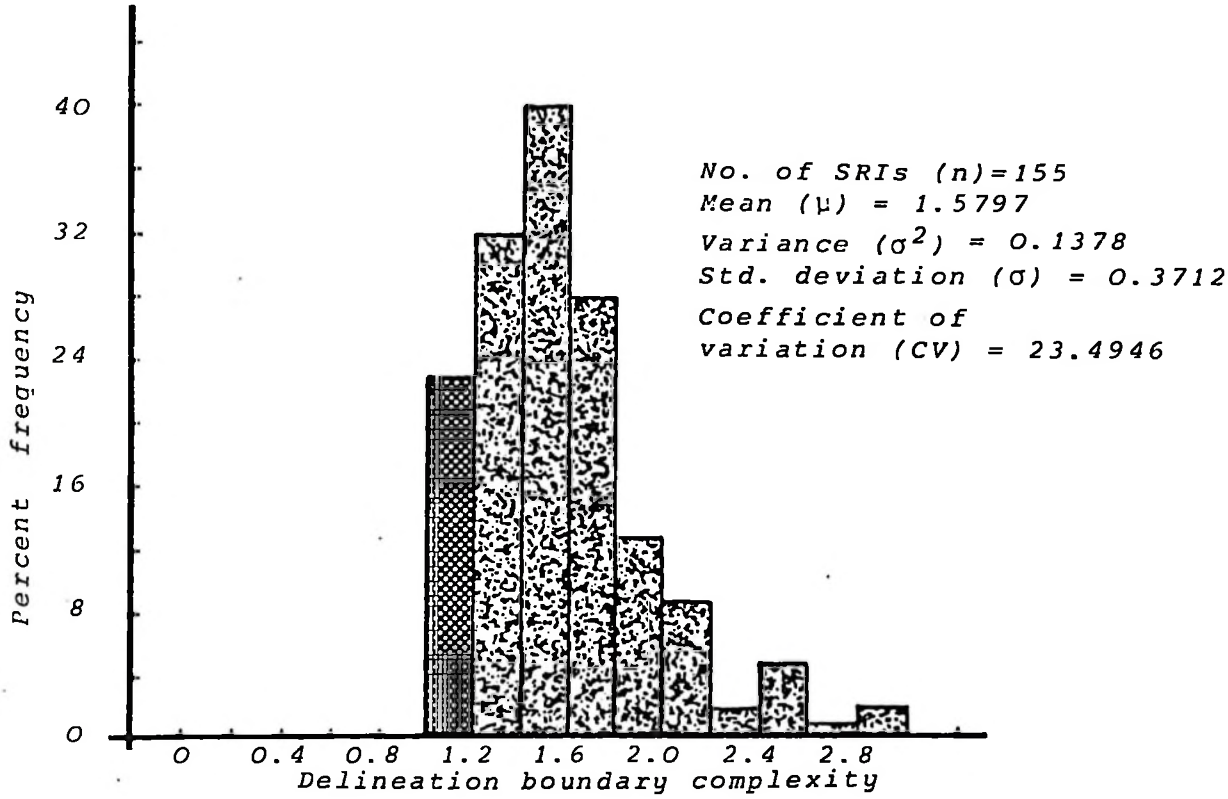
Table 4.5. Distribution of some of the studied SRIs in function of their smallest delineation area.

Map scales	*% of SRIs with SmDeAr≥MiLeDeAr*	*% of SRIs with SmDeAr<MiLeDeAr*	*No. of SRIs used*
1/2,000 to 1/10,000	*83.3*	*16.7*	*18*
1/15,840	*5.9*	*94.1*	*17*
1/20,000	*6.3*	*93.8*	*16*
1/50,000	*8.7*	*91.3*	*23*
1/100,000	*0.0*	*100.0*	*23*
1/125,000 to 1/1,000,000	*0.0*	*100.0*	*19*

Smallest delineation areas and delineation boundary complexities

7. As indicated earlier in this chapter, the smallest delineation areas of soil maps are commonly smaller than the conventional minimum legible delineation of 0.4 sq. cm. This is clearly demonstrated in the present study. Table 4.5. shows that among the studied SRIs, more than 15 % had their smallest delineation areas smaller than the minimum legible delineation area when considering map scales between 1/2,000 and 1/10,000. With decreasing map scale (already from scale 1/15,840) the percentage of SRIs with SmDeAr < MiLeDeAr increases sharply up to 100 % at scales smaller than or equal to 1/100,000. It may be concluded that the SmDeAr is greater than the MiLeDeAr mostly at ultra detailed maps scales.

Figure 4.9. The delineation boundary complexity of the smallest delineation areas of the studied maps.



The delineation boundary complexities (DeBoCo §41.1.19) of the smallest delineation areas (SmDeAr) identified in 155 SRIs were calculated. Their frequency distribution is plotted in figure 4.9. As shown by the more heavily shaded part of the histogram, only about 24 % of the SRIs had their smallest delineation areas with almost circular shapes (DeBoCo between 1 and 1.2). The rest (> 75 %) were invariably irregularly shaped. As pointed out earlier, the complexity of map delineation boundaries cannot be interpreted on its own. Attempt has always to be made to consider in conjuction the sizes of the delineations in question.

Information on soil description sites

8. Presentation in SRIs of information related to the location of soil description sites is important as it aids SRI users to appreciate more the relationship between soil properties as given in the SRI report and their position on the landscape. In a way the presentation of this information may improve the readability of the SRI and certainly the quality of the information. The most plausible and common way of presenting such information is by plotting it directly on the SRI map. In the case where plotting of soil description sites directly on the SRI map is expected to detract from legibility (when for example the base map has already a high density of non-soil information) then the best way is to have a separate map sheet with the information plotted on it, which may eventually be superimposed on the SRI map where interest arises.

Survey on the 176 SRIs used in this study (cf. table 4.6.) indicates that quite few of these documents bear the information on soil description sites on the SRI map or appended as separate sheet to the SRI map. Only 22 % of the documents had this information. No clear relationship could be established between the map scale and the frequency of missing this information.

Table 4.6. Availability in SRIs of information on soil description sites.

Map scale(s)	No. of SRIs of the category	No. of SRIs in which information is given
1/2,000 to 1/2,500	4	1
1/5,000	6	3
1/8,000 to 1/10,000	10	5
1/12,500 to 1/15,840	24	3
1/20,000	16	3
1/22,000 to 1/25,000	27	0
1/30,000 to 1/40,000	10	1
1/50,000 to 1/63,360	30	8
1/100,000 to 1/126,720	32	14
1/200,000 to 1/250,000	10	1
1/500,000 to 1/1,000,000	7	0
Total	176	39(22% of total)

41.4. Conclusions and recommendations

One of the major conclusions that can be made at this juncture is that the various indices established to characterize and evaluate cartographic attributes of soil resource inventories are consistently correlated with each other. This includes also the newly introduced parameters like delineation linear density (DeLnDn) and delineation legibility quotient (DeLeQ). In chapter 5, an attempt will be made using the various correlation equations and in conjuction with other considerations to define and set up acceptable limits of adequacy of SRIs in terms of their cartographic attributes.

In relation to the other observations made on cartographic attributes of SRIs, it can be said that :

1. The concept of map linear reduction factors in many cases is not applied consistently as stipulated in soil survey literature. Of course the available base maps may dictate to a great extent the reduction factors. However, where high levels of accuracy are required, attempt should be made to elaborate appropriate base maps for the surveys in question.

2. Information on soil description sites is only rarely given in SRIs or to be more precise supplied in conjuction with the documents. The significance of such information especially in relation with legibility should not be overlooked in future inventories.

42. LEGEND AND SRI REPORT ATTRIBUTES

42.1. Introduction

Soil surveys must give information to users to enable them make accurate predictions on the performance of surveyed land areas for specific land uses. As indicated earlier, the information in a soil map and its report is contained in the definition of the mapping units which comprise the map legend. A rather detailed basic and conceptual account on map legend is given in chapter 2 (cf. §24).

In more current literature (Forbes et al., 1982) three types of maps legends (which may in practice be combined) are distinguished :

1. An <u>identification legend</u> lists the symbols with which the mapping units are identified on the map, together with the corresponding mapping unit names. This type of mapping legend is printed on the map sheet.

2. A <u>descriptive legend</u> gives information, in either narrative or tabular form about each mapping unit. Such information may include the proportion, landscape patterns and attributes of the soil bodies and non-soil areas making up the mapping unit. The descriptive legend usually forms the bulk of the written SRI report.

3. An <u>interpretive legend</u> gives information about each mapping unit in terms of specific land uses or management systems. The interpretive legend is usually presented as tables or narratives for each land use. Alternatively, the interpretations for each mapping unit may be included in the descriptive legend, with the description of the mapping unit.

42.2. Some principles governing evaluation of map legend

The task in this exercise is to evaluate the information content of the legend and soils report in general. Mapping unit names and their definitions determine the amount and usefulness of information about the land areas shown on the SRI map. Map legends may be evaluated either in terms of a specific use of the SRI or in terms of a more general criterion, such as a soil classification system.

Evaluation is based on two components of map legend quality, ie. the specificity and the homogeneity of the mapping units.

1. The specificity of a mapping unit is the extent to which the mapping unit name, description, or interpretation give information which makes it possible to predict the performance of the land. To assess the specificity of a mapping unit, one has to first select the land attributes that are important for the given land use. Information directly or indirectly related to these attributes should then be traced in the map legend.

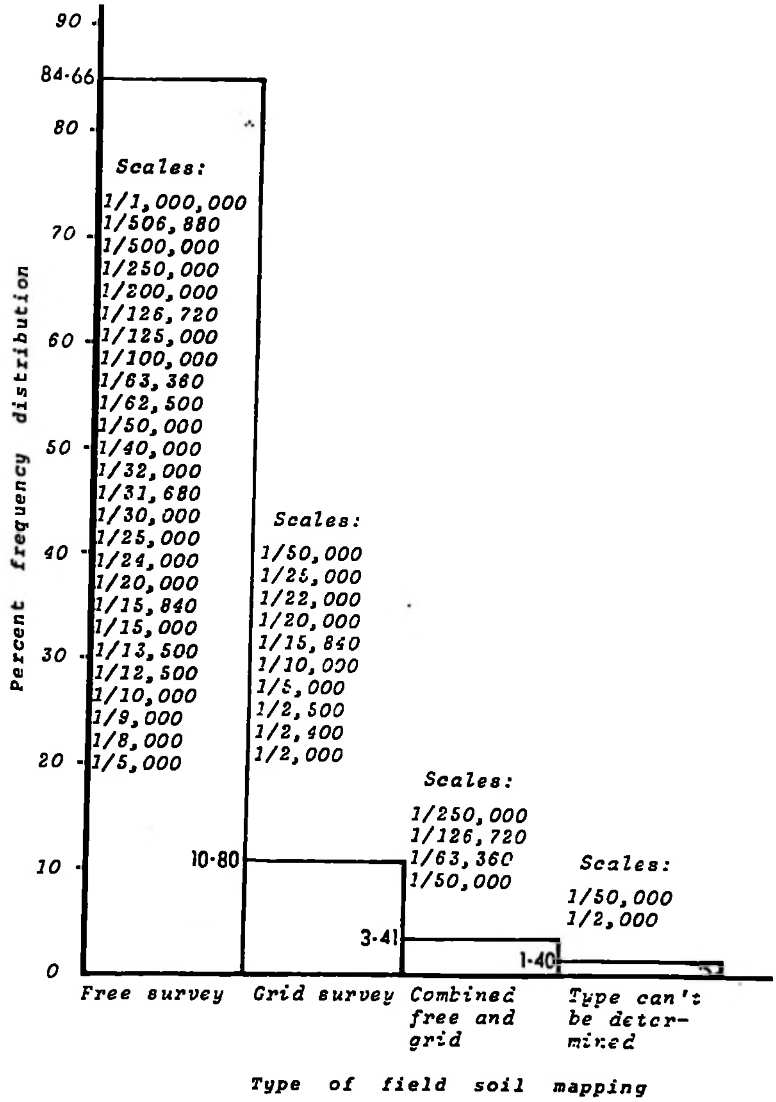
2. The homogeneity (purity) of a mapping unit is the proportion of the land area mapped as delineations of the mapping unit that will perform uniformly as predicted. For purposes of legend evaluation, mapping units may be assigned to three homogeneity classes ie. uniform mapping units, associations or non-homogeneous mapping units.

   Uniform mapping units are those units wherein the major proportion (eg. > 85 %) of the land area is in the same suitability group and thus is expected to perform uniformly for the land use. Moreover, it is expected that the remaining minor proportion will not be strikingly different from the major proportion.

   Mapping units which do not meet the requirements for uniformity are generally called non-uniform and those units whose homogeneity cannot be determined from the legend are assumed to be non-uniform, although in fact they can be considered unknown in terms of the specific land use in question. A non-uniform mapping unit on a small scale map is called an association of uniform land areas if (a) each of the constituents is uniform and could have been assigned to different mapping units at a larger scale; (b) the proportion of each constituent is given; and (c) the landscape pattern of the constituents within the mapping unit is described.

It is also possible to evaluate mapping unit definitions using soil taxonomic classes, with the aim to see whether the mapping units are well defined in terms of the classification rather than in terms of any particular land use. A well defined mapping unit is one which can be unambiguously placed in a taxonomic class.

Figure 4.10. Relationship between field soil mapping procedure and map scale based on the 176 SRIs.



42.3.
<u>General observations on information content of some existing legends and soil reports</u>

<u>Field mapping procedure</u>

1. As pointed out in chapter 2, one way of distinguishing soil surveys is by the types of soil mapping used in their production. Based on this criterion (cf. figure 4.10.), most of the SRIs (about 85 %) used in the present study are free surveys, while only 11 % of them are grid surveys. Though not very common, another type which also exists is the one which

applies free mapping together with fixed grid technique for areas of special interest. In this study this type constitutes only about 3 % of the SRIs. In about 1 % of the SRIs the type of field mapping was not indicated. Purely physiographic surveys (employing only aerial photo interpretation without field checks) were not observed in this study.

It appears that grid surveys are more restricted to detailed soil mapping while free surveys are not particularly inclined to any of the two types of soil mapping. The reasons which necessitate or encourage the use of one type of mapping in preference to another cannot clearly be deduced from the present study. It seems that in some countries it is a matter of fashion or policy to use a particular type of mapping. Nevertheless, free surveys are generally known to be faster and less costly than grid surveys (Veenenbos, 1957, Beckett, 1971). Some workers (eg. Langohr, 1985 - personal communication) stipulate that grid surveys require very experienced soil surveyors because they are more difficult to execute as a relative high number of field observations will be made at the level of map delineation boundaries.

Table 4.7. Attributes used for mapping soils *

Attribute	No. of SRIs in which attribute is used	% frequency
Texture	130	73.9
Drainage	104	59.1
Landform	90	51.1
Topography (slope)	87	49.4
Parent material/rock	86	48.9
Soil depth	72	40.9
Soil reaction	13	7.4
Soil color	13	7.4
Consistence	12	6.8
Erosion status	10	5.7
Stoniness	10	5.7
Vegetation	10	5.7
Profile development	6	3.4
Salinity and alkalinity	6	3.4
Degree of weathering	5	2.8
Type of charge	5	2.8
Nature and thickness of organic horizon	5	2.8
Mode of soil formation	3	1.7
Permeability	3	1.7

*based on 176 SRIs from 46 countries

Attributes used for mapping

2. Table 4.7. shows the frequency distribution of the various attributes used in mapping soils. It can be seen that the most often used attributes in mapping include texture, drainage, landform, topography (slope), parent material/rock and soil depth in order of decreasing frequency. In about 41 to 74 % of the studied SRIs these attributes were invariably used.

It was interesting to note that many soil surveys use landforms and relief attributes in conjunction with others, to map soils. The importance of landforms and relief has been emphasized by various authors (Soil Survey Staff, 1951; Vink, 1963, 1975; Young, 1976; Sombroek and Van de Weg, 1980; Dent and Young, 1981). Landforms and relief facilitate the map user's insight into the spatial variation of soils and landscape. They also enhance greatly the readability of soil maps.

Information on density of field observations

3. It has been stressed that the density of field observations provide a better measure of detail than map scale (Eswaran et al., 1981). It is for this reason that many workers wished to have some indication of density of observations on soil maps. It has been argued that the actual map scale together with the density of observations provide some measure of reliability of the maps, which could be used to characterize and classify soil maps. However, as it has been demonstrated in the present study (cf. table 4.8.) many soil survey documents do not bear any information on density of field observations.

Table 4.8. Availability of information on density of field observations *

Nature of Information	*No. of SRIs in which information is given*	*% frequency*
Density of field observations clearly stated in figures	*58*	*33.0*
Density of field observations just indicated as "varying with landscape/complexity of soils	*22*	*12.5*
No information at all on density of field observations	*96*	*54.6*

*based on 176 SRIs from 46 countries

Among the 176 SRIs used in the study, about 55 % had no information whatsoever related to density of field observations. Only in about 33 % density of observations was clearly stated in figures. In about 13 % of the documents density of observations was just indicated as "varying with landscape/complexity of soils" without quantitative specification.

Soil classification systems encountered

4. Soil classification systems are not indispensable in the making of soil resource inventories. However, they are very important for purposes of correlating soil information between different areas and for extrapolation of agronomic research. Other roles of soil classifications in soil survey are outlined in chapter 2 (cf. §24.3).

There are many soil taxonomic systems used in different parts of the world, some of which at national or regional level and others at international level. Table 4.9. shows the systems of classification encountered in the present study. The USDA and FAO/Unesco classification systems are rather international in the sense of being used in many parts of the world. It was noted for example that among the SRIs which used USDA system, only 37 % originate from the USA. The rest are from many other countries.

The FAO/Unesco system is widely used in the developing countries especially where FAO agricultural development projects are on programme. The French Soil Classification System (CPCS) is also to some extent international, being used in France and the former French colonies. The other systems listed, in table 4.9. still remain national or serve very few countries/places.

Figure 4.11. compares the three most international of the systems of classification encountered in the study. It is clearly indicated that the USDA system has been the most widely used both as basic tool of mapping and for correlation purposes. The FAO/Unesco follows, and the CPCS system has been the least widely used.

Land and/or soil capability data

5. The aim of soil survey is to supply its ultimate users the needed soil information. The ease with which SRI users can use this information is greatly enhanced if the soil map is accompanied by interpretive data in terms of land and/or soil capability. The SRIs under study were analysed to see if they are accompanied by such information and also to see how it is normally presented (cf. figure 4.12).

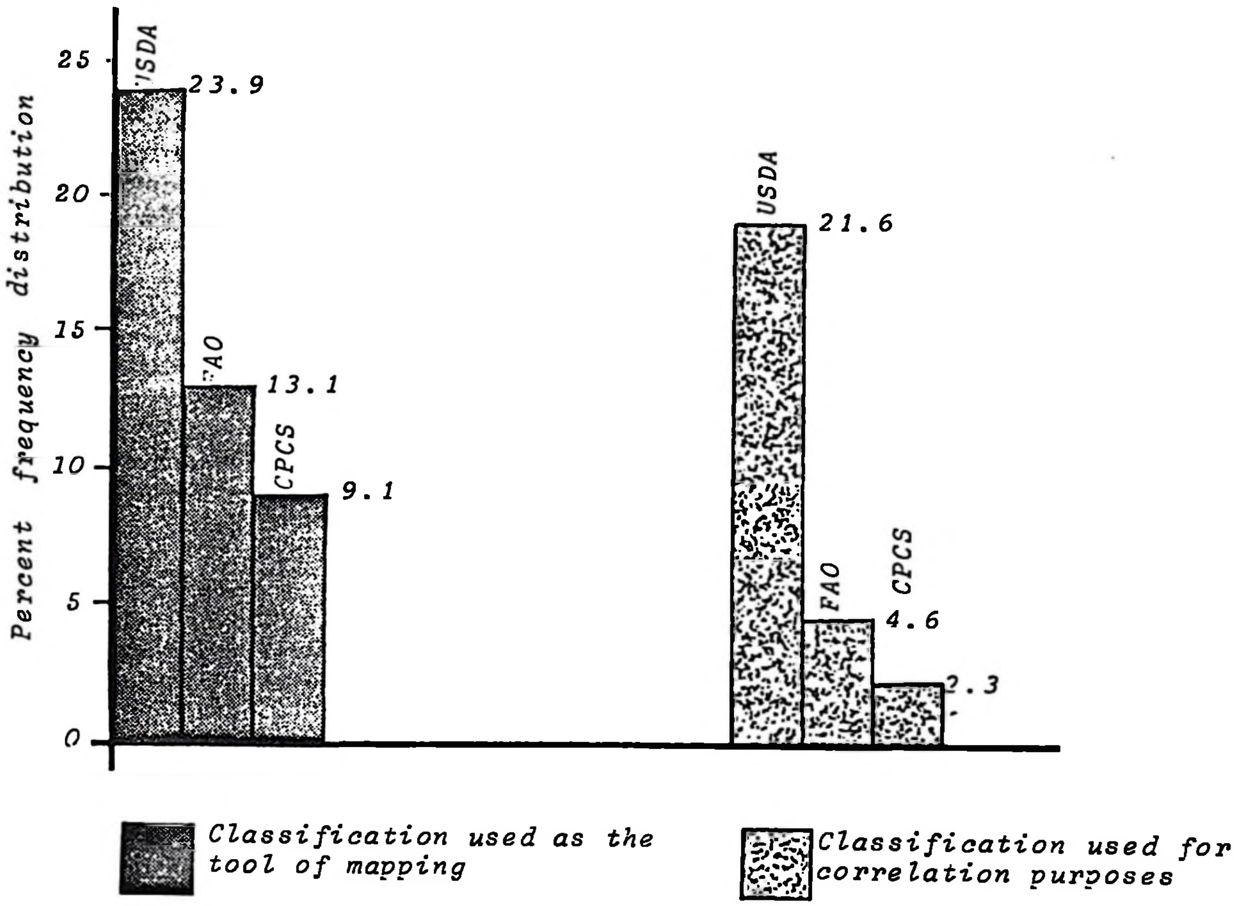
It was observed that about 84 % of the SRIs contained interpretive data in one form or another, while the remaining 16 % had no interpretive information. It has also been generally established that soil maps and memoirs published by INRA (Institut National de la Recherche Agronomique, France) contain only a brief very generalized account of management practices that can possibly be applied on soils surveyed. Those published by ORSTOM (Office de la Recherche Scientifique et Technique Outre-Mer, France) are purely pedological surveys, not covering resource potentials. Most of the SRIs published by the USDA (United States Department of Agriculture) and the New Zealand Soil Bureau are accompanied by quite detailed information on land and/or soil capability.

Table 4.9. Soil classification systems encountered in the study.

Classification system	No. of SRIs	% frequency
1. US Department of Agriculture(USDA) including mostly 7th Approximation and Soil Taxonomy(1975)	39	22.2
2. French system(Commision de Pédologie et Cartographie des Sols - CPCS)	16	9.1
3. FAO/Unesco(1974)	10	5.7
4. New Zealand Genetic Classification	10	5.7
5. Classification of Institut National d'Etude Agronomique du Congo - INEAC (Sys, 1961)	7	4.0
6. Australian Classification (after Northcote, 1971)	1	0.6
7. D'Hoore (1964) Classification	6	3.4
8. Belgian Morphogenetic Classification (Tavernier, 1956; Tavernier and Maréchal, 1962)	4	2.3
9. British Classification(Soil Survey of England and Wales)	6	3.4
10. Canadian Classification System	5	2.8
11. South-East Asian Classification System (after Dudal and Moormann, 1964)	2	1.1
12. Netherlands Soil Classification	2	1.1
13. Unpublished local classifications	8	4.6
14. New Zealand Genetic Classification + USDA Classification	5	2.8
15. FAO/Unesco(1974) + USDA Classification	13	7.4
16. Australian Classification + USDA Classification	1	0.6
17. D'Hoore(1964) Classification + USDA Classification	1	0.6
18. USDA Classification + CPCS Classification	3	1.7
19. South-East Asian Classification + USDA Classification	1	0.6
20. Unpublished local classifications + USDA	8	4.6
21. Unpublished local classif. + USDA + FAO	8	4.6
22. Unpublished local classif. + USDA + CPCS	1	0.6
23. No conventional soil classification	19	10.8
Total	176	100%

NB. From 14 to/and 22, the first classification system is used as the basic tool for mapping while the proceeding one(s) is/are used only for correlation purposes.

Figure 4.11. Type of use of three of the soil classification systems encountered.



The results of the study did also indicate that generally SRIs with publication scale greater than 1/100,000 are accompanied by interpretive data.

<u>Homogeneity of mapping units as a yardstick of quality of SRIs</u>

6. As regards the reliability of the information given on a soil map, one should check for the purity (§42.2.2) of the mapping units. Degree of purity is the proportion of the mapping unit area which is actually occupied by the soils named in the legend. In the Netherlands, purity of mapping units has been set at 70 %, while in the United States it is at 85 %. Recent soil resource inventories (Leslie, 1980; Campbell, 1982; Wilson, 1982 and Trangmar and Cutler, 1983) indicate that in New Zealand mapping unit purity is also set at 85 % for pure or simple units. In some soil surveys of Tanzania, purity is at 80 % (Stonehouse and Duff, 1977 and FAO, 1982); in some recent soil surveys of Canada it is reported as 85 % (MacDougall and Veer, 1981).

It has been stressed that the inclusions in mapping units should be mentioned in the descriptions of the units in the report with an indication of the percentages involved (Legros, 1978 and Sombroek and Van de Weg, 1980). Miller et al. (1979) argued that the user of SRI should

Figure 4.12. Presentation and nature of interpretive data given in the 176 SRIs

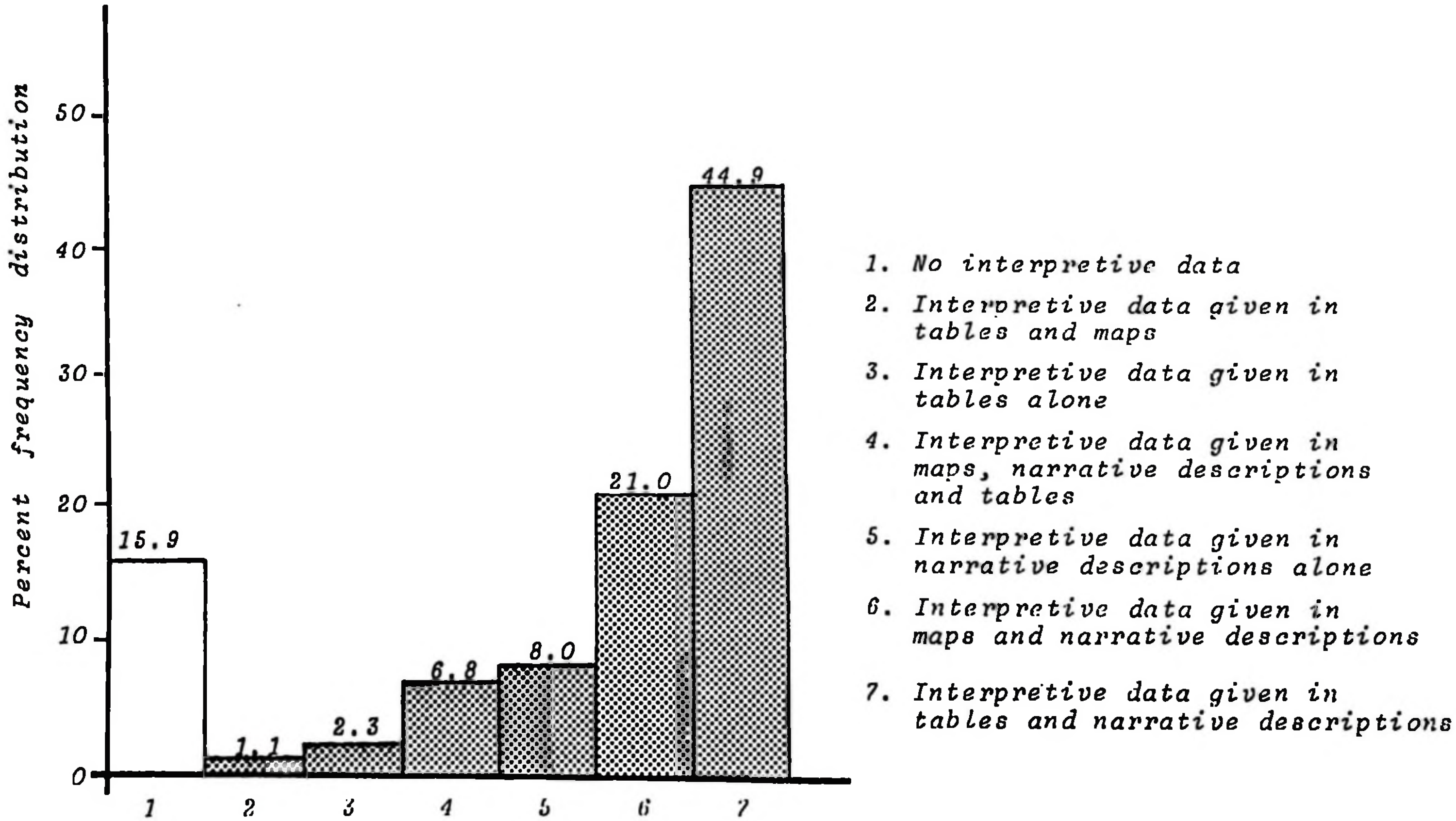


Table 4.10. Sources and map scales of the SRIs in which information on purity checked in this study

SRI map scale	Source of SRIs	No. of SRIs	% frequency
1/2,000	New Zealand	2	3.0
1/2,400	Nigeria	1	1.5
1/2,500	Kenya	1	1.5
1/5,000	Cameroon	1	1.5
	Kenya	2	3.0
	Nigeria	1	1.5
	Zambia	1	1.5
1/8,000	New Zealand	1	1.5
1/9,000	Tanzania	1	1.5
1/10,000	Kenya	1	1.5
	New Zealand	1	1.5
	Nigeria	2	3.0
	Tanzania	2	3.0
	Zambia	1	1.5
1/12,500	Thailand	1	1.5
1/15,000	New Zealand	3	4.5
1/15,840	New Zealand	2	3.0
	Nigeria	1	1.5
	USA Indiana	11	16.7
	USA New York	1	1.5
	USA Wisconsin	2	3.0
1/20,000	Belgium	3	4.5
	Cameroon	1	1.5
	Nigeria	1	1.5
	Thailand	1	1.5
	USA Alabama	1	1.5
	USA Indiana	4	6.1
	USA Kansas	1	1.5
1/22,000	Cameroon	1	1.5
1/24,000	USA Alabama	1	1.5
	USA Hawaii	1	1.5
1/25,000	Barbados	1	1.5
	Britain	3	4.5
	Cayman Islands	1	1.5
	Malaysia	2	3.0
	Montserrat	1	1.5
	Trinidad	1	1.5
1/30,000	New Zealand	1	1.5
1/31,680	Malta	1	1.5
1/32,000	Ghana	1	1.5

No. of SRIs = 66; no. of countries = 17 be made aware of the composition of the mapping units with respect to inclusions, the relationship of taxonomic heterogeneity to interpretive accuracy, the different degrees of variability of soil properties, and the confidence limits of interpretations of soil behaviour.

In the present study, 66 detailed and semi-detailed multipurpose SRIs were selected from the total of 176. Table 4.10. shows the source and their distribution over the different countries. Although a great number of these SRIs are from the United States, they originate from different states and previous observations (Msanya, 1985) indicated that in many aspects they were substantially different. Information on purity of mapping units was systematically checked in the SRIs by reading both the SRI map and the report.

The results (cf. table 4.11.) indicate that in many SRIs, the information on purity of mapping units is not given, or is presented vaguely. About 50 % of the SRIs had no information at all on mapping unit inclusions. In about 8 % the presence of inclusions was acknowledged but the percentages involved were not given. Full information on purity was given only in about 27 % of the documents.

Table 4.11. Availability and presentation in SRIs of information on purity of mapping units.

Nature of information	*No. of SRIs*	*% frequency*
Presence of inclusions not at all indicated	*34*	*51.5*
Inclusions acknowledged but their percentages not given	*5*	*7.6*
Inclusions fully described for all mapping units	*18*	*27.3*
Inclusions fully described for most mapping units (≥75% of units)	*4*	*6.1*
Inclusions fully described for few mapping units (< 50% of units)	*5*	*7.6*

**No. of SRIs = 66*

42.4. Conclusions and recommendations

Important observations have been made with regard to the information content of legends and soil reports of existing SRIs. It was noted that :

1. Most SRIs are produced by free survey method most probably because of the implied high speed of work and low costs involved (§42.3.1).

2. Texture, drainage, landform, topography (slope), parent material and soil depth are among the most commonly used attributes in soil mapping (§42.3.2).

3. Information on density of field observations is often missing in SRIs and is commonly vaguely presented. In the case where this information is completely missing, it is not clear whether or not it is presented elsewhere. Due to its importance in judging reliability of SRIs, it is hereby recommended that in future, density of field observations should be given in SRIs as one of the routine data (§42.3.3).

4. The USDA and the FAO/Unesco soil classification systems are the most widely used internationally. The publicity which is often made especially about the former system could explain the trend by many countries of indiscriminately adopting this system for mapping at the expense of their national, regional or local soil classification systems. Care has to be taken as the USDA classification system was devised for mapping soils of the United States and may not necessarily be ideal for other countries (§42.3.5).

5. Most SRIs bear interpretive information in relation to land and/or soil capability. Only the presentation differs from one inventory to another (§42.3.5).

6. Information on purity of mapping units is often missing in SRIs and in other cases only partly presented. Its importance calls for more attention in future inventories (§42.3.6).

43. BASE MAP ATTRIBUTES OF SOIL RESOURCE INVENTORIES

43.1. Introduction

Some basic concepts about base maps were dealt with in chapter 2. A base map for a SRI was defined as any cartographic material on which soil information is shown. It is a representation of the landscape, cultural features and abstractions (such as political divisions) by which points or areas may be located in the field, and on which planning or interpretive maps may be prepared (Forbes et al., 1982). The SRI user normally does not have access to, and therefore cannot evaluate directly the base map that was used by the soil surveyor in the field. This map is in most cases different from the published SRI map. Hence, the evaluation of base map quality is only limited to the base map information which is still with the SRI or which can be deduced from it.

The different types of base maps discussed under §23.1. may be classified into two main classes : photographic and schematic. Photographic base maps are photos usually modified after exposure of the survey area. They are normally panchromatic black and white aerial photographs, but may include color or false-color (infra-red) imagery. Schematic base maps use lines, symbols and colors to represent land areas and cultural features. They are mostly compiled from a photographic base. Topographic maps are the most conventional type of schematic maps. In practice, photographic base maps also present some information such as political boundaries, place names and roads, in schematic form.

The selection of base maps for soil surveys follows certain norms dictated by the fact that these surveys are made with many different objectives. Thus it has been stressed (SRI Study Group, 1978; draft) that after all the available base material has been considered, the selection of the base map should be done according to the degree to which a given base map meets the survey objectives and the degree of detail required. The relative advantages the base map has in relation to all the activities of a survey (including field work, office work and map publication) should be of major concern.

43.2. Criteria that could be used to assess base maps

According to Forbes et al. (1982), eight components of base map quality are considered important. These are namely, physical quality, resolution, point accuracy, area measurement accuracy, date, location of points, location of areas and clarity of soil information.

Physical quality

1. The physical quality of a base map are the qualities that are independent of the information content of the map. They include paper grade and finish, format and size of map sheets, and the reproduction quality. Another important aspect of physical quality is shrinkage (Langohr, 1987 - personal cummunication) which could be a serious limitation when using the base map. Base maps should be printed on good quality paper especially when they are to be used in the field or as a base for planning maps. It is recommended that maps to be used in the field should be cloth-backed. The sizing and the finish of the paper should allow sharp lines to be clearly represented. If additional information is to be put on the map by the user, the paper should be able to take well the drawing ink or pencil, and any drawing should erase cleanly without erasing any of the original information.

The size and format of the map should allow easy handling and storage. Except for wall displays, map sheets should not exceed the dimensions of a medium size drafting table (ie. 75 x 100 cm). Smaller sheets (about 30 x 50 cm) are most useful in the field. Folding maps should be easy to unfold and fold, and it should be possible to read both the map and the identification legend at the same time.

By map reproduction here it is meant the actual printing, photography or other means of putting information on the map sheet. Printed information eg. lines, symbols or text, should be clear and sharp with no blurring or running of ink on the paper. Lines of a given kind (eg. representing soil boundaries) should be of uniform width and darkness. If aerial photographs are with line information (such as roads), the line information and the photograph should show the lines in the same place.

Resolution of aerial photographs and digital imagery

2. In photographic reproduction, resolution is the size of detail that can be discriminated in the photograph. The same definition of reproduction applies to digital remote sensing imagery. Since the SRI user is concerned with objects on the ground, resolution is normally measured in terms of ground distances, rather than on the image. Hence the smallest object in the image that can be clearly identified defines the ground resolution. If for example

a road known to have a width of 10 meters can be clearly discriminated on a photo, the ground resolution is 10 meters or less (better). The better the ground resolution, the more the ground detail that can be used for location of points and areas.

Point accuracy

3. Map accuracy (§23.4.) refers to the agreement between the map and the area it represents. Accuracy of points on a map can be either relative or absolute, in horizontal (plan) or vertical (elevation) dimension. Absolute accuracy is the relation of points as represented on the map to their geodetic positions, referred to known horizontal and vertical coordinate system. The Universal-Transmercator (UTM) Grid is an example of a horizontal reference system. Another example is the latitude-longitude system. The 1927 North American Datum of Mean Sea Level is an example of a vertical control system. In many cases absolute accuracy is not important for most SRI users, although a horizontal grid may be used as a convenient tool of referring to points in the field.

Relative accuracy is the relationship between horizontal or vertical distances between points represented on the map and the distances as actually existing on the ground. Vertical accuracy, relative or absolute, is seldom important for SRI applications, although it may be necessary for some engineering and hydrologic interpretation of the soil map. Absolute horizontal accuracy on the other hand is important to SRI users for locating points or areas in the field or on the map, and measuring land areas and distances from the map.

Base map accuracy is mostly important for detailed (large scale) maps. If the map legend consists mostly of general mapping units such as associations (§24.1) or if the map scale is too small to allow detailed planning, the accuracy of the base map is not considered very important. The degree of accuracy asked for by a SRI evaluator should correspond well with the ground accuracy which is necessary and possible in the actual ground operations for which the soil survey may be used.

It is also important to stress that horizontal accuracy can only be determined for ground control points (ie. points on the map which are easily visible or recoverable in the field). Examples include surveyor's reference monuments and benchmarks, but more frequently they could be any well defined locations such as crossroads, bridges, buildings, or railway crossings. As stated earlier (§41.1.17) a well defined ground point may be plotted to an accuracy of 0.25 mm on a map. This means that the point on the ground must be locatable with an uncertainty of at most 0.25 mm, scaled up to ground distance (cf. table 4.3). For example a ground control point on a map with the scale of 1/2,000 must be locatable within 0.5 m in the field.

Area accuracy

4. Some uses of soil surveys require that land areas be accurately represented. An example is when one is interested to measure the portion of the surveyed area covered by each of the mapping units. The area represented on a map depends on the map projection (ie. representation of the three-dimensional surface of the earth on a two-dimensional map) used. For large scale maps it can be said that the effect of projection is negligible but on small scale

maps, areas may be misrepresented. This implies that accurate measurement of area is not generally possible on such maps. However, it should be noted that the uncertainty in the area of map delineations that accrues from the uncertainty related to soil boundaries is usually much greater than the distortion of areas introduced by map projection.

Date of the base map

5. Land areas change with time as a result of natural events, human activities and their interactions. These changes vary in velocity, quantity and extent depending on where the land is situated. Land areas within or around towns or other settlements tend to change faster than in unsettled remote areas. If as a result of these changes a compiled map no longer correctly represents the corresponding land area, such a map is less useful for location purposes.

The date of the base map is important. Generally, recent maps are easier to use for location than older ones. However, as stated above, this depends on the situation of the represented land area. In rapidly changing area for example, a map may become obsolete in few years, whereas in slowly changing areas a 40 year old base may still be substantially up to date. Hence, the date of a base map should be evaluated with care. One of the best ways to check the currency of a base map is to compare it with maps or imagery of known and acceptable date.

The compilation date of a map should be given on the map sheet. This unfortunately is not always the case with soil maps. Moreover, the date the soil survey was completed may be later than the base map date, and the date the soil survey results were published will definitely be later than the base map date. Hence, the survey date or publication date has to be taken with caution.

Location of points

6. The SRI user often wants to find a known ground point on the soil map, to find out for example in which mapping unit that particular point is found and consequently what type of soil should be found at the point. Conversely, he may want to locate in the field a point shown on the soil map. Two methods have been proposed for location of points : location using ground control points, and location by interpolation. In the first method, angles and distances are measured from well defined points to the point of interest (or vice-versa), and the point is located geometrically. Methods of measurement vary in precision and in general only pacing (for distances) and hand compass (for angles) are available for most SRI users. The method of location by interpolation employs any features that are visible both on the map and on the ground to interpolate an approximate position of the point of interest. The interpolation features may be points, lines or areas. The approximate distance from each of a set of points or lines and the approximate bearing to several points are used in combination on provide an accurate location of the point of interest.

Location of areas

7. Just like for point location, the SRI user often wants to find on a map the area which corresponds to a land area of interest. Conversely, he may wish to locate a given map area on the ground for planning or operational

purposes. These are the two basic aspects of area location. Since an area is defined as the interior of a geometric figure which is determined by its boundaries, the area location problem is equivalent to boundary location problem.

Area location may be more difficult than point location, since two-dimensional geometric figures, rather than zero-dimensional points, must be transferred from map to field, and vice-versa. It is for this reason that in general, the overall accuracy of a base map for area location is evaluated in non-quantitative terms. It is normally assumed that once a map is accurate for point location, it is also accurate for area location.

Clarity of soil information

8. Clarity of presentation of the soils information is an important property of a soils map. Soils information should be presented sufficiently different from base map information to avoid confusion. Boundary lines of soil areas must be of a different width or boldness than other lines that might be confused with soil boundaries, such as roads or drainage ways. Delineation symbols should be unambiguous.

In colored soil maps, colors should be light enough to permit the readability of all printed base map information. Moreover, colors should be sufficiently different from each other so that areas of similar colors cannot be confused, even when widely separated on the map. As pointed out earlier (§41.1.18), not too many different colors may be used.

Summary and remarks

9. It can be summarized that for a base map to be adequate for a given land use :

a. It's physical qualities including paper grade and finish, printing, size and folding, and reproduction of colors (if any) should be acceptable.

b. Photographic resolution should be enough in the case of airphoto base map.

c. Appropriate accuracy standards must be met by the map.

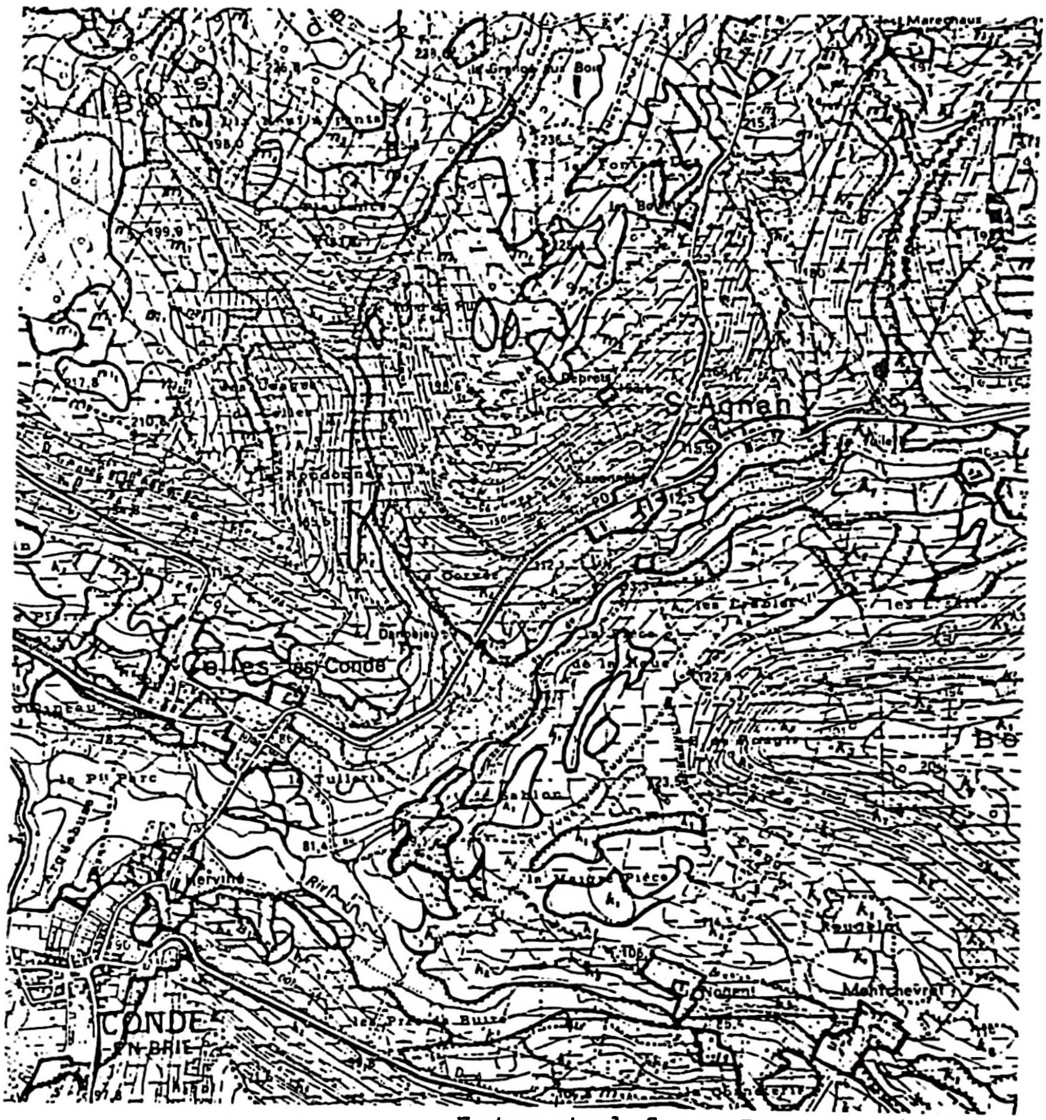
d. The map must be sufficiently recent.

e. The map must be adequate for both point and area location, and

f. Base map information must be clearly different from soils information.

Certainly some of the points above are more critical than others and it is doubtful if it is necessary to consider some of the attributes for serious assessment under certain conditions. For example poor physical quality could be tolerated if the map were otherwise accurate and useful. If the map is not to be used for site specific purposes, accuracy standards may not be so important. Moreover, the assessment of some base map attributes can only be made subjectively. Another important consideration is whether the criteria are sufficiently feasible for routine assessment of base map quality.

Figure 4.13. An example of a soil map in which base map information (non-soil information) competes with soils information.



Extracted from Jamagne (1967)

43.3. Methods of determining the density of non-soil information

The amount of non-soil information (base map information) particularly ground control features on a soil map determines the accuracy with which points and areas can be located. The amount of this information should neither be too low nor too high, although the latter situation is only occasionally encountered. In both cases it is feared that legibility of the SRI map may be impaired. Figure 4.13. shows a soil map in which non-soil information is obviously competing with soil information itself, thereby reducing substantially the legibility of the map. Determination of the accuracy with which ground control points are located is not feasible in the office. It can only be done in the field; and for that matter it could be considered part of ground truthing, a subject which is not treated here. Hence, the utility of a map as a function of the quantity of base map information is estimated with the assumption that the ground control features are located accurately.

Two methods are described here for the determination of the quantity of base map information. The SRI Study Group (1978; draft) proposed what I have called circular method. In this method two circles, one of 4.85 cm radius and the other of 2.91 cm radius are employed for SRI maps of respectively map scales > 1/20,000 and map scales ≤ 1/20,000 (cf. figure 4.14.I). Depending on the SRI map, the appropriate circle on a transparent overlay is selected, and by using a method similar to the one described by Forbes et al. (1982) for cartographic attributes (§41.2.1), ten counts of randomly selected points are made to assess the ground information per area ie. average number of reference points within the circle. When linear features like rivers, roads, railways etc. are branching into separate ends, the branches are counted separately as independent features. I have proposed to call the base map information quantity obtained by the circular method, average base map areal information density (AvBmArInDn). Based on this, a soil map classification was suggested (cf. table 4.12).

The other method which I proposed is a linear one, similar to the one of determining delineation linear density (§41.1.9). A 10 cm long line (cf. figure 4.14.II) on a transparent overlay is randomly placed on the SRI map and all the intersections made with any ground control features are counted. The procedure is repeated several times to have 10 samples. The counts are added and an average value is obtained by eventually dividing the sum by 10. I proposed to call this parameter, average base map linear information-density (AvBmLnInDn).

Table 4.12. Classification of soil maps in function of the number of observed reference points per area (SRI Study Group, 1978; draft, modified).

Average number of reference points within circle (average of 10 counts)	*Circular area in cm² representing 1 reference point*		*Usefulness of base map for location*
	4.85 cm radius circle	*2.91 cm radius circle*	
< 2	>37.0	>13.3	*Low (unacceptable)*
2 - 5	37.0 - 14.8	13.3 - 5.3	*Moderate*
6 - 8	12.3 - 9.3	4.4 - 3.3	*High*
9 - 30*	8.2 - 2.5	3.0 - 0.9	*Very high*
>30	<2.5	<0.9	*Too high (unacceptable)*

I proposed this figure as the upper limit that could be accepted without sacrificing too much map legibility

Figure 4.14. I. Circular test areas for estimating density of base map information (ground control features).

II. Line for estimating density of base map information (ground control features).

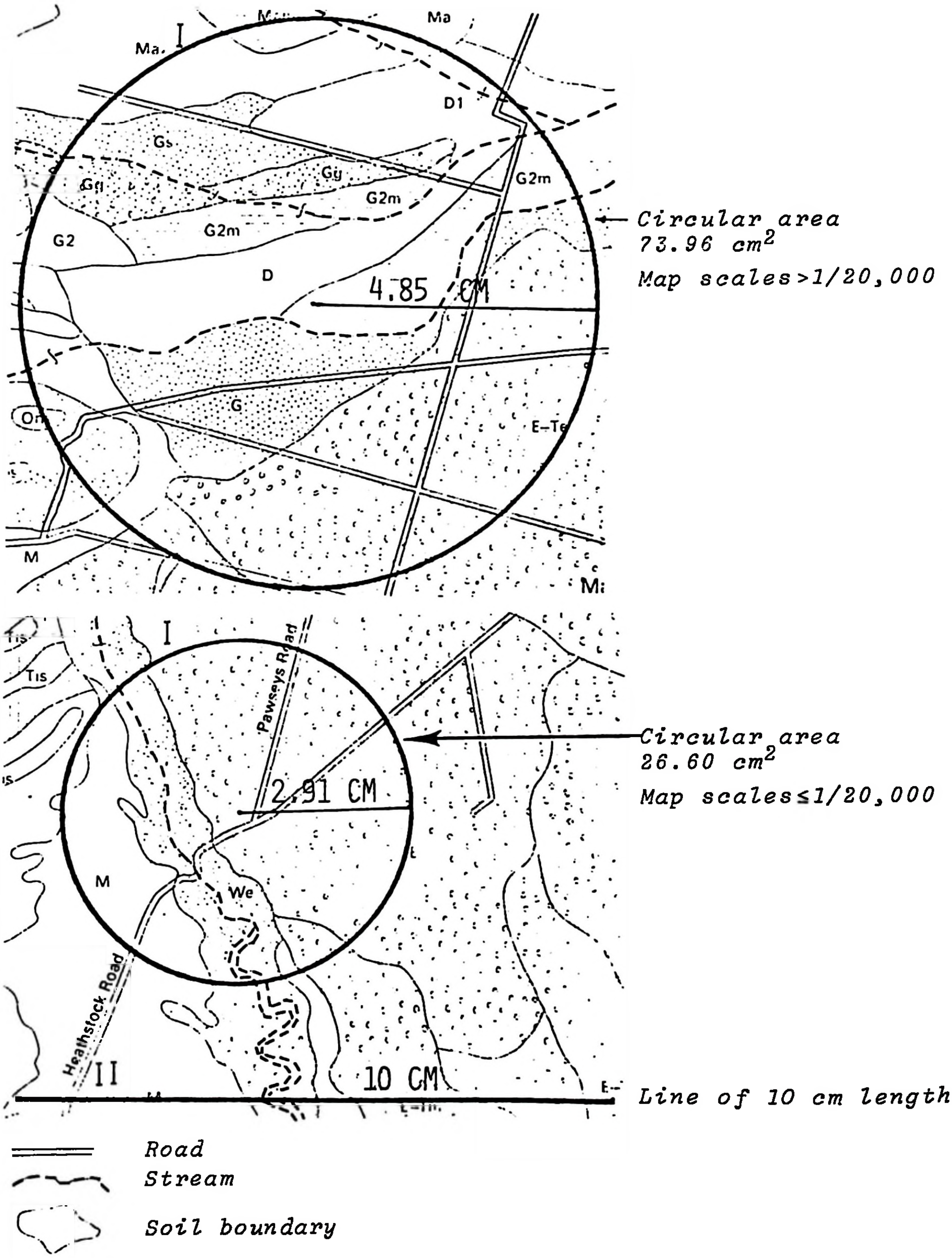
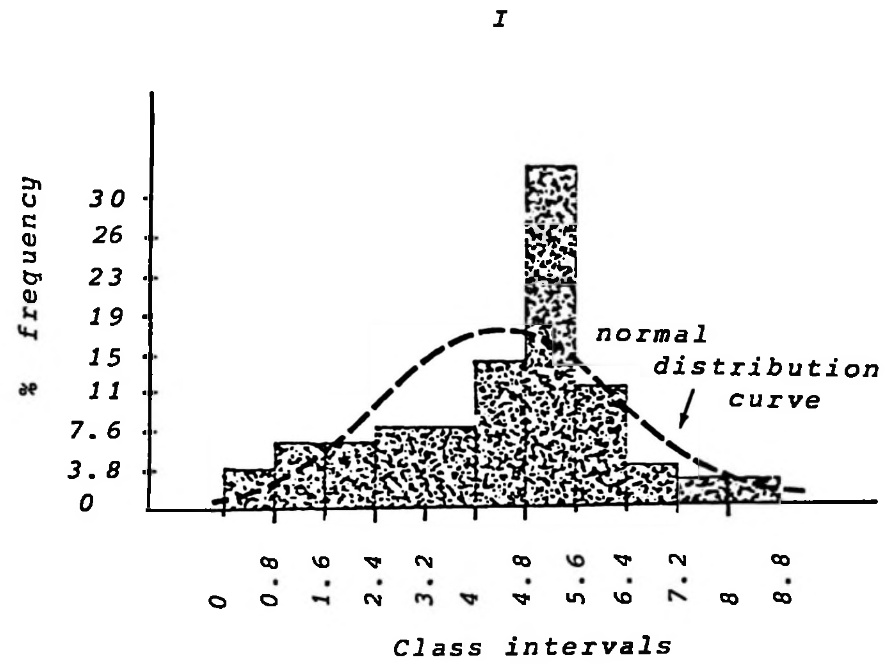
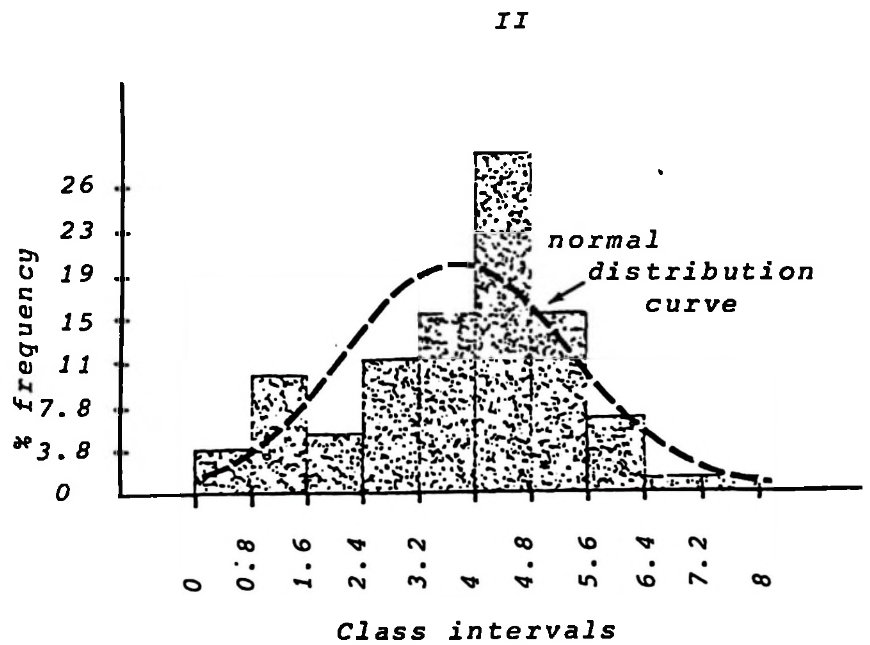


Figure 4.15. Statistical description of I : Average base map areal information density and II : Average base map linear information density.





43.4. Results

1. Methods

The two methods described above were applied to the 176 SRIs and the results have been analysed and correlated statistically using a computer, model HP-85 of Hewlett-Packard Co. with basic language. Figure 4.15. shows that the two parameters are reasonably consistent; their values corresponding rather well with the normal distribution curve. This implies that these parameters could be used to characterize SRIs in terms of their base map information content.

Correlation analysis on the parameters (cf. figure 4.16.) indicates that they are highly correlated ($r = 0.9116$). This means that values of one parameter could be used to determine corresponding values of the other. In table 4.13. corresponding values of AvBmLnInDn are established by using those of AvBmArInDn (SRI Study Group, 1978; draft) and by applying the linear equation AvBmLnInDn = 0.246 + 0.8 (AvBmArInDn). These values can be used for an alternative classification of soil maps in relation to their base map utility (cf. table 4.14).

It was observed that the values of AvBmLnInDn were systematically lower than those of AvBmArInDn. A possible explanation is that during sampling, in the linear method the chances of missing ground control features represented on the map by points are higher, than in the case of the circular method in which a circular area encloses features of all forms which have to be counted.

Figure 4.16. Correlation between AvBmArInDn and AvBmLnInDn

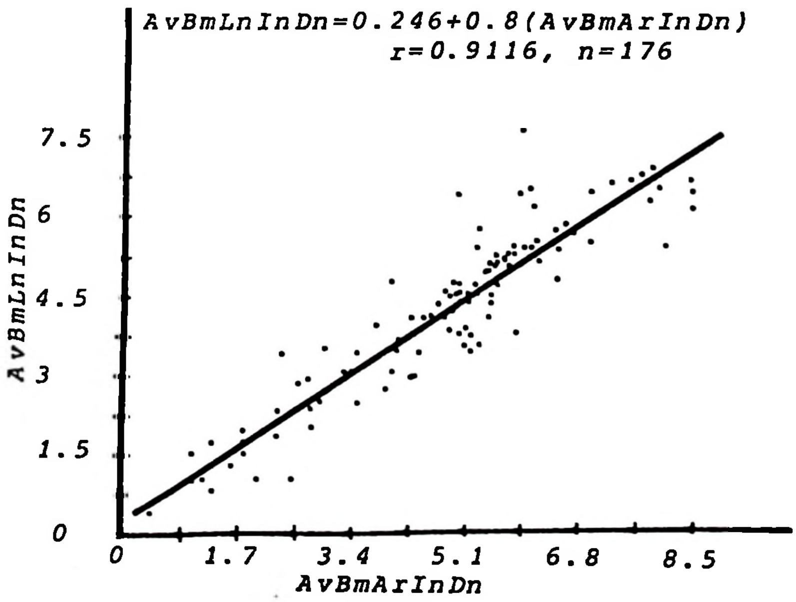


Table 4.13. Established values of AvBmLnInDn corresponding to specified values of AvBmArInDn, as given by their correlation equation.

Specified values of AvBmArInDn	*Corresponding values of AvBmLnInDn*
2	1.85
5	4.24
6	5.04
8	6.64
9	7.44
30	24.25

Table 4.14. Proposed soil map classification based on corrected values of AvBmLnInDn.

Average no. of intersections with 10 cm long line (average of 10 counts)	*Length in cm representing 1 reference point*	*Approximate circular area in cm² representing 1 reference point*	*Usefulness of base map for location*
<2	>5.0	>19.6	*Low (unacceptable)*
2 - 4	5.0 - 2.5	19.6 - 4.9	*Moderate*
>4 - 7	<2.5 - 1.4	<4.9 - 1.5	*High*
>7 - 25	<1.4 - 0.4	<1.5 - 0.1	*Very high*
>25	<0.4	<0.1	*Too high (unacceptable)*

2. <u>Other observations on base map information</u>

<u>Type of base maps/documents used in soil resource inventories</u>

In table 4.15. the different types of base maps/documents used in the studied SRIs are presented. It is shown that aerial photos/aerial photo mosaics and topographic maps are the most commonly used; having been employed respectively in about 61 % and about 47 % of the inventories. Worthwhile to note also is the fact that about 41 % of the SRIs in which aerial photos/aerial photo mosaics were used, soils information is directly printed on them. This is the situation with all the studied county SRIs of the USA. Base documents other than those two types mentioned above are only used to a small extent (used only in less than 15 % of the SRIs). Only in about 3 % of the SRIs information on the type of base maps/documents was not indicated.

Table 4.15. Type of base maps/documents used in the soil resource inventories.

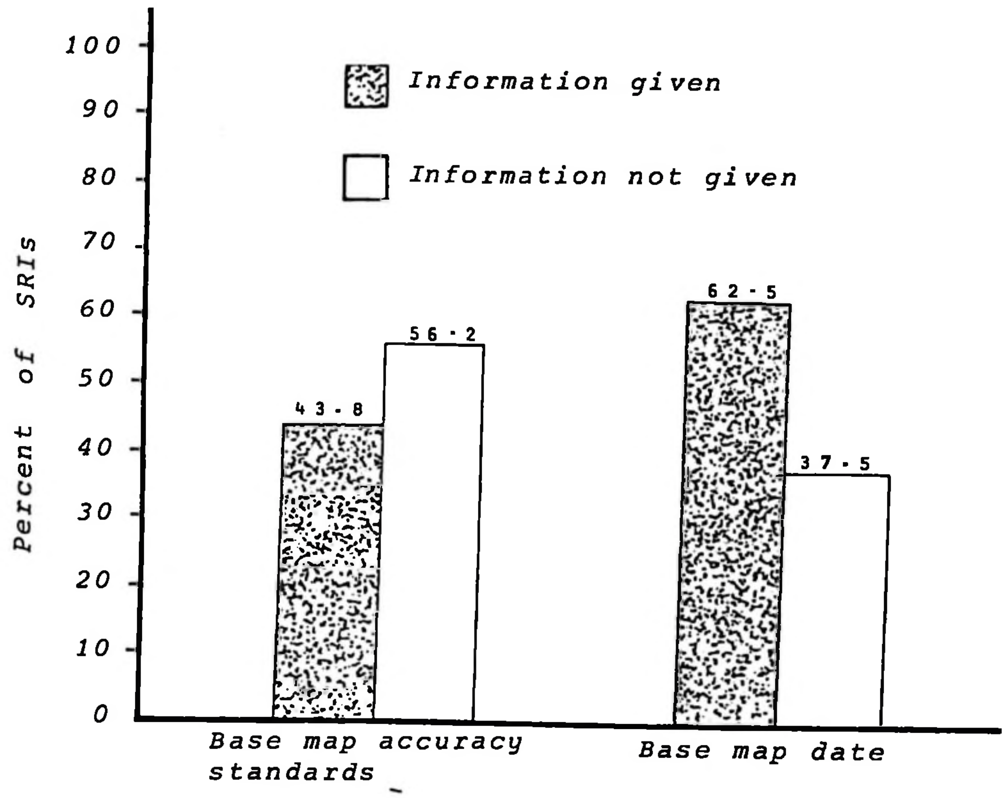
Base maps/documents	*No. of SRIs*	*% based on the 176 SRIs*
1. Aerial photos/aerial photo mosaics	*107**	*60.8*
2. Topographic maps	*83*	*47.2*
3. Geographic maps	*14*	*8.0*
4. Geological maps	*14*	*8.0*
5. Climatological maps	*11*	*6.3*
6. Ecological maps	*11*	*6.3*
7. Other soil maps	*9*	*5.1*
8. Cadastral and site plans	*6*	*3.4*
9. Satellite imageries	*2*	*1.1*
10. Land use maps	*2*	*1.1*
11. Type of base map/documents not indicated	*6*	*3.4*

**In about 41% of these SRIs, soils information is directly printed on aerial photos and aerial photo mosaics*

Information on base map accuracy standards and base map date

One way of inferring the accuracy of SRI base maps is by checking if information is given in relation to specified accuracy standards implying that the maps have already been tested for compliance with these standards. If a map contains a reference to such standards, the SRI evaluator should accept that the map does indeed meet the standards unless it can be proved otherwise. Unfortunately, the results of the present study (cf. fig. 4.17.) indicate that not many SRIs give this information. Only about 44 % of the studied SRIs (mostly those of the USA and New Zealand) had this information.

Figure 4.17. Availability in SRIs of information on base map accuracy standards and base map date.



Another important information although of limited value when used on its own without using ground truth, is the base map date. In about 63 % of the studied SRIs (cf. figure 4.17.) this information is given. It is surprising that in the rest (about 38 %) this information does not appear.

43.5. Conclusions and recommendations

In relation to methods of determining base map utility

As pointed out, the two methods described above for the determination of base map utility are well correlated and consistent and hence could be used for characterizing SRIs and evaluating their adequacy for different uses. However, the question remains as to which is better than the other and for what reasons. The experience in the present study tells me that the linear method is better for reasons of simplicity, practicality and accuracy. It was observed that with the circular method there are problems of siting and counting ground control features especially when their density is very high. This can easily lead to erroneous results. With the linear method chances of making counting errors are very minimal; and a higher speed of counting is another advantage over the former method. Hence, it is hereby recommended for routine assessment of base map information of SRIs.

In relation to presentation of information on base map standards and base map date.

It was noted with grave concern that many SRIs do not have information related to their compliance with specified base map accuracy standards. In this respect, there is still much room for improvement in future SRIs, and thus SRI elaborators are urged to invest much more effort to that end. Similarly, information on base map date should be considered as an essential part of a SRI.

44. SOME CONCEPTS ON GROUND TRUTH OF SOIL RESOURCE INVENTORIES

44.1. Introduction

Soil resource inventories are based on observations scattered on the landscape. The observations constitute samples that are used to identify soils and estimate proportions of different types of soils. SRI maps reveal the location and pattern of kinds of soils that have been identified by the map legend.

By definition, the ground truth of a SRI is the degree to which the map and legend accurately represent the soilscape (Forbes et al., 1982). There are two ways of expressing the ground truth of a SRI. The first one is by checking the accuracy with which soil boundaries on the map (the delineations) are located in relation to the field boundaries. The second method is by checking the reliability of the information presented in the SRI about the soil at each map point. The first approach concerns boundary errors between delineations while the second one concerns what I have termed identification and determination errors of one or more components of the mapping units. Forbes et al. (1982) have called these, classification errors but I fear confusion may arise in relation with classification sensu stricto as used in pedology. Boundary errors are difficult to detect and quantify, and their determination requires expert judgement by a well trained soil surveyor. Thus checking for identification/determination errors is more commonly preferred. When ground truth of a SRI map is cheked in terms of classification errors, this means that the measure being used is the proportion of the map area in which the reported soils information is substantially correct.

The ground truth is only checked when a SRI is judged to be sufficiently adequate on the other three aspects ie. cartographic attributes, legend and soils report attributes and base map attributes. If these are not sufficiently adequate, there is no point wasting time and money on ground truth since it is checked against information provided by these attributes. Ground truth involves considerable amount of work both in the office and in the field. At least 30 test sites or 1 point per 50 cm2 of map (whichever is greater) must be located and examined in the field (Forbes et al. 1982).

44.2. Ground truth criteria

The criteria for ground truth are generally land and soil characteristics or other attributes of interest to the SRI user, derived from the map legend. A land characteristic is an attribute of the land that can be measured or estimated (FAO, 1976). The characteristics chosen may be the same as those used in map legend evaluation. Although land qualities should be preferable for legend evaluation, by definition these are composite attributes, not directly measurable by ordinary field methods. Thus land characteristics are preferred to land qualities as ground truth criteria.

Ground truth can also be evaluated in terms of a more general standard, such as a soil classification system. In this case the evaluator must use as ground truth criteria all land characteristics that are used as soil differentiae in the classification system.

The procedure of ground truth evaluation starts with setting ground truth criteria from the map legend as stated above. Then sample sites in field have to be selected for testing. These sites constitute a sample drawn from the total population of map locations. At each site, each ground truth criterion is checked against the soil actually found, and the site is scored for ground truth. Finally the results of all samples are combined statistically and assessed in function of a specified adequacy criterion, and the map is accepted or rejected. For further reading on the subject of SRI ground truth, the reader is referred to the works of Beckett and Burrough (1971), Bie and Beckett (1971), Legros (1978), Arnold (1981), Hajek and Steers (1981), Schelling (1981) and Burgess and Webster (1984).

45. OVERALL LEGIBILITY OF SOIL RESOURCE INVENTORIES

The legibility of a SRI map was defined as the ease with which the map user can read the information recorded on the map (§41.1.1). The overall legibility of a SRI does not embrace only the features of the map but also those of the SRI report. Legibility could be a primary factor determining the acceptability of a SRI, and indeed, whether it will be used at all. The following discussion on legibility of SRIs is mostly based on my personal experience while consulting a large and varied collection of soil resource inventories.

45.1. Factors affecting legibility of SRIs

With regard to the SRI map, the following factors appear to play an important role in determining the readability of the document :

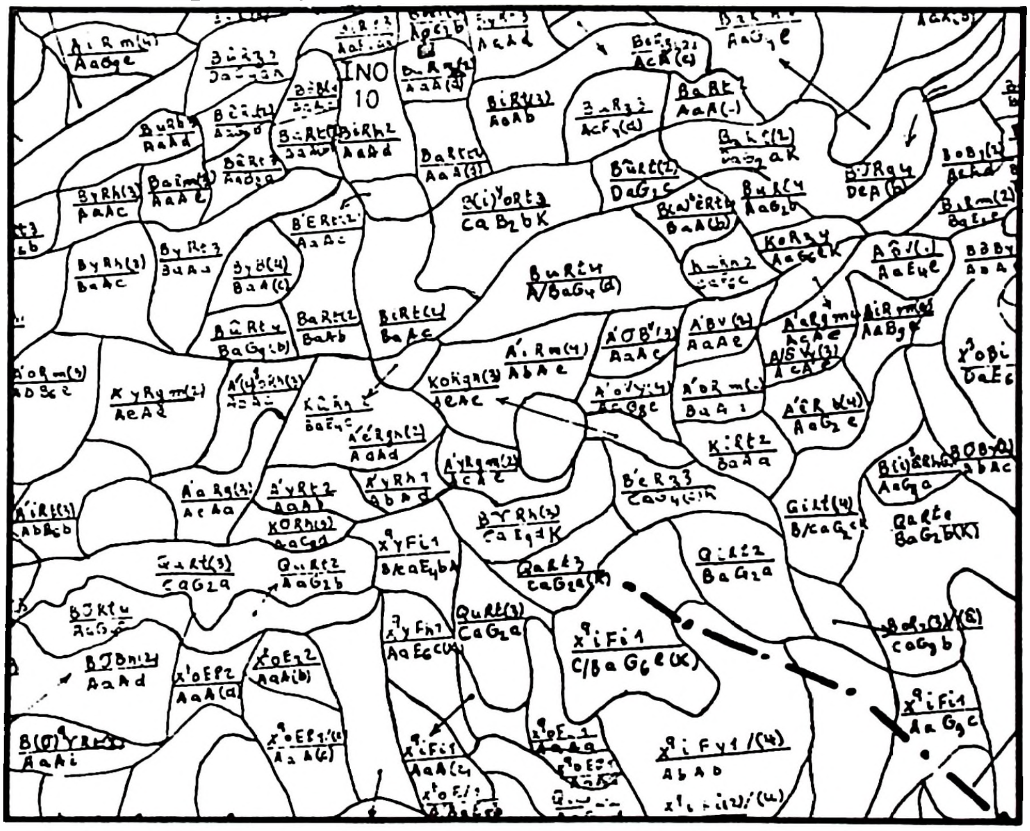
1. The use and choice of colors

When properly used, colors enhance distinction among map delineations or present interpretive groupings. The color itself can also be made to carry information rather than just differentiate one delineation from another. For example in some soil maps of Canada, notably those of Saskatchewan, color carries a parent material connotation, while in others it is used to show physiographic regions. However, it is still worth noting that in colored maps, the choice of colors or patterns to represent delineations can be critical. As pointed out also in §41.1.18, colors which are too dark for example may obliterate substantially ground control detail or important non-soil features which are essential in locating soil areas. Associated stripes of colors in most cases reduce legibility, while low contrast between colors may also to some extent detract from legibility. Logical arrangement of colors with gradients following the pattern of the colors of the rainbow tend to be nice and pleasant. The soil association map of Belgium (Maréchal et Tavernier, 1971) is a good example where this kind of logic is displayed.

2. Symbolization

The prime objective of putting symbols on map delineations is to increase distinction among them and thereby improve the legibility. The type of symbols to be used can be critical. Use of too many digits substantially reduces legibility, especially in the case where the average delineation area of a map is small. Nieuwhuis and Botero (1976) observed that when mapping unit symbols are composed of more than four symbol elements *, map legibility is reduced.

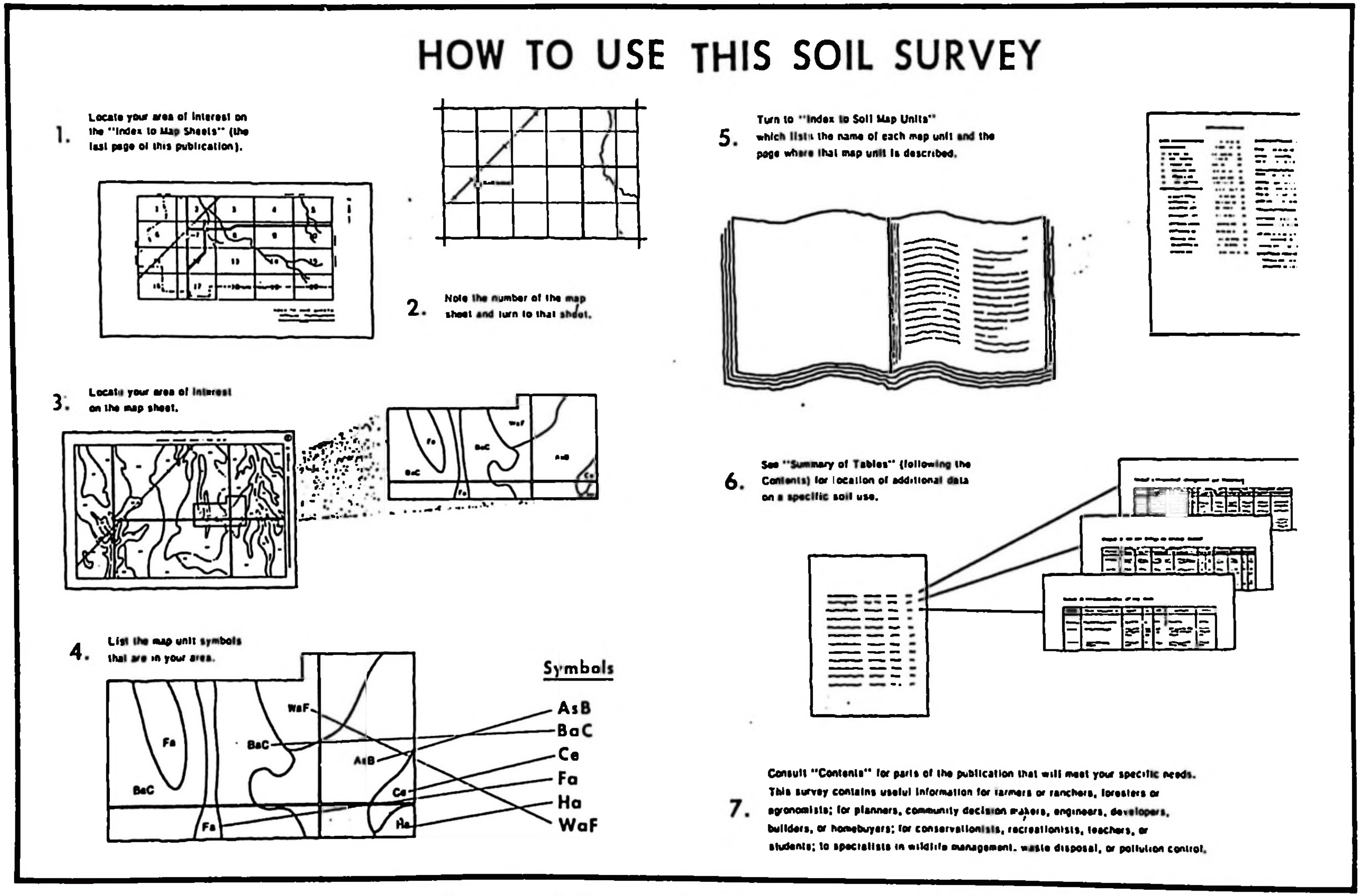
Figure 4.18. An example of a map in which symbolization detracts from legibility (Extracted from Opdecamp, 1983).



Another aspect of symbolization is the structure or configuration of the mapping unit symbols. There should be a logical and systematic arrangement of the symbol elements. The same letter, number or sign should not be used with different meanings for different sections of the soil profile. Figure 4.18. gives an example of a map in which symbolization seems to detract from

* **Symbol element** : each of the letters or numbers or other signs that compose the mapping unit symbol.

Figure 4.19. An example of instructions on how to use a soil survey.



Extracted from Soil Survey of White County, Indiana : USDA-SCS (1982).

legibility. The symbol elements are too numerous and some numbers cannot be differentiated from letters.

3. <u>Non-soil information (eg. ground control detail)</u>

A map has little value for most uses if the soil boundaries cannot be located with reasonable accuracy in relation to landmarks and cadastral reference points (Cline, 1978). Thus features like roads, railway lines and buildings are very important in location and their presentation on a soil map increases its legibility. Insufficient ground control features make a soil map unusable. Contour lines when presented together with other features like roads can also be very useful for locational pruposes. Moreover, contours help to understand how landscapes look like. However, on themselves contours mostly cannot be used for locaiton. When the content of non-soil information presented on a SRI map is too high, this may compete with soil information and result in reduced legibility (cf. figure 4.13).

4. <u>Printing quality of the SRI map</u>

The quality of paper, quality of the print and layout determine the clarity of graphic representation and hence affect the legibility of a SRI map. If the quality is low, the representaion is bound to be unclear, whereas if the quality is high the representation will be clear and legibility is expected to be high. Printing quality affects the report in the same way it affects the SRI map.

5. <u>Density of delineations on the SRI map</u>

This has been well discussed under sections 41.1.8 and 41.1.9. The higher the density, the lower the legibility of the map.

With regard to the SRI report, the following are among the more important factors affecting its legibility :

6. <u>Information on how to use the soil resource inventory</u>

It is logic that when one produces a product that has to be used by others he should give instructions on how to use it. In the case of SRIs there should be no exception. It is a very common experience that many SRIs do not give such instructions (cf. figure 4.20). This is unfortunate because most users of SRIs need this information to facilitate their work. It should not be forgotten that most SRIs are lengthy and very boring to read. The non-soil specialist user wants a quick insight about the soil properties and the possible uses of particular surveyed areas. Even soil scientists need instructions to be able to use SRIs properly and efficiently. Figure 4.19. shows a good example of instructions on how to use a soil survey.

7. <u>Index of mapping units and/or soil classification units</u>

The presence of an index of mapping units and/or soil classification units in a SRI report is very important for legibility, especially where there is a large number of different mapping units. It was my personal experience in the course of this study that it takes substantially less time to read information in a SRI with such an index than in a SRI without. A good example of an index of mapping units is given in table 4.16.

Table 4.16. Index of mapping units as given in the soil survey of White County, Indiana (USDA-SCS, 1982)

index to map units

Ab—Abscota loamy fine sand, occasionally flooded	15
An—Ackerman muck, drained	16
AsA—Alvin fine sandy loam, 0 to 2 percent slopes	16
AsB—Alvin fine sandy loam, 2 to 6 percent slopes	17
AuA—Aubbeenaubbee fine sandy loam, 0 to 1 percent slopes	17
BmA—Brems loamy fine sand, 0 to 2 percent slopes	17
Ca—Chalmers silty clay loam	18
ChB—Chelsea fine sand, 2 to 6 percent slopes	18
ChC—Chelsea fine sand, 6 to 15 percent slopes	19
Ck—Cohoctah fine sandy loam, occasionally flooded	19
CnA—Conover loam, 0 to 1 percent slopes	20
CsA—Crosier silt loam, 0 to 2 percent slopes	20
Dc—Darroch silt loam	21
ElA—Elliott silt loam, 0 to 2 percent slopes	21
FoA—Foresman silt loam, 0 to 2 percent slopes	22
Gf—Gilford fine sandy loam	22
Gv—Gilford fine sandy loam, limestone substratum	23
MaA—Martinsville silt loam, 0 to 2 percent slopes	24
MaB2—Martinsville silt loam, 2 to 6 percent slopes, eroded	24
Mb—Maumee loamy fine sand	25
MoA—Montmorenci loam, 0 to 2 percent slopes	26
Mr—Morocco fine sand	26
MuA—Mundelein silt loam, 0 to 2 percent slopes	27
Mw—Muskego muck	27
OaA—Oakville fine sand, wet substratum, 0 to 3 percent slopes	28
OcB—Octagon silt loam, 2 to 6 percent slopes	28
OcC2—Octagon silt loam, 6 to 12 percent slopes, eroded	29
OeA—Odell loam, 0 to 1 percent slopes	29
OwA—Owosso fine sandy loam, 1 to 3 percent slopes	30
Pa—Pella silty clay loam	30
Ph—Pella silty clay loam, till substratum	31
Pt—Pits, quarries	31
Re—Rensselaer clay loam	31
Rg—Rensselaer loam, sandy substratum	32
Rm—Rensselaer Variant loam	34
RsA—Riddles silt loam, 0 to 2 percent slopes	35
RsB2—Riddles silt loam, 2 to 8 percent slopes, eroded	35
Se—Seafield fine sandy loam	36
Sf—Seafield Variant fine sandy loam	36
SpA—Sparta fine sand, 0 to 3 percent slopes	37
ToA—Toronto silt loam, 0 to 1 percent slopes	37
VaB2—Varna silt loam, 1 to 6 percent slopes, eroded	37
Wa—Watseka loamy fine sand	38
Wh—Whitaker silt loam	38
WnB2—Wingate Variant silt loam, 1 to 6 percent slopes, eroded	39
Wo—Wolcott clay loam	39
Wv—Wolcott clay loam, limestone substratum	41

8. <u>Glossary of specialized terminology and description of range of soil characteristics of mapping units</u>.

In some SRIs it is rather common to find descriptions of mapping units in terminologies that are not defined in the documents. This probably accrues from the general tendency of assuming that these terminologies are universally known and accepted, which is not necessarily true. Such documents pose difficulties to users who may end up guessing what the SRI maker might have meant by a certain terminology.

Another important thing related to above is the description of range of soil characteristics of mapping units which is sometimes not presented in SRIs (cf. figure 4.20). It is quite possible to find in a SRI a description reading as follows : "The soils of this mapping unit are deep to very deep" alone without definition of depth classes somewhere in the report or soil map. With this kind of information it is difficult to make precise comments on the depth characteristics of the mapping unit. Figure 4.17. gives a good example of how range of soil characteristics is defined, with particular reference to New Zealand soils (Leslie, 1980). Such information is appended to the SRI report.

Most SRI institutions have their terminologies defined in their field manuals. However, this should not be taken as an excuse of not including this information in the SRI report. It should always be remembered that most SRI users have no access to the surveyors' field manuals.

9. The kind of attributes used for mapping

The properties used in the definition of mapping units determine to some extent whether or not the information given in a SRI can be understood by the user. The importance of landforms in soil mapping has been stressed by various authors (eg. Sombroek and Van de Weg, 1980). The results of the present study (cf. §42.3.2) indeed show that landforms is among the most frequently used attributes in soil mapping. It has been argued that the spatial distribution of soils is related to landforms at all scales and that soil surveyors make intensive use of landforms and relief as a means of recognizing assumed soil patterns. Furthermore, landforms should also play a major role in the presentation of mapping units, as they facilitate the map user's insight into the spatial variation of the landscape * and soilscape ** concerned.

Table 4.17. An example of how range of some soil chemical properties is defined (Leslie, 1980)

The following ratings of chemical properties are used for New Zealand soils (Blakemore et al., 1977):

RATING	Cation-Exchange Properties						
	CEC (me.%)	Σ cat. (me.%)	BS (%)	Ca (me.%)	Mg (me.%)	K (me.%)	Na (me.%)
very high	> 40	> 25	80-100	> 20	> 7	> 1.2	> 2
high	25-40	15-25	60-80	10-20	3-7	0.8-1.2	0.7-2
medium	12-25	7-15	40-60	5-10	1-3	0.5-0.8	0.3-0.7
low	6-12	3-7	20-40	2-5	0.5-1	0.3-0.5	0.1-0.3
very low	< 6	< 3	< 20	< 2	< 0.5	< 0.3	< 0.1

RATING	pH (1:2.5, soil:water)	Reserve		Organic C (%)	Total N (%)	C/N
		Mg_r (me.%)	K_c (me.%)			
very high	> 9.0 (extremely alkaline))8.4-9.0 (strongly alkaline))7.6-8.3 (moderately alkaline)	> 30	> 0.5	> 20	> 1.0	> 24
high	)7.1-7.5 (slightly alkaline))6.6-7.0 (near neutral)	15-30	0.35-0.5	10-20	0.6-1.0	16-24
medium	)6.0-6.5 (slightly acid))5.3-5.9 (moderately acid)	7-15	0.20-0.35	4-10	0.3-0.6	12-16
low	4.5-5.2 (strongly acid)	3-7	0.10-0.20	2-4	0.1-0.3	10-12
very low	< 4.5 (extremely acid)	< 3	< 0.10	< 2	< 0.1	< 10

RATING	Phosphorus (mg %)			P retention (%)	Adsorbed SO_4 (mg % S)	Tamm Oxalate		
	Total	0.5 M H_2SO_4	Truog			Al (%)	Fe (%)	Si (%)
very high	> 120	> 40	> 5	90-100	> 15	> 3.0	> 2.0	
high	80-120	20-40	3-5	60-90	5-15	1.0-3.0	1.0-2.0	> 0.5
medium	40-80	10-20	2-3	30-60	1.5-5	0.5-1.0	0.5-1.0	0.15-0.5
low	20-40	5-10	1-2	10-30	0.5-1.5	0.2-0.5	0.2-0.5	0.05-0.15
very low	< 20	< 5	< 1	0-10	< 0.5	< 0.2	< 0.2	< 0.05

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* The term landscape as defined by Harris (1968) is "a stretch of country as seen from a particular vantage point". From pedological standpoint, a landscape is a grouping of bodies of soil and non-soil and associated items, including cultural features.

** The term soilscape is a contraction of "soil landscape". Soilscapes are distinct clusters of polypedons in a landscape (Buol et al., 1980). Soil mapping units are working representations of polypedons or soilscapes, depending on the scale of the maps.

10. Availability of interpretive data

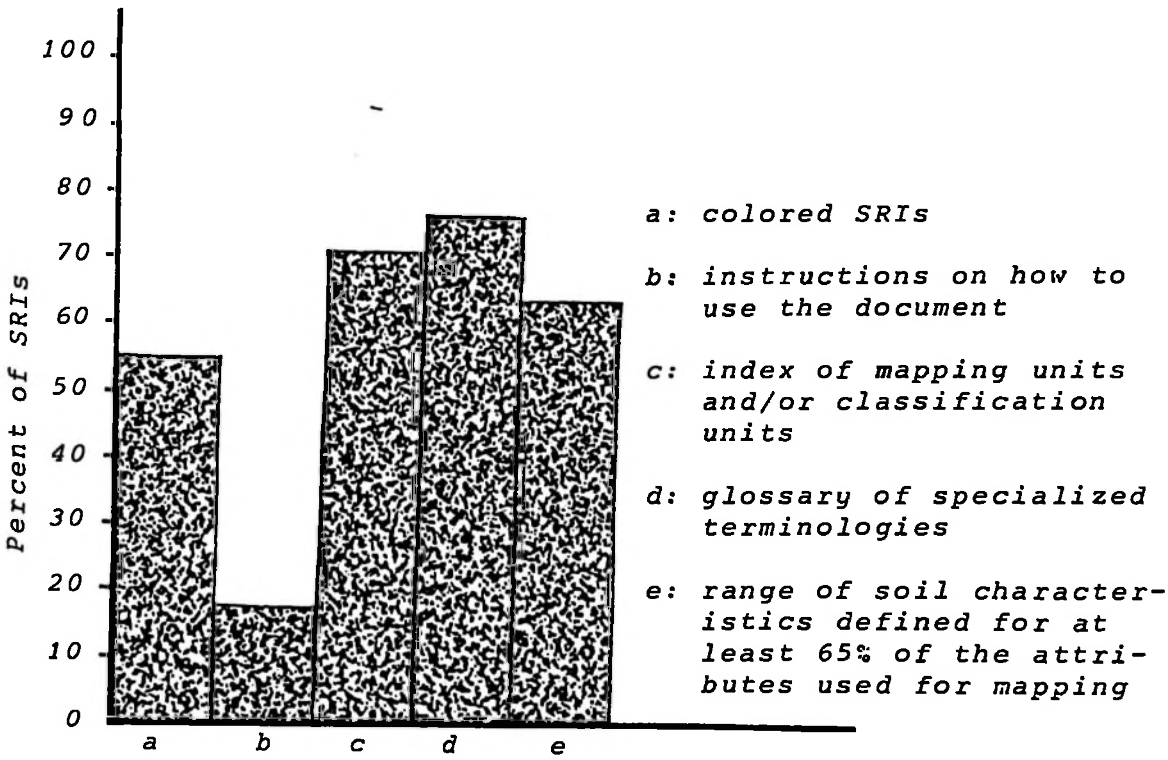
At the level of soil and land management, SRI users would prefer to have interpretive data which they can use more directly. If this information is made available in the SRI report it greatly facilitates the work of the user. In that case he does not have to consult the whole bulk of technical data registered in the report. The present study revealed that 16 % of the studied SRIs did not have any interpretive data (§42.3.5).

45.2. Observations on some legibility aspects of SRIs

1. Procedure

All 176 soil resource inventories were used in this study. It was intended to check the proportion of the documents with (a) colored soil maps, (b) instructions on how to use the inventory, (c) index of mapping units and/or classification units, (d) glossary of specialized terminologies (e) description of range of soil characteristics of mapping units.

Figure 4.20. Frequency distribution of the SRIs in terms of some data related to legibility *



*based on 176 SRIs

2. Results and comments

Figure 4.20. is hereby referred to. It is shown that :

a. Only about 56 % of the studied SRIs had colored maps. Although color substantially improves legibility of SRI maps when properly used; it is an extra cost. This explains why quite a great portion of maps are produced without color.

b. Very few of the documents (about 18%) had instructions on how to use the inventory. It is worthwhile to mention also that most of them (about 94%) are the detailed county inventories of the United States of America. Most SRIs produced in other countries do not normally give this information.

c. Index of mapping units and/or soil classification units was presented in 71 % of the studied SRI.

d. About 77 % of the SRIs had definitions of specialized terminology in form of either the conventional glossary or explanations elsewhere in the documents.

e. About 63 % of the SRIs had descriptions of range of soil characteristics at least for 65 % of the attributes used for mapping. Further comments will be made in chapter 5 in relation to missing data in description of mapping units.

3. Conclusions and recommendations

Based on the parameters of SRI legibility checked in this study, it is concluded that there is still a lot to be done towards improvement in the production and preparation of future soil resource inventories. Soil surveyors and others involved in making these documents are urged to put more effort when and where applicable to improved their presentation so that they can be more easily acceptable to users. Among the most important things :

a. Provision of instructions on how to use the SRIs has for long been neglected. Serious consideration must be made by soil surveyors to include this as one of the routine data.

b. For easiness of reading and understanding a SRI, it is imperative for soil surveyors to include in their documents both glossaries of specialized terminologies and ranges of soil characteristics of mapping units.

c. Also for the sake of improved readability, indices of mapping units/classification units should be provided especially when there are many different mapping units.

Chapter 5

TESTING OF PREDICTIVE ADEQUACY OF SRIs FOR THREE DIFFERENT LAND USES

51. INTRODUCTION

The predictive adequacy of a SRI is hereby defined as the degree to which the document can supply information crucial to the implementation of a given land use. The adjective "predictive" has been used to emphasize the fact that the adequacy being referred to is related to the ability of the document as a whole to predict the performance of land for a given use. A SRI can be adequate for one land use while it may not be for another. Some SRIs may be adequate for several land uses.

In chapter 4 the attributes determining the adequacy of a SRI for a given land use have been discussed at length. In short, they include (1) cartographic attributes, (2) map legend and SRI report attributes, (3) base map quality, and (4) ground truth. Information pertaining to these attributes has to be assessed to be able to judge if a SRI is adequate or not for the given land use. In this chapter, an attempt will be made to demonstrate on how an evaluation of SRI adequacy can be made based on the mentioned attributes for some selected land uses. Due to practical problems, ground truth will not be evaluated despite its importance (cf. §12); hence only the first three attributes will be considered in this assessment. However, it is only for those SRIs qualifying as adequate in the three attributes that ground truth can justifiably be made ultimately.

Three land uses will be discussed in relation to SRI adequacy. They are namely corn production, production of tropical tree crops (oil palm example) and forestry (Eucalyptus deglupta example). As these have different requirements, they will be discussed separately. The approach in this study is such that information pertaining to the adequacy criteria is traced in the SRIs for each selected land use. Acceptable limits are established, on the basis of which a SRI may be accepted or rejected as adequate for the land use in question.

52. ADEQUACY FOR CORN PRODUCTION

Corn production has been selected in this study for reasons of its importance. Corn ranks next to rice and wheat as one of the most important cereals in the world (Ochse et al., 1970). It is eaten by millions of people in Asia, the American tropics and in Africa, and it is used for many other purposes in the Western World. In the United States for example, corn is the chief feed grain; about 90 % of the corn grown there being used for that purpose.

52.1. Materials and methods

In this particular study, 66 SRIs from 17 different countries (cf. table 4.10) have been used. Their selection was based on the following criteria :

(a) they should be multi-purpose in nature, (b) they should be sufficiently detailed (at least semi-detailed) and (c) they should represent as many countries as possible.

1. Adequacy of cartographic attributes

The adequacy of cartographic attributes can be evaluated for general use without considering specific land uses. This is because these attributes concern the readability (legibility) of the SRI map. Whether a SRI map is to be used for checking its predictive adequacy for corn production or for forestry it must in either case be sufficiently legible.

In chapter 4, a rather comprehensive index of map legibility was established. This index, the average legibility index (§41.1.16) was found to be highly correlated with other established cartographic parameters (cf. figure 4.4. : g, o, r, w and y). It was highly correlated with map scale (r=-0.7955), average legible reduction factor (r=-0.9998), average delineation area (r=-0.9779), delineation linear density (r=-0.8883) and with delineation areal density (r=-0.9324). Hence, average legibility index (AvLeId) has been recommended in this study to be used as one of the major yardsticks of estimating the legibility of SRI maps. An AvLeId value of at least 50 is a requirement for legibility. SRI maps with AvLeId values of less than 50 were observed to be difficult to read because their delineations are too small (Msanya, 1984).

Other important considerations :

If the SRI map is colored, the colors should not detract from legibility (§41.1.18). The easiest way to assess this feature is by sampling different areas of the SRI map and observe the color patterns and characteristics. By using the circular test areas that were used for quantification of base map information (cf figure 4.14.I), the SRI map is sampled 10-times. At each sample area it must be ascertained by visual observation without use of special equipment or treatment * that there is sufficient distinction among the presented colors. The requirement is, in at least 85% of the cases the colors should be distinguishable.

Symbols must be legibly presented (§45.1.2) It must be verified that in at least 85% of the cases, this is the situation. The same sampling method as above is employed to randomly locate sample areas of observation on the SRI map. The symbols must be clear and it should be possible to read the various symbol elements.

The three mentioned requirements average legibility index, color legibility and symbol legibility are considered equally important. Hence, they must all be fulfilled as stipulated.

2. Adequacy of map legend attributes

Here the term map legend will be used in the broad sense covering identification, descriptive as well as interpretive legends (cf. §42.1).

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* Spectacle lenses adjusted to the eye sight are not considered special equipment. Here special equipment or treatment would include things like magnifying hand lenses, color densitometers or color scanners.

Adequacy evaluation of map legend starts by checking the information given in the SRI report and on the SRI map; and also on the interpretive map if supplied. Then the homogeneity and specificity of the mapping units (cf. §42.2) are assessed against the requirements for corn production. The procedure is summarized below :

(a) Land suitability table for corn is prepared (cf. table 5.1) showing the limiting soil properties and the acceptable limits.

(b) If the SRI map has 20 or more different mapping units, a part of these is sampled and assessed as a representative of the whole population of mapping units. If there are less than 20 mapping units, all are assessed. Sampling is also inevitable where the number of mapping units is less than 20 and the percent area proportions of the various mapping units are not given.

Point count method for sampling mapping units and determining their composition classes

(c) To enable the determination of the homogeneity and specificity of the various mapping units, their percentage proportions are determined by a point-count sampling method using a 2.5 cm-radius circle drawn on a clear acetate inside which is drawn a grid of 20 points (cf. figure 5.1). The acetate is thrown 10-times at random on a SRI map, and each time all mapping unit symbols covered by the circle are listed (cf. appendix 5), followed by a count of the grid points superimposed over each mapping unit. Parts of mapping units truncated by the circle are also included as full counts. Then same mapping units are grouped together and the percent proportion of the map area represented by each mapping unit-(Mi) is calculated by dividing the number of grid points representing a particular mapping unit by the total number of points counted for all mapping units and multiplied by 100.

(d) Information given in the SRI on the mapping units is controlled against the requirements for corn and the composition classes of the sampled mapping units are established. The <u>composition classes</u> which **combine aspects of both homogeneity and specificity are defined below :**

i. **<u>Uniform-suitable (U-S)</u>**: those mapping units which are considered uniform, ie. they contain ≤ 15% inclusions, and some or all their soil properties described are limiting to the land use.

ii. **<u>Uniform-limiting (U-L)</u>**: those mapping units which are considered uniform, ie. they contain ≤ 15 % inclusions, and some or all their soil properties described are limiting to the land use.

iii. **<u>Nonuniform-predominantly suitable (N-PS):</u>** those mapping units which contain > 15 % inclusions, and the soil properties of the predominant soils of the mapping unit are suitable for the land use.

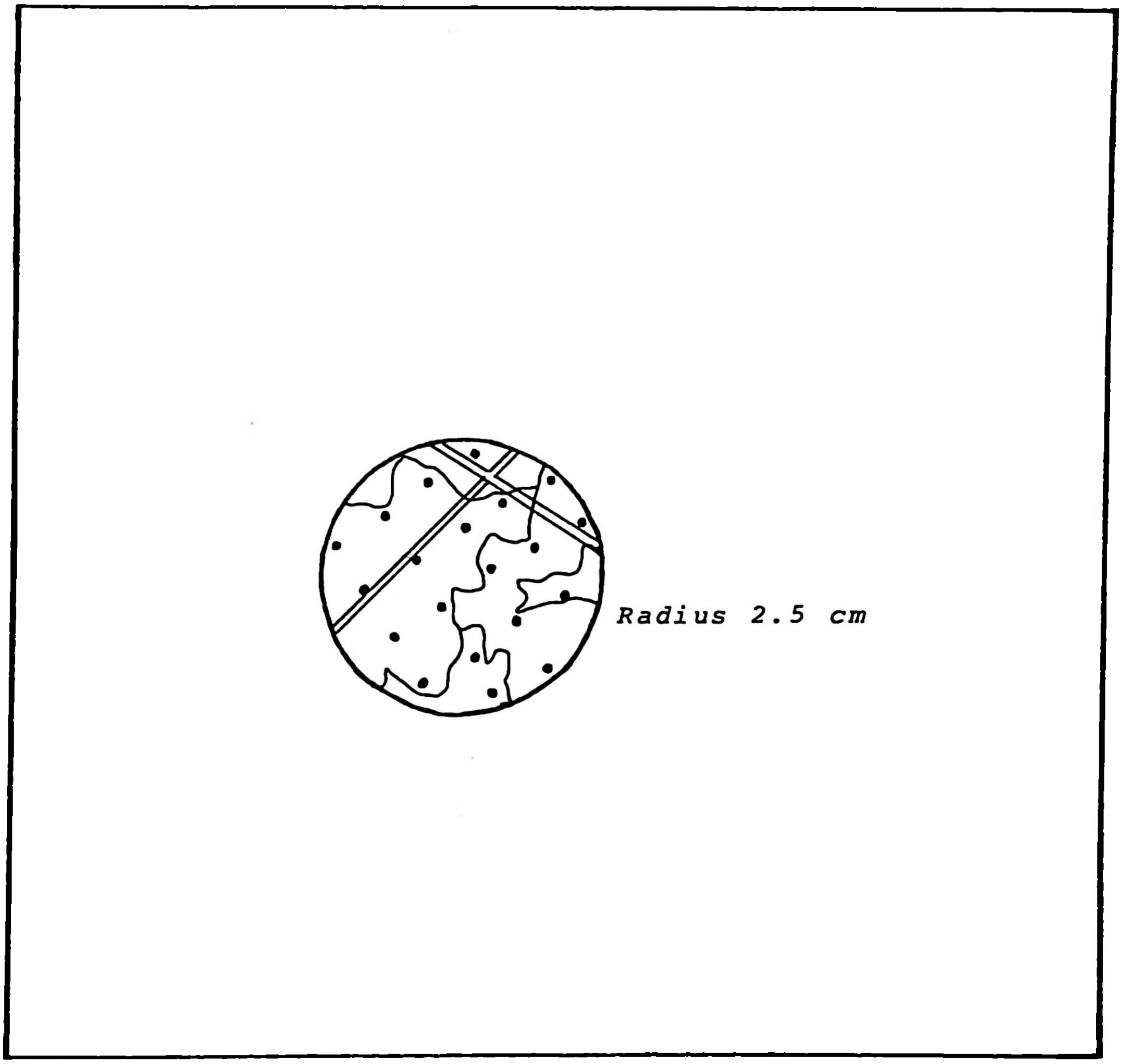
iv. **<u>Nonuniform-predominantly limiting-(N-PL)</u>**: those mapping units which contain > 15 % inclusions, and the soil properties of the predominant' soils of the mapping unit are limiting to the land use.

Table 5.1. Limiting soil properties for corn production under shifting cultivation including mixed cropping with cassava, grain legumes etc. *

Properties to be evaluated	*Critical limits*
1. Topography (slope)	*Not more than 30%*
2. Drainage	*Not more poorly drained than imperfectly drained*
3. Flooding	*Not more than occasional light flooding*
4. Texture	*Not heavier than 70% clay*
5. Stoniness	*Not more than 40% by volume weighted average of the upper 50 cm*
6. Effective soil depth	*Not less than 40 cm*
7. Cation exchange capacity (CEC)	*Not less than 16 meq/100 g clay; no net positive charges*
8. Base saturation (BS)	*Not less than 35% in the surface horizons*
9. Organic matter (OM)	*Not less than 1% in the surface horizons*

**Prepared mostly from SRI Study Group (1978, draft) and Sys (1980)*

Figure 5.1. Grid points in a 2.5 cm-radius circle for estimating % proportions of mapping units (NB : Dimensions are not to scale)



v. Unknown (X): those mapping units (a) whose soil properties are not adequately described to classify them as either suitable or limiting, or (b) whose amount of undescribed inclusions is $>$ 40 % * , or (c) whose percent purity is not given and the described properties of the inclusions cannot classify them into the same class of suitable or limiting as the dominant soil.

(e) To each mapping unit, a mapping unit description adequacy coefficient (Ci) (cf. appendix 5) is assigned depending on the mapping unit composition class it belongs to. All mapping units with X composition are given a coefficient of 0; the rest are given a coefficient of 1. The overall legend description adequacy (OLDA) for each SRI is computed as follows :

% OLDA = Σ (MiCi), where Mi is the % proportion of each mapping unit and Ci its mapping unit description adequacy coefficient.

(f) The following interpretation of description adequacy has been suggested based on the % OLDA :

% OLDA more than 85 : High
% OLDA between 60 and 85 : Medium
% OLDA less than 60 : Low (unacceptable)

These classes have been suggested based on the experience in this study, and so far in literature this subject is not covered. The limits given here therefore remain tentative subject to revision with further studies. However, the logic behind the proposed limits is that, it was strongly felt that it would be very expensive to improve a SRI with a % OLDA value of less than 60.

3. Adequacy of base map attributes

In chapter 4, several possible criteria to assess the quality of base map information were described and elaborated (cf. §43.2). As pointed out, not all of them can rationally be used in a routine method for assessing the adequacy of base maps for given land uses. Some criteria are too subjective and difficult to quantify, while others are relatively unimportant.

Since base maps are more concerned with location of points and areas, criteria related to these will be more emphasized. Hence, it is hereby stressed that for a base map to be adequate for a site specific land use, it must first of all be referred to specified accuracy standards indicating that it complies with these standards. Secondly, the average base map linear information density (AvBmLnInDn) should be at least 2 and at most 25 (cf. table 4.14). Alternatively, the average base map areal information density (AvBmArInDn) should be at least 2 and at most 30 (cf. table 4.12).

Another important requirement is that base map information must be clearly different from soils information. The circular test areas used for quantification of base map information (cf. figure 4.14) can also be used to randomly sample areas on the map where this requirement can be checked. At each point of

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* In most soil surveys the maximum amount of undescribed inclusions allowed for mapping units is 40 %

of observation it should be verified that there is no confusion between base map information and soils information. The requirement is that in at least 85 % of the cases this is the situation.

For site specific purposes, the adequacy of base map information can be evaluated in general terms as it is not expected to vary in function of the land uses in question.

52.2. Results and discussion

1. Cartographic attributes

Table 5.2 gives the frequency distribution of the 66 SRIs in terms of the stipulated adequacy criteria for cartographic attributes. It is shown that the studied SRI maps are all adequate in terms of the average legibility index (AvLeId) and the clarity of symbols. In the case of colored maps, it has also been observed that they are all adequate as far as color distinctions are concerned. In totality it can be said that all the studied SRIs are adequate in terms of cartographic attributes (cf. appendix 8.1).

Table 5.2. Frequency distribution of the studied SRIs in function of the adequacy criteria for cartographic attributes *

SRI maps / *Adequacy criteria*	*Colored 22*	*Non-colored 44*
Average legibility index (AvLeId) ≥ 50	*22(100%)*	*44(100%)*
In case of colored SRI maps, colors distinguishable in at least 85% of cases	*22(100%)*	*N.A.*
Symbols clear and symbol elements readable in at least 85% of cases	*22(100%)*	*44(100%)*

**Based on 66 SRIs (cf. table 4.10); N.A.= not applicable*

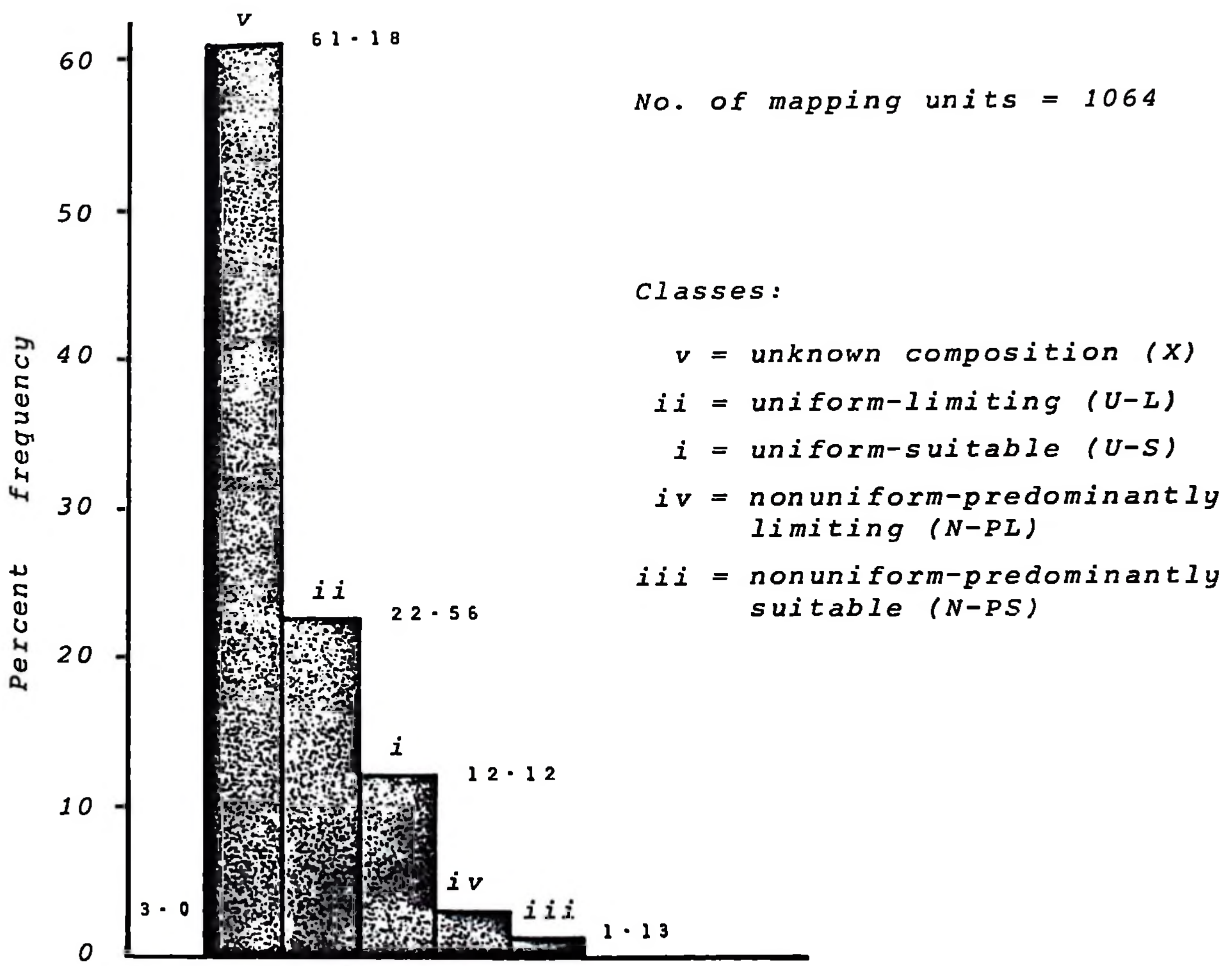
2. Map legend attributes

The predictive adequacy of the information given in map legends with reference to corn production has been checked for 1064 mapping units extracted from the 66 detailed and semi-detailed SRIs (cf. table 4.10).

a. Composition classes of the mapping units

The mapping units were analysed for their composition classes by consulting the information given on them and controlling it using the requirements for corn production given in table 5.1. The results are presented in figure 5.2. The percent frequencies of the composition classes are arranged in order of decreasing magnitude. It is revealed that 651 mapping units (about 61 % of total) belong to the unknown class of composition. This can be attributed mostly to the fact that purity of mapping units is not defined or not fully described. As shown in table 5.3., in 585 mapping units (about 55 % of total) information on purity is not given. This implies that about 90 % of the mapping units are of unknown composition because in the first place their purity is not given. In chapter 4, it was generally observed that in many SRIs this information is missing or is vaguely presented (cf. table 4.11).

Figure 5.2. Frequency distribution of the mapping unit composition classes in relation to corn production



The information on soil depth, slope, stoniness and flooding are to a much lesser extent frequently missing. Experience also shows that sometimes they are presented qualitatively and hence cannot stand a quantitative assessment in such cases.

c. <u>Overall map legend description adequacy</u>

The adequacy of the information given in map legends was checked for the 66 SRIs following the procedure given in § 52.1.2. The overall legend description adequacy (OLDA) was calculated for each SRI map, the results of which are presented in appendix 6 and summarized in table 5.4. According to the criteria put forward, quite a large number of the documents (about 70 %) are of low adequacy and hence inadequate for predicting the performance of corn. Only about 30 % of the SRIs had acceptable adequacy ie. with a % OLDA value of at least 60. These include about 18 % of high adequacy and about 12 % of medium adequacy.

Table 5.4. Classification of the studied SRIs according to the predictive adequacy of their map legends for corn production *

Adequacy classes	*No. of SRIs*	*% frequency*
High adequacy *% OLDA > 85*	*12*	*18.2*
Medium adequacy *% OLDA 60 - 85*	*8*	*12.1*
Low adequacy (unacceptable) *% OLDA < 60*	*46*	*69.7*

**Based on 66 SRIs*

3. Base map attributes (see also appendix 7).

Table 5.5. presents the frequency distribution of the studied SRIs with respect to the adequacy criteria for base map attributes. In all the documents, base map information is clearly separated from soils information. In about 85 % of the SRIs, the density of base map information is ideal as indicated by the values of average base map linear information density (AvBmLnInDn) (cf. table 4.14). The most limiting criterion is the base map accuracy standards (cf. § 43.4.2) which is presented only in about 64 % of the documents. As indicated in appendix 8.1., the three criteria are met in combination only in 38 documents (57.6 %). These are the SRIs that could be considered totally adequate as far as base map information is concerned.

4. Predictive adequacy scores of the studied SRIs for corn production

The last stage of adequacy evaluation involves the assignment of what I have termed SRI Predictive Adequacy Score (SPAS) to each document. First, each individual attribute is given its score : + standing for pass and - standing for fail; and where a requirement is not applicable N.A. notation is given and this is equivalent to a pass score. In order that a document may have a pass score at the SPAS level, it must have passed in all the individual attributes.

Table 5.5. Frequency distribution of the studied SRIs in relation to the adequacy criteria for base map attributes *

Adequacy criteria	*No. of SRIs*	*Percent frequency*
Base map accuracy standards given	*42*	*63.6*
AvBmLnInDn 2 - 25 or AvBmArInDn 2 - 30	*56*	*84.8*
Base map information clearly separated from soils information in at least 85% of cases	*66*	*100.0*

* *Based on 66 SRIs (cf. table 4.10.)*

This means that these attributes are considered equally important and a 'fail' score in anyone of them implies a fail too at the SPAS level. Appendix 8.1. presents the predictive adequacy scores of the studied SRIs with respect to corn production. Only 18 documents (about 27.3 %) have pass scores at the SPAS level, meaning that they are the ones adequate in all the criteria applied, and that they can be used to predict conditions related to the performance of corn. The rest (about 72.7 %) have 'fail' scores by not meeting one or more of the stipulated criteria.

53. ADEQUACY FOR TROPICAL TREE CROPS (Oil palm example)

Oil palm is a very important oil crop, providing edible oil or raw materials for the fat industry. Of all oil-bearing plants, it is the highest yielding (Corley et al., 1976 and Hartley, 1984). It is grown commercially in Africa, Equatorial America, South East Asia and the South Pacific, and on a small scale in other areas. Oil palm industry has been expanding rapidly over the years. In 1968 palm oil represented about 6 % of World trade in edible/soap fats and oils; in 1976 about 10 to 11 %, and in 1980 it was expected to rise to over 14

% (Corley et al., 1976). Another important advantage of the oil palm over most other oil crops is the fact that it is a perennial plant, and hence, in contrast to annual crops, gives complete ground coverage and efficient light interception throughout the year. Also as a tropical crop it has a longer growing season even in areas with a moderate dry season, than temperate crops.

53.1. Materials and methods

The same materials and methods applied for corn (cf. §52.1.) are used here. The findings obtained in that particular section for cartographic attributes and base map attributes will remain the same here as they are not expected to vary in function of land use. This means that only map legend attributes will now be assessed, the results of which will be combined with the already established ones of cartographic and base map attributes to obtain the SRI Predictive Adequacy Scores (SPAS) for oil palm production (cf. appendix 8.2).

Adequacy of map legend attributes for oil palm production

(a) Land suitability for oil palm was prepared (cf. table 5.6) showing the limiting soil properties and the acceptable limits.

(b) The same mapping units sampled for the adequacy evaluation for corn are analyzed here following exactly the same procedure.

53.2. Results and discussion

1. Cartographic attributes (same as for corn production)

2. Map legend attributes

a. Composition classes of the mapping units

Figure 5.3. presents the frequency distribution of the mapping unit composition classes in relation to oil palm production. It can be seen that the results are very similar to those obtained for corn production. About 61 % of the mapping units also belong to the class of unknown composition. Only slight differences are observed. There is a slight decrease in number of uniform-limiting (U-L) mapping units and a concomitant increase in number of uniform-suitable (U-S) ones. The similarity observed in this analysis can be explained by the fact that the two land uses in question have the same number of criteria and similar requirements. The slight increase in number of U-S mapping units has resulted from the fact that some criteria eg. base saturation and organic matter content are more relaxed in the case of oil palm than for corn, thereby allowing some U-L mapping units to become suitable.

b. Missing data in description of mapping units

The observations made here are exactly the same as the ones on corn production.

c. Overall map legend description adequacy

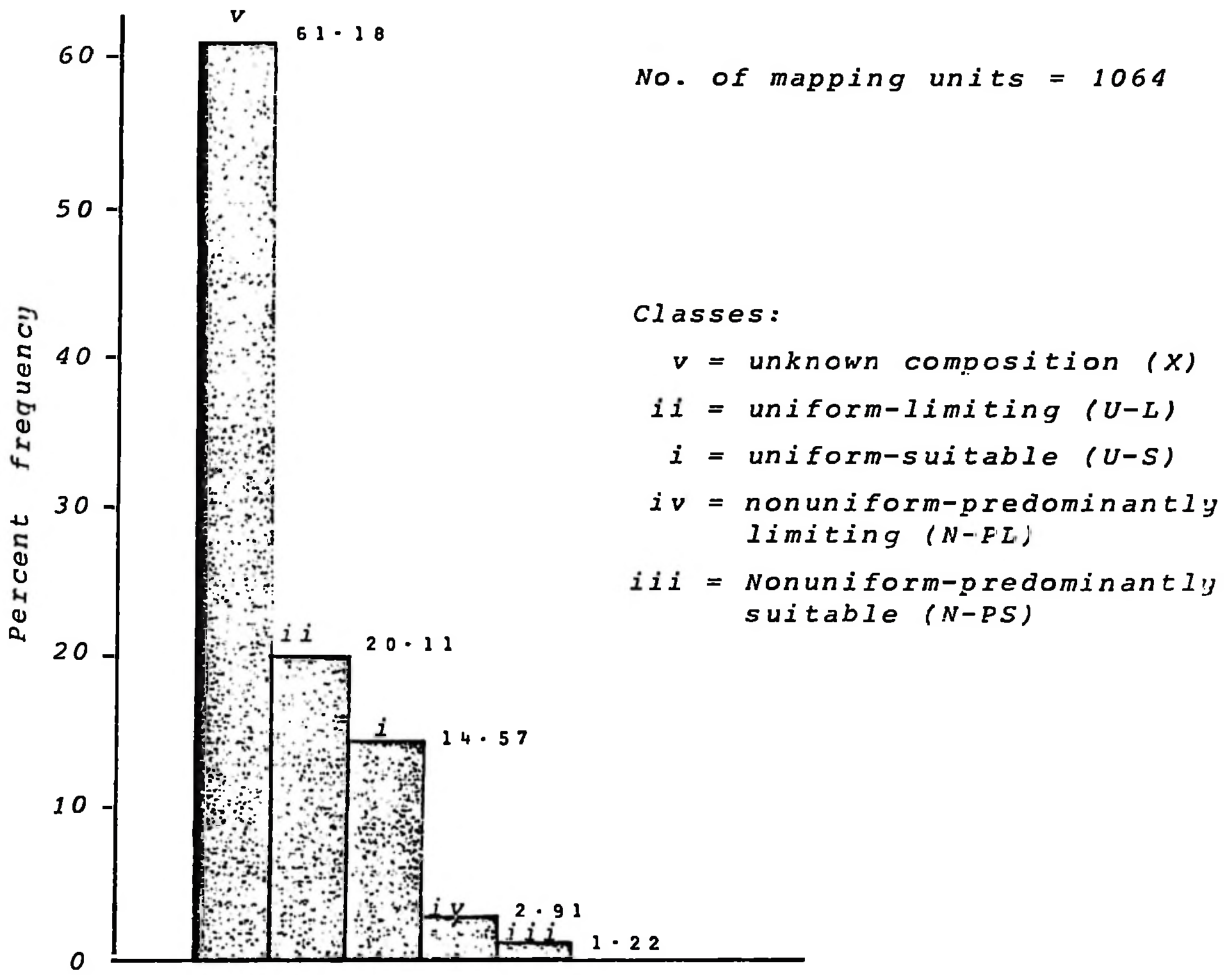
The adequacy of the information given in map legends was checked for oil palm production and the results are presented in appendix 6 and summarized in table 5.7. For the same reason given earlier, the results are exactly the same as those for corn production.

Table 5.6. Limiting soil properties for tropical tree crops (Oil palm example)*

Properties to be evaluated	*Critical limits*
1. Topography (slope)	*Not more than 30%*
2. Drainage	*Not more poorly drained than imperfectly drained*
3. Flooding	*Not more than slight flooding*
4. Texture	*Not lighter than sandy loam*
5. Stoniness	*Not more than 75% by volume weighted average of the upper 50 cm*
6. Effective soil depth	*Not less than 50 cm*
7. Cation exchange capacity (CEC)	*Not less than 16 meq/100 g clay; no net positive charge*
8. Base saturation (BS)	*Not less than 15% in the surface horizons*
9. Organic matter (OM)	*Not less than 0.8% in the surface horizons*

After Sys (1976; 1980)

Figure 5.3. Frequency distribution of the mapping unit composition classes in relation to oil palm production.



3. Base map attributes (same as for corn production)

4. Predictive adequacy scores of the studied SRIs for oil palm production

The SRI predictive adequacy scores ((SPAS) were assigned to each document (cf. appendix 8.2.) the same way as it was done for corn, in function of the individual attributes used as adequacy criteria. The results are exactly the same as those obtained for corn, undoubtedly because the number of criteria in both land uses is the same. Only 18 documents (27.3 %) have pass scores at the SPAS level, meaning that they are adequate in all the criteria stipulated for oil palm production.

Table 5.7. Classification of the studied SRIs according to the predictive adequacy of their map legends for oil palm production*

*Table 5. 7. Classification of the studied SRIs according to the predictive adequacy of their map legends for oil palm production**

Adequacy classes	*No. of SRIs*	*% frequency*
High adequacy		
% OLDA > 85	*12*	*18.2*
Medium adequacy		
% OLDA 60 - 85	*8*	*12.1*
Low adequacy (unacceptable)		
% OLDA < 60	*46*	*69.7*

**Based on 66 SRIs*

54. ADEQUACY FOR FORESTRY (Eucalyptus deglupta)

Wood is one of man's most important resources and its importance in a world of limited resources will almost certainly increase. Supplies of wood are renewable; it has a low energy requirement for processing despite the increasing mechanization of forest operations and the environmental impact of its procurement and ultimate disposal are less than that of most other materials (Hillis and Brown, 1984). The world demand for forest products is increasing because of increases in population and standards of living. The utilization of more land for wood production would increase supply, but land is also increasingly required for other purposes. Consequently, larger and larger proportions of the forested areas must be devoted to intensively managed, fast growing species to meet the need for wood for a widening range of purposes. In tropical regions Eucalyptus deglupta is the fastest wood producer known. It shrives quite well even under conditions of low soil fertility and water stress.

54.1. Materials and methods

The same materials and methods used for corn and oil palm are employed here. The findings obtained for cartographic attributes and base map attributes in the case of corn (§52.2.1 and §52.2.3) have also been carried over to Eucalyptus deglupta as they are not expected to vary. This implies also that in this case only map legend attributes will be assessed and the results will be combined with the already established ones of cartographic and base map attributes to obtain the SRI Predictive Adequacy Scores (SPAS) for production of Eucalyptus deglupta (cf. appendix 8.3).

Adequacy of map legend attributes for production of Eucalyptus Deglupta

(a) Land suitability table for Eucalyptus deglupta has been prepared (cf. table 5.8.) showing the limiting soil properties and the acceptable limits.

(b) The same mapping units sampled and used for the adequacy evaluation for corn and oil palm are analyzed here following exactly the same procedure.

Table 5.8. Limiting soil properties for intensively managed forestry (with reference to Eucalyptus deglupta)*

Properties to be evaluated	*Critical limits*
1. Flooding	*Areas of severe flooding to be delineated*
2. Drainage	*No waterlogging and poor drainage*
3. Effective soil depth	*Not less than 50 cm*

**Prepared from SRI Study Group (1978) draft, and Hillis and Brown,(1984)*

54.2. Results and discussion

1. Cartographic attributes (same as for corn and oil palm production)

2. Map legend attributes

a. Composition classes of the mapping units

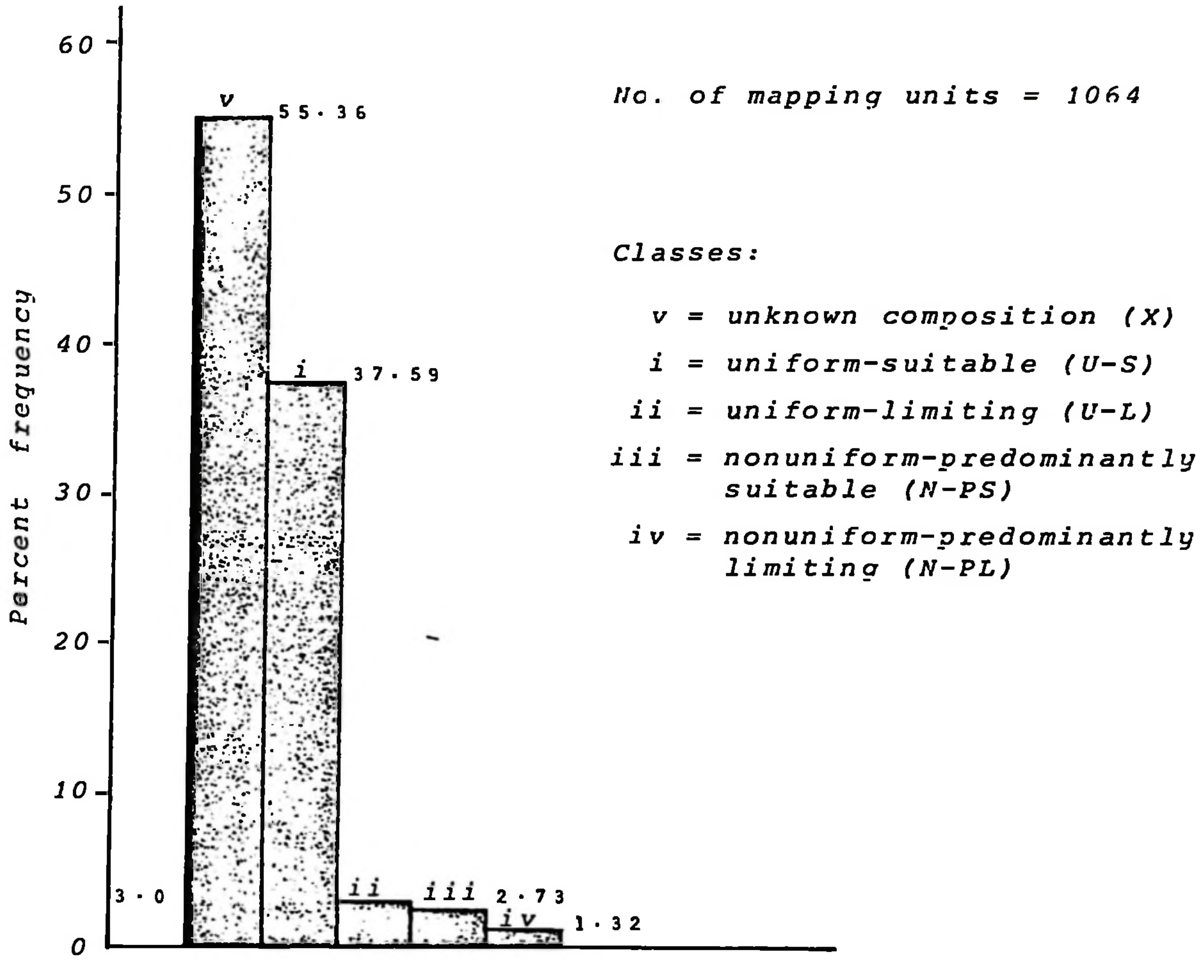
Figure 5.4. gives the frequency distribution of the mapping unit composition classes in respect of production of Eucalyptus deglupta. The results are quite different from those obtained for corn and oil palm. There is a substantial decrease in the number of unknown mapping units. Moreover, there is a quite remarkable increase in uniform-limiting ones. The differences displayed in this case owe their explanation to the fact that the adequacy criteria for production of Eucalyptus deglupta are much fewer when compared to those for corn and oil palm production.

b. Missing data in description of mapping units

Table 5.9. presents the missing data with respect to the requirements for production of Eucalyptus deglupta. It is indicated that fewer number of attributes are missing than in the case of corn and oil palm production. Again this accrues from the fact that the adequacy criteria for Eucalyptus deglupta

are also fewer than those for the other two land uses. Apart from purity of mapping units, information on flooding is the most frequently missing, followed by information on soil depth, and the least missing is information on drainage.

Figure 5.4. Frequency distribution of the mapping unit composition classes in relation to production of Eucalyptus deglupta.



c. Overall map legend description adequacy

The overall legend description adequacy (OLDA) values have been determined for the studied SRIs (cf. appendix 6) in respect of the requirements for production of Eucalyptus deglupta. The results are summarized in table 5.10. They are quite different from those obtained for corn and oil palm. There is a substantial increase in the number of SRIs with high adequacy in terms of legend description, accompanied with a substantial drop in those with medium adequacy. There is a slight drop in the number of low adequacy documents. In totality, about 33 % of the documents have acceptable adequacy (compared to 30 % in the other land uses). The improvement in OLDA values can also be attributed to the very same fact that the criteria used for Eucalyptus deglupta are much fewer than those for corn and oil palm.

55. CONCLUSIONS

The following conclusions can be made from the results of this study :

a. All the studied SRIs are adequate for the three land uses, as far as cartographic attributes are concerned.

b. As for map legend attributes, only 30 % of the documents have acceptable adequacy for corn and oil palm production.

c. About 58 % of the SRIs are adequate with respect to base map attributes for all the three land uses.

d. When all the individual adequacy criteria are considered together, only about 27 % of the documents can be considered completely adequate for predicting performance of corn and oil palm; and about 30 % adequate for Ecalyptus deglupta. The results on SRI predictive adequacy for corn and oil palm are identical due to the fact that the number of adequacy criteria used in the assessment is the same. A greater number of SRIs is adequate for production of Eucalyptus deglupta than for corn and oil palm because the former land use has fewer adequacy criteria than the latter.

e. As far as map legend attributes are concerned, one of the most limiting data is the information on purity of mapping units which is often lacking in SRIs. Other frequently missing data include information on CEC, BS and OM for which it looks as if they are left out with anticipation that they can be deduced from other given properties.

f. As for base map attributes, the most limiting criterion is the information on base map accuracy standards which is presented only in about 64 % of the studied SRIs.

56. PRELIMINARY STUDY ON THE ADEQUACY OF EXISTING SRIs FOR THE PREDICTION OF SOIL EROSION HAZARDS

56.1. Introduction

Soil erosion is essentially a smoothing or levelling process, with soil and rock particles being carried, rolled, or washed down by the force of gravity (Hudson, 1971). The major agents of erosion include water, temperature changes and living organisms. Distinction is normally made between geological and accelerated erosion. The former takes place very slowly and the passage of time is hardly noticeable, and even minutely small or incredibly slow changes become significant only over a long period of time. On the other hand, accelerated erosion (erosion sensu stricto) which is the focus in this study, is in excess of geological erosion and is induced by man's activities which have brought about changes in natural cover and soil conditions. Fundamentally, soil erosion should be regarded as a result of the incorrect use of the land which fails to protect it adequately from the erosive forces of wind and rain (Olembo, 1983).

Soil is an essential support of human life both in relation to food supply and production of fibre and shelter. Hence the loss through erosion and/or degradation of its productive power can seriously affect the development and progress of a nation. The importance of soil erosion and degradation world-wide has been noted with great concern, a fact that inspired more than a decade ago the United Nations Environment Programme and the Food and Agriculture Organization to initiate jointly the planning of a world survey of soil degradation (FAO, 1975).

The rate of soil erosion is a function of the following factors :

a. the erosivity of the climate : This is the potential ability of the climate to cause soil erosion. In the case of water erosion, erosivity is related to the amount and intensity of the rainfall and hence its kinetic energy; and in the case of wind erosion to wind velocity.

b. the erodibility of the soil : This is the vulnerability or susceptibility of the soil to be attacked by the climate. This depends on such soil factors as texture, structure, organic matter content and permeability.

c. the topography : In this case the slope gradient and slope length are important components.

d. the amount of vegetative cover under natural conditions or under agricultural and pastoral situations. In the latter two cases, the degree of protection provided by the farming system used has to be put into consideration.

Soil resource inventories being by definition any documents that describe the attributes and spatial distribution of soils, could be useful in the prediction of soil erosion hazards and hence sould be used to guide future land use and soil management. The usefulness of such documents in predicting soil erosion hazards will depend on the adequacy of the information registered in them; in this particular case the adequacy of a SRI being the degree to which the document gives information crucial to the prediction of soil erosion hazards.

The objective of this study is to find out to what extent already existing soil resource inventories give information that could be used in predicting soil erosion hazards.

56.2. Materials and methods

Fifty soil resource inventories of detailed and semi-detailed levels from 18 countries (cf. table 5.11.) were used in this study. These were selected from a collection of 176 published documents; the selection being roughly based on scale, countries and availability of SRIs. It was intended that reasonably detailed SRIs (scale 1/50,000) should be used and should be as much as possible representing different countries.

The availability in these documents of information important for the prediction of soil erosion hazards was used as the only criterion of their adequacy for this particular use. Thus information on climate, topography (slope gradient and slope length), soil texture, soil structure, organic matter content, permeability and vegetation/land use was systematically analysed in the SRIs to see if these attributes are sufficiently described to allow the prediction of soil erosion hazards. The first attempt on this assessment was done on a relatively fewer documents (32 SRIs) and the results are reported elsewhere (Msanya et al., 1986b).

56.3. Results and discussion

1. Information on climate

Table 5.12. shows the climatic attributes described in the studied SRIs. Rainfall, temperature and winds are among the more important components of climate crucial for soil erosion. All documents had elaborate information on rainfall. About 4 % had no information on temperature while about 52 % had no information at all on aspects of winds. In the latter case, only in about 19 % of the SRIs it was indicated that information on winds was not available in the meteorological stations at the time of inventory. Considering the three major components of climate crucial for the stated use, only 48 % of the studied SRIs are considered as completely adequate.

Other climatic factors also described in the documents include relative humidity (in 48 % of SRIs), insolation (in 24 % of SRIs) and evaporation/evapotranspiration (in 22 % of SRIs).

2. Information on topography

As far as soil erosion is concerned, slope (gradient) and slope length are the most crucial elements of topography. Table 5.13. presents the availability of information on topography for the studied SRIs. In all documents, slope is well described for the various mapping units. On the other hand, slope length is not described or cannot be estimated in about 58 % of the documents. In this case, no topographic information (ie. contour lines) is plotted with the soils information or even appended to the SRIs. This means that as far as information on topography is concerned, only about 42 % of the SRIs are completely adequate.

Table 5.11. Map scales and sources of the SRIs used in the study*

Publication scale	Source of SRIs	No. of SRIs	% of SRIs in each scale
1/2,000	New Zealand	1	2
1/2,400	Nigeria	1	2
1/2,500	Kenya	1	2
1/5,000	Cameroon	1	8
	Kenya	1	
	Nigeria	1	
	Zambia	1	
1/8,000	New Zealand	1	2
1/9,000	Tanzania	1	2
1/10,000	Kenya	2	14
	New Zealand	1	
	Nigeria	1	
	Tanzania	1	
	Thailand	1	
	Zambia	1	
1/12,500	Thailand	1	2
1/15,000	New Zealand	2	4
1/15,840	New Zealand	1	8
	Nigeria	1	
	USA (Indiana)	1	
	USA (New York)	1	
1/20,000	Belgium	2	16
	Cameroon	1	
	Nigeria	1	
	Thailand	1	
	USA (Alabama)	1	
	USA (Indiana)	1	
	USA (Kansas)	1	
1/22,000	Cameroon	1	2
1/24,000	USA (Alabama)	1	4
	USA (Hawaii)	1	
1/25,000	Britain	1	4
	Malaysia	1	
1/30,000	New Zealand	1	2
1/31,680	New Zealand	1	2
1/40,000	Burundi	1	4
	Dominica	1	
1/50,000	Canada	1	20
	Jamaica	2	
	Kenya	1	
	Papua New Guinea	1	
	Sierra Leone	1	
	Swaziland	1	
	Tanzania	2	
	Zambia	1	

*based on 50 SRIs from 18 countries

Table 5.12. Availability of climatic data based on 50 SRIs

Component of climate	Yes	No
1. Rainfall	50 (100%)	0 (0%)
2. Temperature	48 (96%)	2 (4%)
3. Winds	24 (48%)	*26 (52%)
Others:		
4. Relative humidity	24 (48%)	26 (52%)
5. Insolation	12 (24%)	38 (76%)
6. Evaporation/ evapotranspiration	11 (22%)	39 (78%)

**Only in about 19% of these SRIs it was indicated that data on winds were not available*

3. Information on vegetation and soil properties (cf. fig. 5.5)

The information on vegetation/land use is rather well narrated in all the studied SRIs. Soil texture has been well described for the various mapping units in all the documents. Soil structure and organic matter content are described respectively in 46 SRIs (92 %) and 48 SRIs (96 %). Information which is commonly lacking in the documents is permeability which was not recorded in 32 SRIs (64 %). Thus strictly speaking, only 36 % of the SRIs are completely adequate as far as this property is concerned. However, in about 97 % of the documents in which this information is missing, it is possible to roughly estimate it using other soil properties eg. soil texture and soil structure. In that respect, 49 SRIs (98 %) could casually be considered adequate in terms of this property.

4. Interpretive data on soil erosion hazards

Although when considering individual crucial attributes quite a big portion of the SRIs (eg. 58 % for slope length) were not completely adequate for the prediction of soil erosion hazards, the good news is that in 6 documents (28.6 %) estimates of soil erosion hazards are given in the case where data on slope length was also given and in 62 % of the documents in which slope length could not be determined (cf. table 5.13). This, consequently has increased the percent of completely adequate SRIs to about 78.

Figure 5.5. Availability of information on vegetation and soil properties based on 50 SRIs.

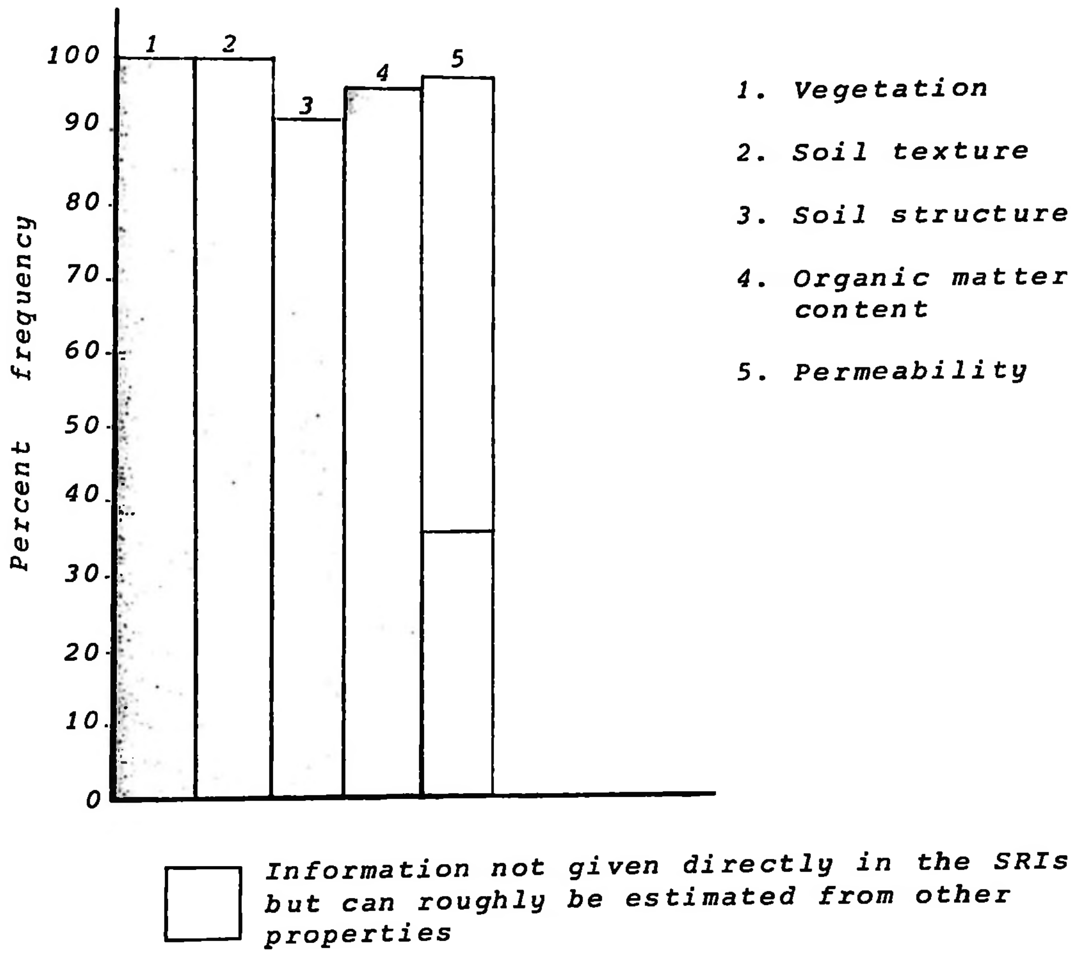


Table 5.13. Availability of information on topography and erosion hazards based on 50 SRIs.

	1. Slope		2. Slope length			
	Yes 50(100%)	No 0(0%)	Yes 21(42%)		No 29(58%)	
			Yes	No	Yes	No
+ Estimates of soil erosion hazards			6(28.6%)	15(71.4%)	18(62.1%)	11(37.9%)

56.4. Conclusions and recommendations

From this study it can be concluded that :

a. Quite a great portion of the documents could be considered adequate for the prediction of soil erosion hazards. In 24 SRIs (48 %) interpretive data on erosion hazards was directly given for the various mapping units, in which case they qualify as adequate for the use in question even without considering the individual attributes of adequacy assessment. However, it is worthwhile to bear in mind that the results of the adequacy assessment are true only when the documents have no limitations on other important attributes such as cartographic attributes, quality of base map for location, ground truth etc. which are not considered here.

b. Assessment of the SRIs considering the individual crucial attributes reveals that

i - Although information on climate is given in all the documents, aspects of winds are frequently not given. More emphasis on description of winds as an important component of climate is deemed necessary to increase the predictive ability of SRIs for soil and land management.

ii - Information given on topography is limited by the lack of contour lines printed directly with the soils information or the lack of contour maps even as appendices to the soil maps. To be able to get a clear impression of the topography, it will be advisable to print soils data directly on topographic maps. In this way, slope direction, slope form and slope length can also be estimated from such maps. Topographic base maps should be preferred to even good photomosaic maps.

iii - Information on vegetation and/or land use is rather well narrated in the SRIs.

iv - Information on soil properties is quite adequate in most SRIs except for permeability which is often not described. Although in many cases it is possible to estimate it using other properties, it is still better to have the direct measurements determined and recorded in the SRIs.

Chapter 6

QUESTIONNAIRES TO SOIL SURVEYORS AND TO USERS OF SOIL MAPS AND REPORTS

61. THE QUESTIONNAIRE TO SOIL SURVEYORS

61.1. Introduction

Many soil surveys have been made in different parts of the world by different people and organizations with different schools of thought. Hence, different methodologies have inevitably been employed, leading to the production of a wide range of soil resource inventories. Beckett and Bie (1978) have ascertained that even within one country soil survey procedures can vary very widely.

Since the methodologies used in soil survey are not completely standardized, and moreover are not in many cases wholly documented in the soil resource inventories themselves (Msanya, 1986 - personal observation), comparative studies of these documents may face some problems. The experiences of soil surveyors in terms of the different survey procedures employed in function of objectives and the factors related to the survey area cannot easily be tapped.

The present study aims at finding out crucial information from soil surveyors on the methodologies used in soil survey and on the different norms governing decisions made in the process of soil and/or land inventorization.

61.2. Materials and methods

The questionnaire used in this study is reproduced as appendix 9. Questions were mostly focussed at information related to methodologies employed in soil surveys. 178 copies of the questionnaire were mailed world-wide to soil surveyors whose addresses were sought through professional association membership lists and through personal contacts with individuals and institutions.

After 14 months since the date of dispatch, the number of completed questionnaires received was 70 (39 % of the total mailed) from 40 countries. All these have been used in the present investigation. Tables 6.1. and 6.2. and figures 6.1. and 6.2. characterize the population of respondents of the questionnaire. Basically all the respondents are soil surveyors with or without other specializations in earth science. They include employees of government soil survey institutes (34 %), universities (29 %), ministries or departments of agriculture (20 %), research institutes/experimental stations (14 %) and private soil survey consultancy firms (3 %). About 54 % of the respondents are senior professionals while about 37 % are of mid-career status and about 9 % are of junior level.

Table 6.1. Countries in which questionnaire was answered*

Country	% of respondents	Country	% of respondents
Australia	1.4	Malawi	1.4
Belgium	8.6	Mozambique	1.4
Botswana	2.9	Netherlands	8.6
Brazil	2.9	New Zealand	7.1
Britain	1.4	Nigeria	2.9
Burundi	5.7	Papua New Guinea	2.9
Cameroon	4.3	Peru	1.4
Canada	1.4	Philippines	2.9
Chile	2.9	Sudan	1.4
Denmark	2.9	Syria	1.4
Ethiopia	1.4	Taiwan	1.4
Finland	1.4	Tanzania	1.4
France	1.4	Togo	1.4
Greece	1.4	Turkey	1.4
Hong Kong	1.4	Uruguay	1.4
Indonesia	4.3	USA	2.9
Israel	1.4	West Germany	1.4
Italy	1.4	Yemen	1.4
Kenya	1.4	Zaire	1.4
Luxembourg	1.4	Zimbabwe	2.9

* Total no. of countries = 40, No. of respondents = 70

Table 6.2. Fields of specialization of respondents of questionnaire.

Specialization	*% of respondents*
Soil survey/classification	*44.3*
Soil survey/classification + agronomy	*10.0*
Soil survey/classification + agronomy + geography + geomorphology	*4.3*
Soil survey/classification + agronomy + soil microbiology	*5.7*
Soil survey/classification + geography	*4.3*
Soil survey/classification + geography + geomorphology	*5.7*
Soil survey/classification + geology	*4.3*
Soil survey/classification + geomorphology	*7.1*
Soil survey/classification + geomorphology + geology	*4.3*
Soil survey/classification + land use planning	*2.9*
Soil survey/classification + soil chemistry	*2.9*
Soil survey/classification + soil chemistry + soil physics	*4.3*

NB : based on 70 respondents

61.3. Results and discussion

1. Type of soil resource inventories made and their scales

Table 6.3. reveals that five types of SRI have been made by the soil surveyors. It seems that exploratory and reconnaissance surveys and site evaluations are less commonly made when compared to semi-detailed and detailed inventories. For example only 43 % of the respondents had invariably been involved in exploratory surveys, whereas about twice the number had participated in making semi-detailed surveys.

Figure 6.1. Institutions in which respondents of questionnaire are working.

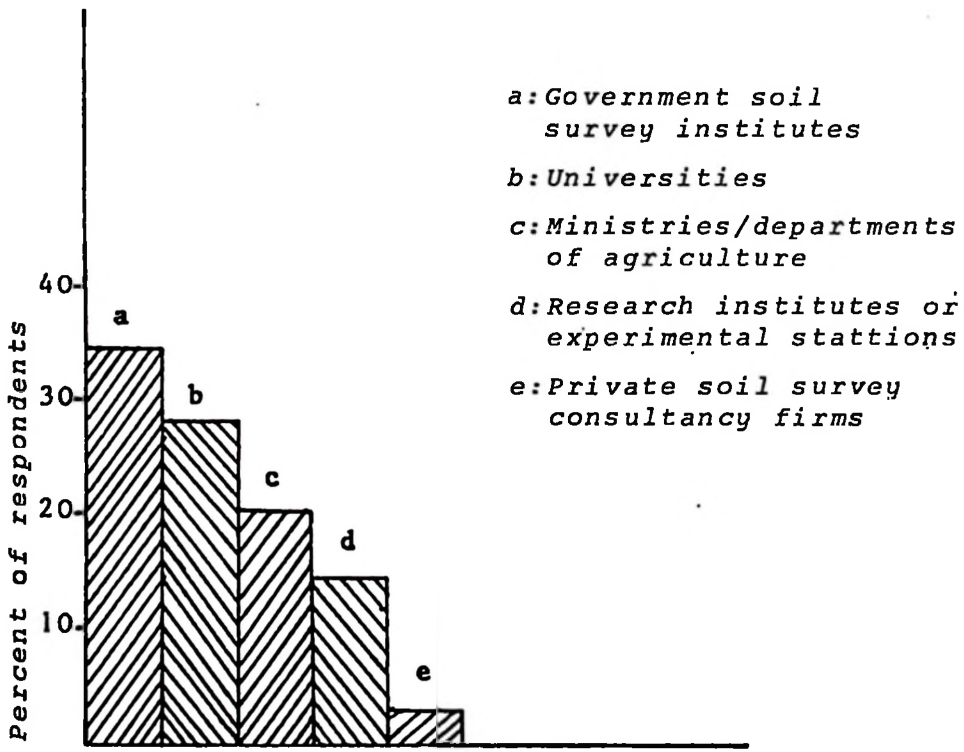
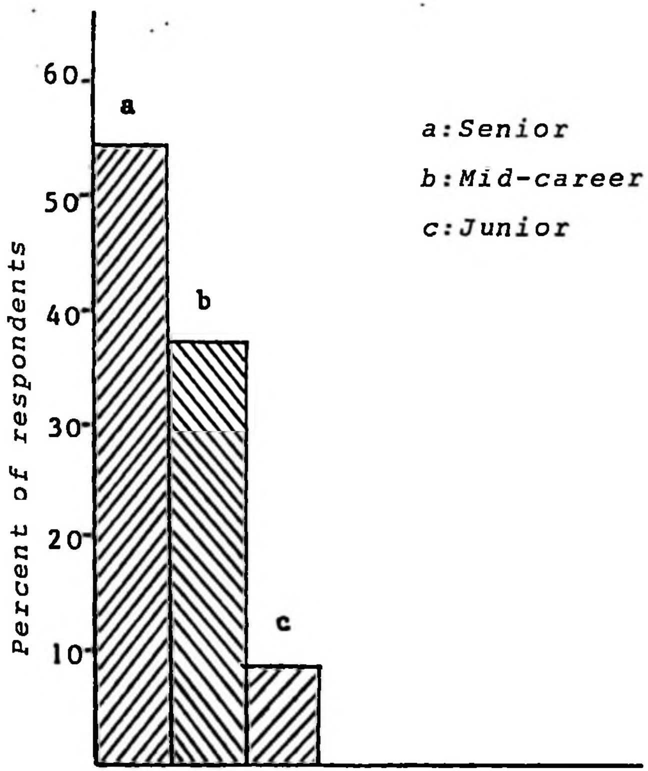


Figure 6.2. Professional levels of respondents of questionnaire



NB. Based on 70 respondents

Table 6.3. Types of soil resource inventory made

SRI	% frequency based on 70 respondents				
	A	F	C	O	N *
1. Site evaluations	4.3	12.9	14.3	34.3	34.3
2. Detailed surveys	11.4	27.1	28.6	15.7	17.1
3. Semi-detailed surveys	14.3	35.7	28.6	7.1	14.3
4. Reconnaissance surveys	10.0	15.7	24.3	21.4	28.6
5. Exploratory surveys	5.7	7.1	7.1	22.9	57.1

*A = always, F = frequently, C = commonly, O = occasionally, N = never

Figure 6.3. confirms that the terminology used to define the different survey intensities in relation to scale is not consistently used by different soil surveyors. There is a lot of overlapping of scales in the various survey intensities. However, it is possible to make the following generalizations :

1. Site evaluations are mostly made at scales ≥1/10,000.

2. Detailed surveys are made at scales between 1/5,000 and 1/20,000.

3. Semi-detailed surveys are mostly made at scales 1/50,000 to 1/63,360. It is also common to find in this category, scales 1/10,000 to 1/25,000.

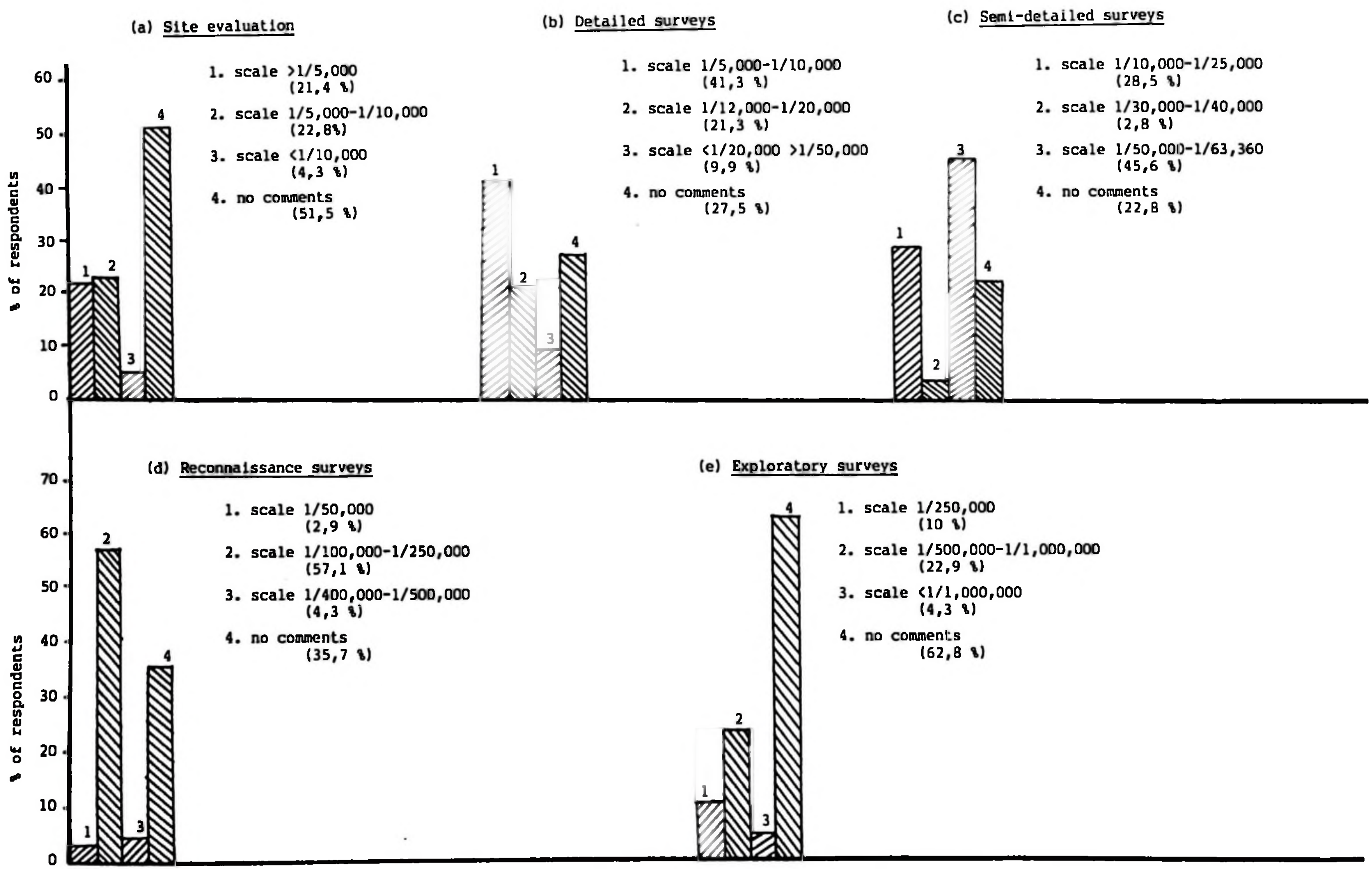
4. Reconnaissance surveys are made at scales between 1/100,000 and 1/250,000, and

5. Exploratory surveys are made at scales 1/500,000 to 1/1,000,000.

2. Forces determining the contents of soil resource inventories

In table 6.4. the forces influencing the nature of SRIs made are presented. To a very large extent, the contents of SRIs are determined by survey institutions/surveyors themselves. This is especially more apparent with site evaluations, detailed surveys, semi-detailed surveys and reconnaissance surveys where at least 50 % of the respondents confirm this trend. Only to a lesser extent, users or persons paying or requesting for SRIs determine the nature of these documents. It is also worthwhile to note that political decisions may influence the nature of SRIs except for site evaluations as indicated by some respondents.

Figure 6.3. Relationship between survey intensity and map scale *



* based on 70 respondents

Table 6.4. Forces determining the nature of SRIs made based on 70 respondents.

Type of SRIs \ Determining forces	Institution's/ surveyor's decision					Person/agency paying or requesting for the SRIs					Political decisions				
	A	F	C	O	N	A	F	C	O	N	A	F	C	O	N *
1. Site evaluations	30.0	17.1	5.7	2.9	44.3	10.0	2.9	4.3	10.0	72.8	0.0	0.0	0.0	0.0	100.0
2. Detailed surveys	34.3	22.9	7.1	4.3	31.4	17.1	8.6	5.7	14.3	54.3	1.4	1.4	2.9	1.4	92.9
3. Semi-detailed surveys	37.1	22.9	8.6	4.3	27.1	7.1	11.4	7.1	15.7	58.7	2.9	0.0	2.9	2.9	91.3
4. Reconnaissance surveys	37.1	27.1	4.3	1.4	30.1	8.6	4.3	2.9	18.6	65.6	1.4	1.4	2.9	1.4	92.9
5. Exploratory surveys	22.9	10.0	2.9	0.0	64.2	5.7	0.0	1.4	2.9	90.0	2.9	1.4	2.9	2.9	89.9

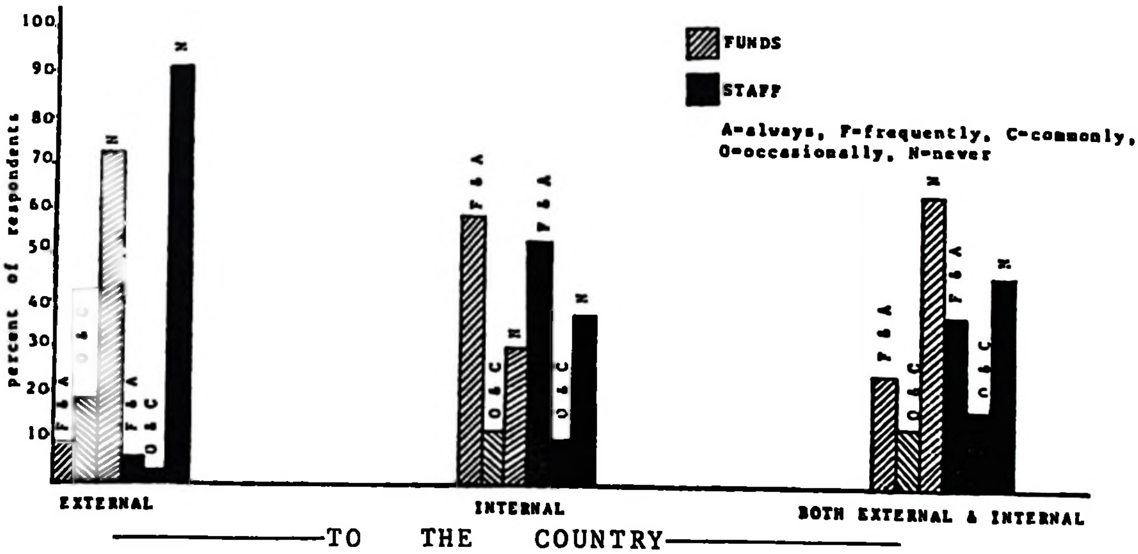
*A = Always, F = frequently, C = commonly, O = occasionally, N = never   NB. figures are in %

3. Funding and staffing of SRI projects

The comments given by the respondents (figure 6.4.) suggest that many SRI projects are funded from within countries. About 70 % of the respondents invariably give this opinion. Only 30 % of them indicate that some of the projects are supported by external funds. It is also disclosed that some projects are jointly funded by internal and external sources.

As regards staffing of projects, a similar trend is given but with relatively more respondents deviating from the view of external source to the one of combined internal and external support.

Figure 6.4. Source of funds and staff for SRI projects based on 70 respondents.



4. Users of soil resource inventories

Table 6.5. is a summary of responses concerning immediate users of the SRIs. It is invariably indicated that the major users include ministries of agriculture and natural resources, private farmers and land owners, engineering departments and state farms. At least 20 % of the respondents give this opinion for all types of SRI except reconnaissance and exploratory surveys. Other minor users of the documents include in order of decreasing magnitude, national planning agencies, military authorities, foreign agro-industrial companies and ministry of education.

Table 6.5. Users of SRIs based on 70 respondents

Users	Type of SRI				
	SE	DS	SDS	RS	Exp.*
1. Ministry of agriculture	41.4	61.4	69.9	62.8	28.6
2. Ministry of natural resources	21.4	34.2	44.3	48.6	20.0
3. Private farmers and land owners	41.4	57.1	44.3	21.5	8.5
4. Engineering departments	25.8	28.6	28.5	21.5	12.9
5. State farms	25.7	35.6	30.1	12.8	10.0
6. National planning agencies	8.6	8.6	14.3	12.8	4.2
7. Military authorities	7.1	8.5	17.1	7.1	5.7
8. Foreign agro-industrial compagnies	4.3	2.8	1.4	0.0	0.0
9. Ministry of Education (secondary schools + universities)	0.0	1.4	2.8	1.4	1.4

* SE = site evaluations, DS = detailed surveys, SDS = semi-detailed surveys, RS = reconnaissance surveys and Exp. = exploratory surveys.
NB. Frequency classes omitted for simplicity; figures in %

Table 6.6. Assessment of utility of SRIs

Type of SRI	% frequency based on 70 respondents				
	A	F	C	O	N*
1. Site evaluations	5.7	12.9	11.4	14.3	55.7
2. Detailed surveys	2.9	11.4	15.7	24.3	45.7
3. Semi-detailed surveys	7.1	11.4	10.0	31.4	40.1
4. Reconnaissance surveys	2.9	4.3	4.3	22.9	65.6
5. Exploratory surveys	1.4	1.4	1.4	11.4	84.4

* A = always, F = frequently, C = commonly, O = occasionally, N = never

5. Assessment of utility of soil resource inventories

The results on the question of whether soil surveyors have been making any attempts to measure the utility of their SRIs is presented in table 6.6. At least 40 % of the respondents have not been doing so. In the cases where assessment of utility of SRIs was made to check if users were satisfied with them or not, emphasis has been put more on site evaluations, detailed surveys and semi-detailed surveys. The least effort was spent on exploratory surveys where only about 84 % of the respondents support this fact.

6. Methods that have been used to monitor utility of SRIs

The methods that have been employed by different people to monitor if users of SRIs are satisfied with these documents or not are presented in table 6.7. Relatively few respondents (less than 25 %) responded to this question. However, the message given by those who responded is clear, and it can be said that the methods were different for the different kinds of SRI. The most common methods that have been used include surveyor-user contacts, use of occasional extension staff, use of questionnaires to users and monitoring of sales and new orders of SRIs as indicated by at least 10 % of respondents except for exploratory surveys. Keeping permanent extension staff in the field to monitor utility of SRIs has been indicated by very few respondents.

Some respondents commented that if clients don't querry them, they assume that they are satisfied with their SRIs.

Table 6.7. Methods of monitoring utility of SRIs based on 70 respondents

Methods	Type of SRI				
	SE	DS	SDS	RS	Exp.*
1. Direct contact between surveyor and user	17.1	20.0	21.5	14.3	8.6
2. Sending occasional extension staff to the field	18.7	24.4	21.4	14.3	5.7
3. Sending questionnaires to users	10.0	17.2	15.7	10.0	1.4
4. Monitoring sales and new orders of SRIs	12.9	15.8	17.2	11.4	2.9
5. Keeping permanent extension staff in the field	7.1	5.7	8.6	2.8	1.4

* SE = site evaluations, DS = detailed surveys, SDS = semi-detailed surveys, RS = reconnaissance surveys and Exp. = exploratory surveys
NB. Frequency classes omitted for simplicity; figures in %

7. Field soil mapping procedures

In table 6.8. the different methods that have been used by soil surveyors in field mapping are presented. The major ones are namely, (1) fixed grid survey, (2) free hand survey and (3) combined fixed grid and free hand survey. A fourth method as indicated by relatively few respondents (less than 15 % in all cases) is one comprising mostly airphoto interpretation (API) and very few field observations. It seems that the field procedures used are a function of the detail of SRI. Roughly speaking it can said that fixed grid mapping is more commonly applied in the more detailed inventories than in reconnaissance and exploratory surveys.

Although free hand survey is also commonly applied in site evaluations and detailed surveys, it is more widely used in semi-detailed, reconnaissance and exploratory surveys. The combined fixed grid and free hand mapping appears to be more common for all but exploratory surveys, while the method of API with very few field observations is mostly for both reconnaissance and exploratory surveys.

Table 6.8. Field soil mapping procedures based on 70 respondents

Procedures / Type of SRIs	Fixed grid			Free-hand survey			Combined fixed grid and free-hand			API* with very few field observations		
	A&F	C&O	N	A&F	C&O	N	A&F	C&O	N	A&F	C&O	N
1. Site evaluations	24.3	8.6	78.5	15.3	14.3	70.4	11.4	12.8	75.8	0.0	4.3	95.7
2. Detailed surveys	32.9	14.3	52.6	16.7	12.8	70.5	15.7	25.7	58.6	2.9	2.9	94.3
3. Semi-detailed surveys	20.0	15.8	64.2	38.6	12.9	48.5	18.5	20.0	61.5	5.6	2.8	91.4
4. Reconnaissance surveys	10.0	8.6	81.4	45.7	5.8	48.5	11.4	7.2	81.4	8.6	2.8	88.6
5. Exploratory surveys	5.8	1.4	92.8	25.7	4.3	70.0	5.7	4.3	90.0	10.0	0.0	90.0

A = always, F = frequently, C = commonly, O = occasionally, N = never; figures in %
* API = airphoto interpretation

8. Determination of purity of mapping units

The results of the question whether or not purity of mapping units was being determined are summarized in table 6.9. The overall picture depicts that quite a big number of surveyors had not been determining purity of mapping units (indicated by at least 43 % of respondents). However, to different degree, purity had been determined for the different types of SRI. Except for exploratory surveys, at least slightly more than 30 % of respondents indicate that purity was being determined. Only less than 20 % of respondents had invariably determined purity of exploratory surveys.

Table 6.9. Determination of purity of mapping units

Type of SRI	% frequency based on 70 respondents *				
	A	F	C	O	N
1. Site evaluations	11.4	8.6	10.0	5.7	64.3
2. Detailed surveys	20.0	10.0	11.4	15.7	42.9
3. Semi-detailed surveys	14.3	11.4	12.9	17.1	44.3
4. Reconnaissance surveys	10.0	7.1	18.6	12.9	51.4
5. Exploratory surveys	2.9	5.7	4.3	5.7	81.4

* A = always, F = frequently, C = commonly, O = occasionally, N = never

9. Purity of mapping units aimed at by soil surveyors

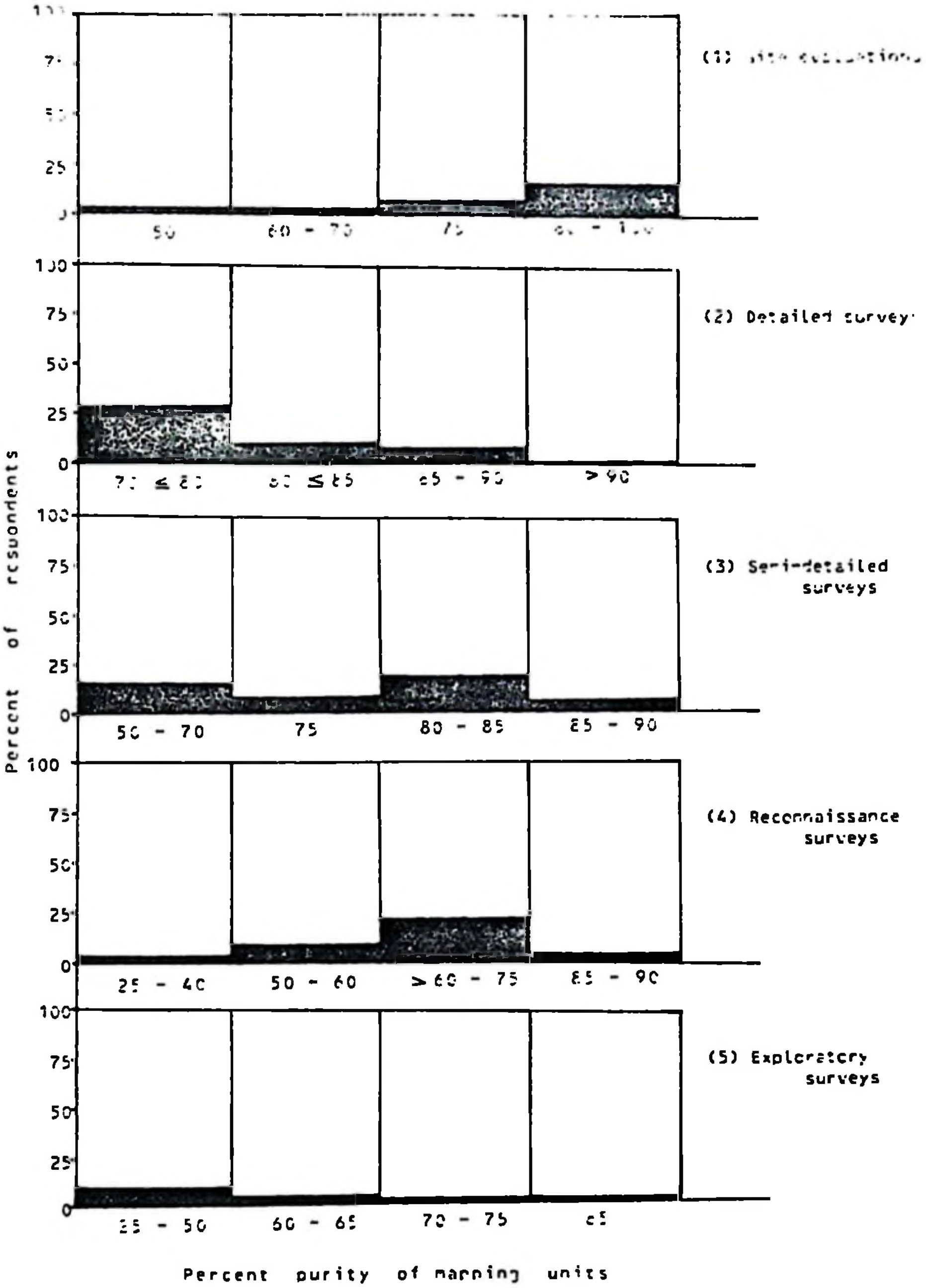
Figure 6.5. presents the values of the average % purity aimed at for mapping units by surveyors in different countries. Some generalizations can be made based on these data. It is shown that the purity aimed at is a function of the nature or detail of the SRI in question. The value is higher for the detailed SRIs than for the less detailed ones.

For site evaluations most respondents indicate a range of values of purity from 75 - 100 %, for detailed surveys 70 - 90 %, for semi-detailed surveys 50 - 85 %, for reconnaissance 50 - 75 % and for exploratory surveys values of 25 - 65 are the commonest.

10. Presentation in SRIs of information on purity of mapping units

One way of assessing the adequacy of SRIs for different uses is by gauging the availability of critical information in these documents. Purity of mapping units is one such critical data. The results on whether or not information on purity of mapping units is included in SRIs are presented in table 6.10. It can be said that many documents don't bear this information as indicated by at least 50 % of the respondents for the different types as indicated by 81 % of the respondents.

Figure 6.5. % purity of mapping units based on 70 respondents



11. Reasons for not determining purity of mapping units

Table 6.11. summarizes the reasons why purity of mapping units is sometimes not determined. Most respondents attribute this to limited time (33 % of respondents) and high cost (30 % of respondents). Some respondents (21.4 %) indicated that it was simply not their habit to determine purity of mapping units while others (12.9 %) did indicate that purity was not so important for

them. A very small portion of respondents (1.4 %) indicated that another reason for not determining purity is that it is already implied by the type of mapping units.

Table 6.10. Presentation of information on purity of mapping units in SRIs

Type of SRI	% frequency based on 70 respondents				*
	A	F	C	O	N
1. Site evaluations	10.0	7.1	4.3	2.6	70.0
2. Detailed surveys	22.9	8.6	2.9	14.3	51.3
3. Semi-detailed surveys	20.0	12.9	4.3	10.0	52.8
4. Reconnaissance surveys	15.7	12.9	5.7	10.0	55.7
5. Exploratory surveys	8.6	2.9	0.0	7.1	81.4

* A = always, F = frequently, C = commonly, O = occasionally, N = never.

12. Extent of using soil maps in different countries

The comments of soil surveyors on the extent of using soil maps in different countries are presented in table 6.12. The documents are used either directly or indirectly through interpretation maps. The results indicate clearly that interpretation maps are more commonly used than the soil maps sensu stricto.

Table 6.11. Reasons for not determining purity of mapping units based on 70 respondents

Reasons	% of respondents	
	Yes	No comments
1. Determination is too costly	30.0	70.0
2. Purity of mapping units is not so important	12.9	87.1
3. Time is too limiting	32.9	67.1
4. Not a habit to determine purity	21.4	78.6
5. Purity is already implied by the type of mapping units	1.4	98.6

Table 6.12. Extent of using soil maps in different countries based on 70 respondents

Type of SRI	Directly used					Use through interpretation maps				
	A	F	C	O	N	A	F	C	O	N*
1. Site evaluations	12.9	14.3	8.6	8.6	55.6	15.7	17.1	5.7	8.6	52.9
2. Detailed surveys	10.0	21.4	15.7	11.4	41.5	12.9	22.9	14.3	12.6	37.3
3. Semi-detailed surveys	7.1	18.6	18.6	11.4	44.3	14.3	24.3	21.4	15.7	24.3
4. Reconnaissance surveys	2.9	11.4	8.6	14.3	62.8	17.1	18.6	15.7	14.3	34.3
5. Exploratory surveys	4.3	8.6	4.3	5.7	77.1	4.3	5.7	4.3	10.0	75.7

*A = always, F = frequently, C = commonly, O = occasionally, N = never NB. figures are in %

Table 6.13. Reasons for not making soil maps in some countries based on 70 respondents

Reasons	% of respondents	
	Yes	No comments
1. The needed information can be obtained from other sources	4.3	95.7
2. There is already enough soils information	4.3	95.7
3. People generally consider soil maps as not being useful	4.3	95.7
4. Soil maps are too complicated	8.6	91.4
5. Soil maps are too expensive to make	2.9	97.1
6. War has been preventing field work	1.4	98.6

13. Reasons for not making soil maps in some countries

In general, very few people (less than 10 %) responded to the question why soil maps are not being made in some countries (cf. table 6.13). This means that there are very few chances that soil maps are not made or only in very few countries this is true. However, it may still be worthwhile to note especially one of the reasons given by the few respondents. About 9 % of the respondents are of the opinion that soil maps are too complicated and this could be a reason for not making soil maps.

Other rather minor reasons include the views that (1) the needed soil information can be obtained from other sources (4.3 % of respondents), (2) there is already enough soils information (4.3 %), (3) people generally consider soil maps as not being useful (4.3 %), and (4) soil maps are too expensive to make (2.9 %).

14. Reasons for not anymore using soil maps in some countries

The reasons why soil maps are not being used in some countries despite their availability are presented in table 6.14. There are two major reasons responsible for the limited use of these documents. They are namely, (1) the complicated nature of soil maps as proposed by about 23 % of respondents, and (2) insufficient knowledge about their existence as indicated by about 21 % of respondents. The former reason was also pointed out as being responsible for the limited production of soil maps in some countries (cf. table 6.13.).

Table 6.14. Reasons for not anymore using soil maps in some countries based on 70 respondents.

Reasons	% of respondents	
	Yes	No comments
1. Soil maps are too complicated	22.9	77.1
2. People have no sufficient knowledge about their existence	21.4	78.6
3. People don't trust soil maps due to previous faulty ones	7.1	92.9
4. The needed information can be obtained from other sources	1.4	98.6
5. Soil maps are too expensive	1.4	98.6
6. People generally don't consider soil maps useful	1.4	98.6

15. Publicity about the existence of soil resource inventories

The responses on the question of publicity of SRIs are summarized in table 6.15. It is invariably indicated that publicity had been made for the various types of SRI. Semi-detailed surveys were the most frequently publicized (indicated by about 66 % of respondents), followed by detailed surveys (about 59 %), then reconnaissance surveys (about 51 %), then site evaluations (about 43 %) and lastly exploratory surveys (about 26 %).

Although publicity was made, most respondents indicated that this was mostly done occasionally. More efforts still ought to be invested in publicizing these documents to increase their use.

Table 6.15. Publicity about the existence of SRIs

Type of SRI	% frequency based on 70 respondents				
	A	F	C	O	N *
1. Site evaluations	1.4	15.7	7.1	18.6	57.2
2. Detailed surveys	7.1	14.3	11.4	25.7	41.5
3. Semi-detailed surveys	12.9	11.4	7.1	34.3	34.3
4. Reconnaissance surveys	7.1	7.1	7.1	30.0	48.7
5. Exploratory surveys	1.4	8.6	2.9	12.9	74.2

* A = always, F = frequently, C = commonly, O = occasionally, N = never

61.4. Conclusions and recommendations

1. The use of the questionnaire as a source of information

The use of the questionnaire has made it possible to find crucial information from soil surveyors regarding methodologies employed in soil surveys. Of course it may be argued that the involvement of only 70 soil surveyors (39 % of the total to whom questionnaire was mailed) may not be adequate to make global generalizations. However, the good thing is that the sample population of respondents used in this study covers 40 different countries, a feature that still makes the study credible as a source of generalized information about soil surveys.

The questionnaire could be further improved by increasing the population size of respondents. Apparently this is not an easy task as could possibly be imagined. It should be borne in mind that it took more than one year to have the mailed response rate of 39 %. Experience elsewhere (Hansen and Richards, 1979 and Valentine et al., 1981) indicate that mailed response rates of 30 % or even slightly less are quite common scores for mailed questionnaires.

At this juncture, the questionnaire used in this study could be recommended to appropriate soil science institutions to carry over the same or simmilar study on even more people with the intention of improving even further the reliability of the derived information. Considering my experience in this kind of work, such institutions are urged to provide travel funds and other facilities to allow physical contacts with the would be respondents. This is envisaged to substantially increase the responserate and save time too.

2. <u>In relation to the information given by the respondents</u>

Some of the information given by the respondents has been noted with much greater concern.

1. It has been disclosed that to a great extent soil surveyors determine the nature of SRIs to be made, and only occasionally do users have the opportunity to determine the nature of these documents. It is hereby recommended that in those cases where users are competent they should be allowed to dictate the nature of the documents that will suit their purpose.

2. Key terminologies and criteria used in soil survey for example survey intensities, field soil mapping procedures and purity of mapping units are not concieved and used consistently. It is thus recommended that soil surveyors should try to standardize such terminologies and criteria to allow easy transfer of information.

3. Many soil surveyors do not monitor the utility of the SRIs they make. It is suggested here that monitoring of utility of SRIs to see if users are satisfied with them or not, should be a responsibility of the soil surveyor or the survey institution.

4. It has been implied that for understandable reasons SRI users prefer interpretation maps to the soil maps sensu stricto. It is therefore recommended that SRI producers should always provide interpretation maps to accompany the soil maps.

5. It has been indicated that soil maps are too complicated for users to understand the information registered in them. Attempts should always be made where possible to make simple legends. The provision of interpretation data as suggested in (4) above, could be another solution.

6. Publicity about SRIs is not sufficiently made. More efforts should be invested in publicizing these documents not only to increase their use but also to prevent duplication of work.

61.5. Summary

A total of 70 respondents (39 %) from 40 different countries replied to a questionnaire about methodologies used in soil surveys. It was indicated by more than 85 % of the respondents that detailed and semi-detailed soil surveys are the most commonly made inventories.

It can be said that some of the terminologies and criteria used in soil surveys are not conceived and used consistently by soil surveyors.

At least 50 % of the respondents indicated that the nature of soil resource inventories (SRIs) made is determined by the surveyors themselves or the survey institutions and only occasionally do SRI users dictate the nature of these documents. Very few respondents did indicate that political decisions can affect the nature of SRIs made.

About 70 % of the respondents invariably indicated that SRI projects are funded and staffed from within countries whereas only 30 % indicated that these projects are supported by external funds and staff. Some projects are funded and staffed by both internal and external sources.

As indicated by at least 20 % of the respondents, except for reconnaissance and exploratory surveys, the most common immediate users of SRIs include ministries of agriculture and natural resources, private farmers and land owners, engineering departments and state farms.

At least 40 % of the respondents had not attempted to monitor utility of their SRIs to see if users are satisfied with them or not. The least effort was spent on exploratory surveys as indicated by 84 % of the respondents. The most common methods of monitoring utility of SRIs as indicated by at least 10 % of respondents (except for exploratory surveys) include surveyor-user contacts, use of questionnaires to users and monitoring of sales and orders of new SRIs.

It was generally indicated that fixed grid mapping is more commonly used in the more detailed inventories than in reconnaissance and exploratory surveys, while free hand surveys are more widely used in detailed, semi-detailed and reconnaissance surveys. Airphoto interpretation with very few field observations is mostly for reconnassance and exploratory surveys.

About 56 % of the respondents indicated that detailed and semi-detailed surveys are the most often used both directly and indirectly through interpretation maps, followed by site evaluations (44 %).

At least 21 % of the respondents indicated that some of the reasons why soil surveys sometimes are not used in some countries despite their availability include the complicated nature of these documents and the insufficient knowledge about their existence. The latter reason is explained by the fact that publicity of SRIs has not sufficiently been made as indicated by quite many of the respondents.

A set of recommendations has been given for improvement of future soil resource inventories.

62. THE QUESTIONNAIRE TO USERS OF SOIL MAPS AND REPORTS

62.1. Introduction

As stated in the USDA Soil Survey Manual (Soil Survey Staff, 1951), the objective of soil surveys is to study soil properties, to describe soils and classify them, and to map their distribution so that predictions can be made about their use and their response to various management practices. Soil surveyors are charged with the responsibility of organizing data into classes for presentation in both soil maps and soil reports. The utility of a soil map is a function of the surveyor's ability and the effort he invests in trying to satisfy users' demands and expectations.

While there is a general agreement about the stated objectives of soil surveys, there is doubt if sufficient use is made of soil survey work (Dudal, 1978). It is often observed that soil data important as a basis for decision making in land use are not utilized. Many times this is thought to be due to various reasons including poor presentation of results, lack of communication between soil scientists and agriculturists, difficulties arising from specialized terminology, inadequate interpretation on the surveyor's side or lack of interest on the side of the planners.

It has also been noted (Cline, 1981 and Valentine et al., 1981) that soil inventories are being used more and more by people who are not soil scientists. Planners, foresters or consulting engineers usually have to include an evaluation of soil information in any of their land use reports or plans, yet only rarely such people have helped in making the maps they use (Valentine et al., 1981). Moreover, whether users of such documents can use them properly or whether these documents offer the users the needed information is a question which needs to be verified. It is therefore the objective of the present study to get a feed-back from users on some aspects of these documents which they have been using. It is envisaged that such feed-back may help identify existing bottle-necks in their use which may eventually send a message to soil surveyors for amelioration in future soil inventories and if possible in existing ones.

62.2. Materials and methods

Appendix 10 is a reproduction of the questionnaire used to get information from users of soil maps and reports. Questions were set with the objective of finding out to what extent soil maps have been used and to identify the problems encountered while using such documents. Copies of the questionnaire were mailed to 274 possible users in different countries whose addresses were sought from professional association membership lists. They included agronomists, foresters, university lecturers, engineers and private farmers. After about 3 months, only 52 replies (19 %) had been received. These were used for a preliminary analysis, the results of which are presented elsewhere (Msanya et al., 1986a and 1987).

Table 6.16. Countries in which questionnaire was answered *

Country	% of respondents	Country	% of respondents
Australia	7.4	Jamaica	2.1
Bangladesh	1.1	Japan	2.1
Belgium	6.4	Kenya	2.1
Botswana	2.1	Netherlands	8.5
Brazil	1.1	New Zealand	4.3
Britain	8.5	Nigeria	1.1
Burundi	1.1	Philippines	1.1
Canada	6.4	Poland	2.1
Chile	2.1	Sudan	1.1
Ciskei	1.1	Syria	1.1
Czechoslovakia	1.1	Taiwan	2.1
Denmark	1.1	Tanzania	1.1
Ethiopia	2.1	Thailand	1.1
France	3.2	Turkey	2.1
Greece	1.1	Uruguay	1.1
India	5.3	USA	9.6
Indonesia	2.1	West Germany	4.3
Ireland	1.1		

* Total no. of countries = 35, No. of respondents = 94

After about 10 months since the date of dispatch, the number of completed questionnaires was 94 (34 % of total mailed) from 35 countries. All these have been used in the present study. Table 6.16. shows the countries from which replies were received and table 6.17. gives a distribution of their fields of specialization. The different institutions in which the respondents were working is given in table 6.18.

Table 6.17. Fields of specialization of respondents of questionnaire *

Specilizations	% of respondents
Agricultural Engineering	1.1
Agronomy	4.3
Forestry	2.1
Geography	2.1
Soil Science	38.3
Agronomy+Soil Science	19.1
Agronomy+Soil Science+Animal Breeding	1.1
Agronomy+Soil Science+Environmental Science	2.1
Agronomy+Soil Science+Extension	1.1
Agronomy+Soil Science+Environmental Science+Extension	1.1
Agronomy+Soil Science+Land reclamation and improvement	1.1
Forestry+Soil Science	5.3
Forestry+Soil Science+Environmental Science	5.3
Forestry+Soil Science+Agronomy	1.1
Forestry+Soil Science+Environmental Science+ Archaeology+Geology	1.1
Soil Science+Environmental Science	3.2
Soil Science+Geography	1.1
Soil Science+Land Reform	1.1
Soil Science+Land use planning	2.1
Soil Science+Research Management	1.1
Soil Science+Horticulture	1.1
Soil Science+Agricultural Engineering	1.1
Soil Science+Agronomy+Forestry+Horticulture	1.1
Soil Science+Environmental Science+Land evaluation+Geomorphology	1.1
Soil Science+Agronomy+Environmental Science+ Extension+Horticulture	1.1

* Based on 94 questionnaires

Table 6.18. Institutions in which respondents of questionnaire are working *

Institutions	% of respondents
1. Ministries of Agriculture	42.6
2. Ministries of Natural Resources including forestry	8.5
3. Ministries of Public Works	1.1
4. Universities	35.1
5. Agricultural Research Institutes	7.4
6. Forest Research Institutes	1.1
7. Private Agricultural Consultancy Firms	4.3

* Based on 94 respondents

62.3. Results and discussion

1. Use of soil maps

95.7 % of the respondents had used soil maps in their professions in one way or another. The 4.3 % who had not used such documents attributed this to the fact that (a) the use of soil maps was not part of their professions and (b) suitable soil maps specific to some professions were not available. As for those who did not respond to the questionnaire, there is no way to ascertain that they had not used soil maps as the questionnaire was open both for those who had used soil maps and those who had not.

2. Objectives of using soil maps

The present study indicates that soil maps have been used with many different objectives and motives (cf. table 6.19.). More than 97 % of the respondents had been using soil maps for locating suitable areas for their professional works. These included agricultural and forest production, soil conservation and studies on environmental pollution and protection. About 14 % had used soil maps for teaching and research while about 13 % strikingly had used them for the sake of getting loans and financial assistance to support their projects. Some of the respondents (about 2 %) had used soil maps for the purposes of soil correlation. Very few had used soil maps with other motives such as preparation of scientific papers, geographical research for national atlases and for preparation of new soil maps (in each case about 1 % of respondents).

3. Use of interpretive information

The aim of soil survey is to supply its ultimate users with the needed information about soils. However, users who are not specialists in soil science may not be able to use directly the information registered on a soil map. This implies that interpretive data for land use would be of more direct use to users.

The present study indicates that quite a great portion of respondents (slightly more than 45 %) had never used interpretation maps in their work (cf. table 6.20.). Only about 5 % had invariably used both interpretive maps completely derived from soil maps and those partly derived from soil maps. This observation may possibly be due to the fact that most of the respondents have a background in soil science and don't necessarily need interpretation maps as such, or it may be a reflection of unavailability of such maps.

Table 6.19. Motives of using soil maps

Objectives	% frequency based on 90 respondents who had used soil maps*				
	A	F	C	O	N
1. Location of suitable areas for professional work/production	36.7	41.1	12.2	7.8	2.2
2. Teaching and research in colleges, universities and in research institutes	3.3	3.3	4.4	3.3	85.7
3. For the sake of securing loans and financial aid from banks and governments	1.1	3.3	4.4	4.4	86.8
4. For soil correlation	0	2.2	0	0	97.8
5. Preparation of scientific papers	0	0	1.1	0	98.9
6. Geographical research for national atlases	1.1	0	0	0	98.9
7. Preparation of new soil maps	0	1.1	0	0	98.9

* A = always, F = frequently, C = commonly, O = occasionally, N = never

Table 6.20. Use of interpretation maps based on 90 respondents

Nature of interpretation maps	% frequency*				
	A	F	C	O	N
1. Completely derived from soil maps	10.0	23.3	10.0	11.1	45.6
2. Partly derived from soil maps	4.4	12.2	15.6	21.1	46.7

*A=always, F=frequently, C=commonly, O=occasionally, N=never

4. Institutions producing soil maps

In most countries soil surveys and production of soil maps are done by specialized government soil survey institutes. Indeed, the present study confirms this (cf. table 6.21.). About 95 % of the respondents had used soil maps made by the conventional government soil survey institutes, while about 50 % had also used soil maps from other government institutions including universities and research institutes. Only slightly less than 20 % had used soil maps made by private soil survey institutes, probably because these are the fewest and that normally documents produced by such institutions are not easily accessible to the public.

Table 6.21. The different institutions making soil maps

Type of institution	% frequency based on 90 respondents*				
	A	F	C	O	N
1. Conventional government soil survey institutes and affiliated organization like FAO	47.8	25.6	13.3	7.8	5.5
2. Other governmental institutions and universities	6.7	20.0	8.9	15.6	48.8
3. Private soil survey institutes including private consultancy firms	1.1	1.1	4.4	12.2	81.2

* A = always, F = frequently, C = commonly, O = occasionally, N = never

5. Characteristics of soil maps used by respondents

The frequency distribution of the responses on the nature of soil maps that had been used is presented in table 6.22. It is apparent that most respondents (more than 85 %) had been using soil maps that were general base maps for multiple uses.

Table 6.22. Type of soil maps that have been used

Type of soil maps	% frequency based on 90 respondents*				
	A	F	C	O	N
1. General base maps for multiple uses	44.4	32.2	7.8	4.4	11.2
2. Maps specific for users' objectives	4.4	16.7	6.7	11.1	61.1
3. Maps with specific objectives different from users'	1.1	4.4	8.9	24.4	61.2

*A=always, F=frequently, C=commonly, O=occasionally, N=never

About 40 % of respondents had also used soil maps specific for their own needs and about the same percent had used soil maps with specific objectives different from theirs. Users' experience when using soil maps made by institutions other than theirs is recorded in table 6.23. It is clearly shown that quite a great portion of the respondents (about 66 %) indicate that there were deficiencies in at least some of these documents. Therefore complementary prospection is required to complete the information contained in them. About 51 % of the respondents had also the opportunity to use soil maps in which all the required information was available.

Table 6.23. Adequacy of soil maps made by institutions other than users'

Adequacy of soil maps	% frequency based on 90 respondents				
	A	F	C	O	N*
1. With such maps, one still has to make complementary prospection	20.0	18.9	10.0	16.7	34.4
2. All the necessary information can be found in the soil maps	6.7	8.9	20.0	15.6	48.8

* A = always, F = frequently, C = commonly, O = occasionally, N = never

6. Knowledge about the existence of soil maps

Table 6.24. gives information on how knowlegde about the existence of soil maps was obtained. It is clearly shown that many respondents (about 63 %) got that knowledge through education at college/university. 50 % of the respondents learned about the existence of soil maps through colleagues and about 30 % through extension services. Other sources of this knowledge include professional contacts directly with producers and related institutions (about 15 % of respondents) and through libraries (10 %). It is well known that television, radio and newspapers are effective means of communication, yet only about 5 % of the respondents learned of the existence of soil maps through these media.

As for the easiness to know about the existence of soil maps, almost 50 % of the respondents invariably had difficulties of getting this information.

7. Competence in using soil maps

The present survey indicates that about 36 % of the respondents only occasionally needed help from soil surveyors or other soil scientists when using soil maps. 10 % commonly to frequently required help when using soil maps. Slightly more than 50 % however, could use these documents without the help of other soil scientists. This is a good score and could be a reflection of the fact that most respondents had background knowledge in soil science (cf. table 6.17.).

Table 6.24. Source of knowlegde on existence of soil maps

Source of knowledge	% frequency based on 90 respondents				
	A	F	C	O	N*
1. Through education at college/university	27.8	14.4	8.9	12.2	36.7
2. Through extension services	4.4	5.6	7.8	10.0	72.2
3. Through libraries	5.6	2.2	1.1	1.1	90.0
4. Through professional contact with producers	5.6	7.8	0.0	1.1	85.5
5. Through colleagues	8.9	17.8	8.9	14.4	50.0
6. Through radio, television, newspapers	0.0	1.1	1.1	2.2	95.1

* A = always, F = frequently, C = commonly, O = occasionally, N = never

8. <u>Problems encountered by users of soil maps</u>

Table 6.25. reveals the problems that users have been facing while using soil maps. It is apparent that the major problems accruing from the documents per se are related to location (32 % of the respondents), low map legibility (33 %), complicated terminology (19 %) and vague terminology (34 %).

Table 6.25. Problems ecountered while using soil maps

Problems	% frequency based on 90 respondents				
	A	F	C	O	N*
1. Problems of location	1.1	12.2	6.7	12.2	67.8
2. Problems related to legibility	1.1	2.2	12.2	17.8	66.7
3. Problems of complicated terminology	2.2	5.6	4.4	6.7	81.1
4. Problems of vague terminology	2.2	3.3	12.2	16.7	65.6
5. Problems of incomplete definition of mapping units	0.0	0.0	1.1	2.2	96.7
6. Problems of incomplete analytical data	0.0	0.0	1.1	1.1	97.8
7. Problems of mapping errors	0.0	0.0	0.0	1.1	98.9

* A = always, F = frequently, C = commonly, O = occasionaly, N = never

Other minor problems encountered include incomplete definition of mapping units, inclomplete analytical data and mapping errors (as indicated by less than 5 % of the respondents in all cases).

9. The significance of soil maps in projects

Table 6.26. summarizes the feelings of respondents about the significance of soil maps. More than 85 % of the respondents indicated that soil maps are an absolute necessity in their projects. About 23 % feel that soil maps are only good when there are soil experts to interpret them, and about 7 % feel that these documents are only a valuable addition to other information. About 9 % of the respondents (foresters) found soil maps completely useless in their projects.

Table 6.26. Significance of soil maps

Users' feelings	% frequency based on 90 respondents				
	A	F	C	O	N*
1. Soil maps are an absolute necessity	51.1	22.2	11.1	2.2	13.4
2. Soil maps are only good when there are experts to interpret	6.7	4.4	2.2	10.0	76.7
3. Soil maps are a valuable addition to other information	2.2	1.1	2.2	1.1	93.4
4. Soil maps are completely useless	1.1	1.1	0.0	6.7	91.1

* A = always, F = frequently, C = commonly, O = occasionally, N = never

62.4. Recommendations

1. In relation to the problems encountered while using soil maps

Based on the problems encountered, a series of recommendations is hereby put forward to those involved in making soil resources on the problems encountered, a series of recommendations is hereby put forward to those involved in making soil resource inventories. (a) To improve their legibility,

1) SRIs should contain a section on "how to use the report and the maps" to enable especially the non-specialists to understand the information recorded in them.

2) Soil reports should contain complete analytical data and both their qualitative and quantitative interpretations.

3) Construction of clear and if possible simple legends will be inevitable.

(b) As for problems of location, careful selection or elaboration of base maps is highly recommended. (c) Provision in the soil report of a clear and concise glossary is deemed necessary to solve the problems due to specialized terminology. (d) Last but not least, much more publicity about the existence and usefulness of soil resource inventories should be made and there are should be at least one center in each country, state or province where the documents can be kept for consultation and use. In order to guarantee the permanence of such centers, their organization should depend on a national institution such as a ministry department.

2. <u>In relation to the questionnaire</u>

Based on the comments made by some respondents of the questionnaire to users of soil maps and reports, some changes are deemed necessary to make such a questionnaire more useful. The ideas of Valentine et al. (1981) have also been incorporated. The changes include (a) additional questions to cover more aspects of design and content of soil maps and reports. (b) removal of frequency classes from some of the questions where they may not increase the value of the answers. (c) simplification of some of the questions for better and easier comprehension. (d) removal of questions which appeared ambiguous.

A copy of the revised version of the questionnaire to users of soil maps and reports is included in this paper as appendix 11.

62.5. <u>Summary</u>

Ninety-four people form 35 countries responded to a questionnaire on the use of soil maps. Most respondents had used soil maps in one way or another in the fields of agriculture and forestry, soil conservation and in studies on environmental pollution and protection.

98 % of the respondents had used soil maps for locating suitable areas for their professional work, 15 % used these maps for teaching and research and 13 % had also used such documents simply for the sake of getting loans and financial assistance.

At least 45 % of the respondents had not used interpretation maps completely or partly derived from soil maps. About 95 % invariably used soil maps produced by the conventional government soil survey institutes most probably because they are the most abundant, 51 % had also used soil maps produced by other government institutions including universities and research stations.

Only 19 % had used soil maps made by private soil survey organizations. 89 % of the respondents had been using soil maps which were general base maps for multiple uses, about 39 % had also used soil maps which were specific for their objectives and about the same percent had used maps with specific objectives but different from theirs.

Knowledge about the existence of soil maps was mostly acquired in colleges and universities (63 % of the respondents), through colleagues (50 %) and to some extent through extension services (28 %) and in libraries (10 %). While about 50 % of the respondents indicated that they had difficulties in knowing about the existence of these documents, there is no suggestion that radio, television and newspapers have played important role in the publicity of soil maps as only 5 % of the respondents learned about their existence through such media.

About 36 % of the respondents only occasionally needed help when using soil maps and slightly more than 50 % of them could use these documents without any help from others.

Major problems encountered in relation to the documents per se include poor legibility (as indicated by 34 % of the respondents), problems of location on the maps (32 %), vague terminology (34 %) and complicated terminology (19 %).

More than 85 % of the respondents feel that soil maps are an absolute necessity in their projects. Only about 9 % (mostly foresters) occasionally found soil maps completely useless in their projects. Others (about 7 %) feel that soil maps are just a valuable addition to other information.

Based on the problems encountered while using soil maps, a series of recommendations has been suggested to those involved in the elaboration of soil resource inventories. A revised questionnaire has also been proposed following comments made by the respondents of the previous one.

Chapter 7

GENERAL CONCLUSIONS AND RECOMMENDATIONS

The objectives of the present study are outlined in the introductory chapter (§12). The following conclusions and recommendations can be made from the results and observations :

71. Literature review on basic concepts of soil surveys (chapter 2) has been compiled as an essential tool to aid understand the principles and methodologies employed in making soil inventories.
It was clearly indicated at this level that, some concepts and definitions (eg. soil survey intensity in relation to map scale and kind of mapping units; density of field observations/map area for different survey intensity levels; types of field mapping in relation to survey objectives etc.) are not conceived and used consistently by different soil surveyors.
In other words, there is some subjectivity in the making of soil inventories.
In order to allow common understanding and easy transfer of information from place to place, soil surveyors are urged to find ways of standardizing the definitions and principles used in soil survey.

72. Characterization of soil resource inventories

1. As shown in chapter 4, it has been possible to elaborate indices that can be used to characterize and evaluate SRIs in terms of their cartographic attributes.
These indices were highly correlated with each other (cf. fig. 4.4) and hence consistent enough for the intended use.

2. Observations made on cartographic attributes of existing SRIs indicated that :

(a) The concept of map linear reduction factors is mostly not applied consistently as stipulated in soil survey literature (§41.3.3). Although the available base maps dictate to a great extent the reduction factors, it is hereby recommended that where high levels of accuracy are required, attempt should be made to elaborate appropriate base maps to match the objectives of the survey.

(b) Information on soil description sites is only rarely given in SRIs (§41.3.8.). Its significance in helping to understand the relationship between soil properties as given in a SRI and their position on the landscape, calls for more attention with regard to such information in future soil inventories.

3. Important observations were made in relation to the information content of map legends and soil reports of existing SRIs :

(a) Most SRIs are produced by the free survey method (§42.3.1) most probably because of the implied high speed of work and low costs involved.

(b) Among the most commonly used attributes in soil mapping include texture, drainage, landform, topography (slope), parent material and soil depth (§42.3.2).

(c) Information on density of field observations is often missing in SRIs and is commonly vaguely presented (§42.3.3).
With respect to its importance in judging SRI reliability, it is recommended that it should be given in SRIs as one of the routine data.

(d) The USDA and the FAO/UNESCO soil classification systems are the most widely used internationally (42.3.4).
Due to over-publicity, there is an obvious tendency of many countries adopting particularly the former system at the expence of their national, regional or local classification systems.
Care has to be taken as the USDA classification system was devised for mapping soils of the United States and may not necessarily be ideal for other countries.

(e) Most SRIs contain interpretive data on land and/or soil capability (§42.3.5).

(f) Information on purity of mapping units is often not given in SRIs and in many cases it is only partly presented (§42.3.6).
Its importance calls for more attention in future soil inventories.

4. (a) Two methods, circular and linear (§43.3), have been developed to estimate base map utility.
For reasons of simplicity, practicality and accuracy, the linear method is hereby recommended.

(b) It was noted with grave concern that many SRIs do not have information about their compliance with specified base map accuracy standards (§43.4.2).
This information is crucial in the judgement of the base map accuracy and utility, and hence it should be considered as an essential part of a SRI.

5. With regard to general legibility of SRIs, the following points are emphasized (§45.2.3) :

(a) Provision of instructions on how to use the SRIs is mostly neglected.
Serious consideration must be given by soil surveyors to include this as one of the routine data.

(b) For easiness of reading and understanding a SRI, it is felt necessary that soil surveyors include in their documents both glossaries of specialized terminologies and ranges of soil characteristics of mapping units.

(c) Also for the sake of improved readability, indices of mapping units/classification units should be provided particularly when there are many different mapping units.

6. A method has been developed to characterize and evaluate information given in map legends and soil reports in function of specified land uses (§52.1.2).

73. Predictive adequacy of SRIs for three different land uses

1. In chapter 5, a comprehensive method has been developed to asses the predictive adequacy of some SRIs for three land uses namely, corn production, oil palm production and production of Ecalyptus deglupta (forestry) in terms of (1) cartographic attributes, (2) map legend and SRI report attributes and (3) base map attributes.
   Guidelines are provided (appendix 13) for assessing the quality and adequacy of SRIs for a specified land use.

   Based on this method, the following conclusions can be made about the studied SRIs :

   (a) As far as cartographic attributes are concerned, all the studied SRIs are adequate for predicting performance for the three land uses (§52.2.1, §53.2.1, §54.2.1).

   (b) As for map legend attributes, rather few (30 %) of the documents have acceptable adequacy for corn and oil palm production (§52.2.2, 53.2.2) and about 33 % were adequate for production of Eucalyptus deglupta (§54.2.2).

   (c) More than half of the studied SRIs (about 58 %) are adequate with respect to base map attributes for all the three land uses.

   (d) Considering all the criteria of adequacy together, only about 27 % of the SRIs are completely adequate for predicting performance of corn and oil palm and about 30 % adequate for Eucalyptus deglupta. A great number of SRIs is adequate for Eucalyptys deglupta than for corn and oil palm production because the former has fewer adequacy criteria than the latter.

   (e) As far as map legend attributes are concerned, one of the most limiting data is the information on purity of mapping units which is often lacking in SRIs, while for base map attributes the most limiting adequacy criterion is the information on base map accuracy standards.

2. A preliminary study on the adequacy of some SRIs for predicting soil erosion hazards revealed that :

   (a) By using the stipulated criteria per se, most of the studied SRIs could be considered adequate for the prediction of soil erosion hazards (§56.4).
   However, as stressed here this is only true if the documents have no limitations on other important attributes such as cartographic attributes, quality of base map for location, ground truth etc. which are not incorporated in this particular analysis.

   (b) Considering the individual crucial attributes of adequacy it can be said that :

      (1) Although information on climate is given in all the documents, aspects of winds are frequently not given (56.3.1). More emphasis on description of winds as an important component of climate is deemed necessary to increase the predictive ability of SRIs for soil and land management.

(2) Information on topography is limited by the lack of contour lines printed directly with the soils information or the lack of contour maps as appendices to the soil maps (§56.3.2). To be able to get a clear impression of topography, it is advisable to print soils data directly on topographic maps.
(3) Information on soil properties is quite adequate in most SRIs except for permeability which is often not described (§56.3.3). Although it could be possible to estimate it using other given data, it is still better to have the direct measurements determined and recorded in the documents.

74. Questionnaires (chapter 6)

Two questionnaires have been developed (appendices 9 and 10), one with the intention of getting information from experienced soil surveyors about the principles and methodologies employed in soil inventories, and the second one with the intention of finding the opinion of users about SRIs and the role they play in development projects. The information supplied by these questionnaires has to a great extent complemented observations made in other chapters.

1. The questionnaire to soil surveyors

The following information given by the respondents has been noted with great interest :

(a) It has been disclosed that to a great extent soil surveyors determine the nature of SRIs to be made, and only occasionally do users have the opportunity to determine the nature of these documents (§61.3.2).
It is hereby recommended that in the case where users are competent they should be allowed to dictate the nature of the SRIs that will suit their purpose.

(b) Key terminologies and criteria used in soil survey eg. survey intensities, field soil mapping procedures and purity of mapping units are not conceived and used consistently (§61.3.1, §61.3.7, §61.3.8, §61.3.9, §61.3.10).
These findings corroborate very well the observations made in chapter 2.
It is thus recommended that soil surveyors should standardize these terminologies and criteria to allow transfer of information.

(c) Many soil surveyors do not monitor utility of the SRIs they make (§61.3.5).
It is recommended that monitoring of SRI utility should be the responsibility of the surveyor or the survey institution.

(d) It has been implied that for understandable reasons SRI users prefer interpretation maps to the soil maps sensu stricto.
It is thus recommended that SRI producers should always prepare such maps to accompany the soil maps.

(e) It has been indicated that soil maps are too complicated to understand (§61.3.13, §61.3.14).
It is therefore recommended that where possible simple legends should be made.
Another solutions as indicated earlier is to provide interpretation maps.

(f) Publicity about SRIs has not sufficiently been made. More efforts should thus be put in publicizing these documents to increase their use and at the same time prevent duplication of work.

2. The questionnaire to users of soil maps and reports

Interesting results have been obtained from the answers given by the respondents :

(a) The majority of respondents do feel that soil maps are an absolute necessity in development projects (§62.3.9).

(b) Although most users had invariably used soil maps in their professional work, at least half of them indicated that they had not used interpretation maps (§62.3.3). This observation may possibly be due to the fact that most of the respondents have a background in soil science and do not necessarily need interpretation or it may be a reflection of unavailability of such maps.

(c) About half of the respondents had difficulties in knowing about the existence of soil maps (§62.3.6), yet only about 5 % of them learned of such existence through television, radio and newspapers (media generally known to be effective in communication).

(d) Major problems encountered while using soil maps and reports (§62.3.8) include poor legibility, problems of location on the maps, use of vague and in some cases complicated terminology.
In relation to these problems a series of recommendations is given :
To improve their legibility,

(1) SRIs should include a section on "how to use the report and the maps" to enable particularly the non-specialists to understand the information.
(2) Soil reports should contain complete analytical data and both their qualitative and quantitative interpretations.
(3) Construction of clear and if possible simple legends is enevitable.

As for problems of location, careful selection or elaboration of base maps is highly recommended.
To solve the problems due to specialized terminology, provision in the report of a clear and concise glossary is necessary.

3. Based on comments made by some respondents of the questionnaire, some changes have been incorporated in a revised version of the questionnaire to users of soil maps and reports (appendix 11) to make it more useful as a source of information.

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APPENDIX 1. LIST OF THE SOIL RESOURCE INVENTORIES USED IN THE STUDY

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APPENDIX 2. GENERAL SOIL RESOURCE INVENTORY (SRI) CHECKLIST

1. Title of the SRI and author(s)

2. Identification or reference no. of SRI :

3. Country :

4. Type of SRI and its purpose :

5. Years(s) of soil survey/compilation :

6. Year of publication :

7. Scale of publication :

8. a) Type of base maps/documents : (mark with X)

☐ aerial photos/mosaic ☐ satellite imagery ☐ topographic map

☐ land use map ☐ geological map ☐ soil map

☐ geographical map ☐ vegetation map ☐ climatic map

☐ site plan ☐ other(s) (specify) ....

....

b) Information on base map accuracy standards : (mark with X)

☐ included in the SRI ☐ not included in the SRI

c) Information on base map date : (mark with X)

☐ included in the SRI ☐ not included in the SRI

9. Density of field observation :

10. Type of mapping intensity based simply on observed map texture : (mark with X)

☐ mono-intensity ☐ multi-intensity

11. Type of soil classification used if any :

12. Attributes used to define mapping units :

13. Land suitability / capability data : (mark with X)

☐ included ☐ not included

14. Soil description sites : (mark with X)

☐ plotted on the SRI map ☐ not plotted on the SRI map

15. Index of mapping units / classification units : (mark with X)

☐ included in the SRI ☐ not included in the SRI

16. Presence of inclusions in mapping units : (mark with X)

☐ simply acknowledged in the SRI ☐ acknowledged and percentage of inclusions given

☐ no information on inclusions

17. Information on how to use the SRI : (mark with X)

☐ given ☐ not given

18. Definition of descriptive terms (glossary) : (mark with X)

☐ given ☐ not given

19. Range of soil characteristics : (mark with X)

☐ given ☐ not given

20. SRI map attributes :

a. MiLeLaAr (ha) = $(1/RpFr)^2 / 2.5 \times 10^8$ =

b. DeArDn (no. of deln./map cm^2) =

c. AvDeAr (cm^2) = 1/b =

d. AvLaAr (ha) = AvDeAr (cm^2) $\times (1/RpFr)^2 \times 10^{-8}$ =

e. DeLnDn (soil boundary lines/map cm) =

f. SmDeAr (cm^2) =

g. DeLeQ (%) = (MiLeDeAr/AvDeAr) x 100 = (0.4 / AvDeAr) x 100 =

h. AvLeRdFa = $\sqrt{AvDeAr/MiLeDeAr}$ = $\sqrt{2.5 \times AvDeAr}$ =

i. AvLeSc = RpFr x 1 / AvLeRdFa =

j. $$AvLeId\ (\%) = \frac{ScFa_{(AvLeSc)} - ScFa_{(PSc)}}{ScFa_{(AvLeSc)}} \times 100 =$$

k. MaxLoAc (in metres) = $ScFa_{(PSc)} \times 0.25 \times 10^{-3}$

l. Estimation of quantity of base map information :

- circular method : no. of features/specified map area = AvBmArInDn =

- linear method : no. of intersections/specified map distance = AvBmLnInDn =

m. If the map is colored, (mark with X)

☐ color pattern detracting from legibility

☐ color pattern not detracting from legibility

n. Map symbols : (mark with X)

☐ clear ☐ not clear

o. Other remarks : (put here)

APPENDIX 3. SOME MEASURABLE CARTOGRAPHIC ATTRIBUTES OF THE SRI MAPS USED IN THE STUDY

SRI MAP NUMBER	TYPE	MEASURABLE ATTRIBUTES											
		RpFr	MiLeLaAr	DeArDn	AvDeAr	AvLaAr	DeLnDn	SmDeAr	DeLeQ	AvLeRdFa	AvLeSc	AvLeId	MaxLoAc
1	bDmu	1/100,000	40.00	0.39	2.56	256.00	1.60	0.33	15.63	2.53	1/253,000	60.47	25.00
2	bDmu	1/100,000	40.00	0.45	2.22	222.00	1.30	0.31	18.01	2.36	1/236,000	57.63	25.00
3	bCmu	1/50,000	10.00	0.34	2.94	73.50	1.10	nd	13.61	2.71	1/135,500	63.10	12.50
4	bDmu	1/100,000	40.00	0.47	2.13	213.00	1.35	nd	18.78	2.31	1/231,000	56.71	25.00
5	bBmo	1/15,840	1.00	0.19	5.26	13.20	0.41	3.94	7.60	3.63	1/57,499	72.45	3.96
6	aFmu	1/1,000,000	4,000.00	0.94	1.06	10,600.00	2.09	0.06	37.74	1.63	1/1,630,000	38.65	250.00
7	bBmo	1/20,000	1.60	0.36	2.78	11.12	1.18	0.08	14.39	2.64	1/52,800	62.12	5.00
8	cBmo	1/25,000	2.50	0.11	9.10	56.90	1.09	0.27	4.40	4.80	1/120,000	79.20	6.25
9	bCmu	1/50,000	10.00	0.28	3.60	90.00	1.44	0.20	11.10	3.00	1/150,000	66.70	12.50
10	bEmu	1/200,000	160.00	6.61	1.64	656.00	1.30	nd	24.39	2.02	1/404,000	50.50	50.00
11	aDmo	1/100,000	40.00	0.63	1.59	159.00	1.77	0.07	25.16	1.99	1/199,000	49.75	25.00
12	aDmu	1/100,000	40.00	0.63	1.59	159.00	1.95	nd	25.16	1.99	1/199,000	49.75	25.00
13	aBmo	1/100,000	40.00	0.63	1.59	159.00	2.06	0.09	12.16	1.99	1/199,000	49.75	25.00
14	bBmo	1/20,000	1.60	0.35	2.86	11.44	1.23	0.08	13.99	2.67	1/53,400	62.55	5.00
15	bDmu	1/100,000	40.00	0.40	2.50	250.00	1.55	0.13	16.00	2.56	1/250,000	60.00	25.00

SRI MAP NUMBER	TYPE	MEASURABLE ATTRIBUTES RpFr	MiLeLaAr	DeArDn	AvDeAr	AvLaAr	DeLnDn	SmDeAr	DeLeQ	AvLeRdFa	AvLeSc	AvLeId	MaxLoAc
16	aDmu	1/100,000	40.00	0.64	1.56	156.00	1.94	0.08	25.64	1.97	1/197,000	49.23	25.00
17	cBmo	1/25,000	2.50	0.16	6.30	39.40	1.11	1.05	6.30	4.00	1/100,000	75.00	6.05
18	bBmo	1/25,000	2.50	0.18	5.60	35.00	1.12	1.69	7.10	3.70	1/92,500	73.00	6.25
19	bBmo	1/25,000	2.50	0.18	5.60	35.00	1.14	1.26	7.10	3.70	1/92,500	73.00	6.25
20	bBmu	1/15,000	0.90	0.22	4.55	10.24	0.90	0.41	8.79	3.37	1/50,550	70.33	3.75
21	bDmu	1/100,000	40.00	0.47	2.13	213.00	1.40	0.29	18.78	2.31	1/231,000	56.71	25.00
22	aEmu	1/250,000	250.00	0.64	1.56	975.00	1.63	nd	25.64	1.97	1/492,500	49.24	62.50
23	cAmo	1/12,500	0.63	0.09	11.10	17.30	0.60	2.28	3.60	5.30	1/66,250	81.10	3.03
24	bDmo	1/100,000	40.00	0.56	1.79	179.00	1.72	0.08	22.35	2.12	1/212,000	52.61	25.00
25	bCmo	1/50,000	10.00	0.31	3.23	80.75	1.24	0.46	12.38	2.84	1/142,000	64.79	12.5
26	bCmu	1/63,360	16.06	0.50	2.00	80.29	1.81	0.10	20.00	2.24	1/141,926	55.40	15.84
27	bEmu	1/200,000	160.00	0.45	2.20	880.00	1.49	0.08	18.20	2.30	1/460,000	56.50	50.00
28	aFmu	1/1,000,000	4,000.00	1.18	0.85	8,500.00	2.62	0.09	47.06	1.46	1/1,460,000	31.51	250.00
29	cAmo	1/5,000	0.10	0.08	12.50	3.13	0.49	nd	3.20	5.59	1/27,950	82.11	1.25
30	bBmo	1/20,000	1.60	0.32	3.13	12.52	1.00	nd	12.78	2.80	1/56,000	64.29	5.00
31	cCmo	1/50,000	10.00	0.16	6.000	157.50	1.36	0.21	6.30	4.00	1/200,000	75.00	12.50

SRI MAP NUMBER	TYPE	MEASURABLE ATTRIBUTES RpFr	MiLeLaAr	DeArDn	AvDeAr	AvLaAr	DeLnDn	SmDeAr	DeLeQ	AvLeRdFa	AvLeSc	AvLeId	MaxLoAc
32	cCmo	1/32,000	4.10	0.15	6.70	68.60	1.20	0.18	6.00	4.10	1/131,200	75.60	8.00
33	bCmo	1/32,000	4.10	0.17	5.90	60.40	1.22	0.25	6.80	3.80	1/121,600	73.70	8.00
34	bCmo	1/32,000	4.10	0.30	3.30	33.80	1.21	0.28	12.10	2.90	1/92,800	65.50	8.00
35	bCmo	1/32,000	4.10	0.20	5.00	51.20	1.28	0.35	8.00	3.50	1/112,000	71.40	8.00
36	bCmu	1/50,000	10.00	0.40	2.50	62.50	1.30	nd	16.00	2.50	1/125,000	60.00	12.50
37	aEmu	1/250,000	250.00	0.66	1.50	937.50	1.68	0.19	26.70	1.90	1/475,000	47.40	62.50
38	bBmu	1/22,000	1.94	0.20	5.00	24.20	0.94	nd	8.00	3.54	1/77,880	71.75	5.50
39	bCmo	1/50,000	10.00	0.25	4.00	100.00	1.05	0.30	10.00	3.16	1/158,000	68.35	12.50
40	bCmu	1/50,000	10.00	0.31	3.23	80.75	1.15	0.18	12.38	2.84	1/142,000	64.79	12.50
41	bEmu	1/250,000	250.00	0.57	1.75	1,093.75	1.53	0.21	22.86	2.09	1/522,500	52.15	62.5
42	bAmo	1/12,500	0.63	0.19	5.26	8.22	0.77	nd	7.60	3.63	1/45,375	72.45	3.13
43	aDmu	1/100,000	40.00	0.65	1.54	154.00	1.83	0.07	25.97	1.96	1/196,000	48.98	25.00
44	bDmo	1/100,000	40.00	0.60	1.67	167.00	1.75	0.10	9.79	2.04	1/204,000	50.98	25.00
45	aEmu	1/506,880	1,027.71	0.63	1.59	4,085.14	1.64	0.06	25.16	1.99	1/1,008,691	49.75	126.72
46	bCmo	1/50,000	10.00	0.30	3.30	82.50	1.37	0.20	12.10	2.90	1/145,000	65.50	12.57
47	bDmu	1/126,720	64.23	0.46	2.17	348.46	1.41	0.19	18.43	2.33	1/295,258	57.08	31.68

SRI MAP NUMBER	TYPE	MEASURABLE ATTRIBUTES RpFr	MiLeLaAr	DeArDn	AvDeAr	AvLaAr	DeLnDn	SmDeAr	DeLeQ	AvLeRdFa	AvLeSc	AvLeId	MaxLoAc
48	bCmo	1/40,000	6.40	0.17	5.90	94.40	1.31	0.23	6.80	3.80	1/152,000	73.70	10.00
49	bCmo	1/40,000	6.40	0.48	2.10	33.60	1.34	0.09	19.00	2.30	1/92,000	56.50	10.00
50	bEmu	1/250,000	250.00	0.60	1.67	1,043.75	1.61	nd	23.95	2.04	1/510,000	50.98	62.50
51	bDmu	1/100,000	40.00	0.38	2.63	263.00	1.50	0.11	15.20	2.56	1/256,000	60.94	25.00
52	aEmu	1/200,000	160.00	0.64	1.56	624.00	1.41	nd	25.64	1.97	1/394,000	49.24	50.00
53	bCmo	1/50,000	10.00	0.25	4.00	100.00	1.37	0.18	10.00	3.20	1/160,000	68.80	12.50
54	bBmo	1/15,000	0.90	0.18	5.56	12.51	0.93	nd	7.19	3.73	1/55,950	73.19	3.75
55	bCmu	1/31,680	4.01	0.32	3.13	31.41	1.13	0.23	12.78	2.80	1/88,704	64.29	7.92
56	bDmo	1/100,000	40.00	0.52	1.90	190.00	1.60	0.20	21.10	2.20	1/220,000	54.50	25.00
57	cAmo	1/5,000	0.10	0.07	14.29	3.57	0.42	nd	2.80	5.98	1/29,900	83.28	1.25
58	bBmo	1/20,000	1.60	0.37	2.70	10.80	1.35	0.09	14.81	2.60	1/52,000	61.54	5.00
59	bDmu	1/100,000	40.00	0.55	1.82	182.00	1.66	0.11	21.98	2.13	1/213,000	53.05	25.00
60	bBmu	1/15,840	1.00	0.34	2.94	7.38	1.13	0.19	13.61	2.71	1/42,926	63.10	3.96
61	bBmu	1/25,000	2.50	0.33	3.03	18.94	1.01	nd	13.20	2.75	1/68,750	63.64	6.25
62	bDmu	1/125,000	62.50	0.50	2.00	312.50	1.21	nd	20.00	2.24	1/280,000	55.00	31.25
63	aEmu	1/250,000	250.00	0.63	1.59	993.75	2.16	0.40	25.16	1.99	1/497,500	49.75	62.50

SRI MAP NUMBER	TYPE	MEASURABLE ATTRIBUTES											
		RpFr	MiLeLaAr	DeArDn	AvDeAr	AvLaAr	DeLnDn	SmDeAr	DeLeQ	AvLeRdFa	AvLeSc	AvLeId	MaxLoAc
64	bBmo	1/20,000	1.60	0.26	3.85	15.40	1.09	0.12	10.39	3.10	1/62,000	67.74	5.00
65	dAmo	1/5,000	0.10	0.03	33.33	8.33	0.40	6.41	1.20	9.13	1/45,650	89.05	1.25
66	bCmo	1/50,000	10.00	0.39	2.60	65.00	1.40	0.04	15.40	2.50	1/125,000	60.00	12.50
67	cAmo	1/10,000	0.40	0.13	7.69	7.69	0.50	16.33	5.20	4.38	1/43,800	77.17	2.50
68	bCmo	1/50,000	10.00	0.32	3.10	77.50	1.38	0.28	12.90	2.90	1/145,000	65.50	12.50
69	bBmo	1/25,000	2.50	0.18	5.60	35.00	1.13	1.08	7.10	3.70	1/92,500	73.00	6.25
70	cBmo	1/25,000	2.50	0.16	6.25	39.40	1.09	0.27	6.40	4.00	1/100,000	75.00	6.25
71	bBmo	1/25,000	2.50	0.25	4.00	25.00	1.19	0.73	10.00	3.20	1/80,000	68.80	6.25
72	bBmo	1/25,000	2.50	0.20	5.00	31.30	1.17	0.64	8.00	3.50	1/87,500	71.40	6.25
73	bBmo	1/25,000	2.50	0.24	4.20	26.30	1.15	1.37	9.50	3.20	1/80,000	68.80	6.25
74	bBmo	1/25,000	2.50	0.18	5.60	35.00	1.16	0.96	7.10	3.70	1/92,500	73.00	6.25
75	bBmo	1/25,000	2.50	0.20	5.00	31.30	1.28	0.86	8.00	3.50	1/87,500	71.40	8.25
76	bBmo	1/25,000	2.50	0.20	5.00	31.30	1.14	1.01	8.00	3.50	1/87,500	71.40	6.25
77	bCmo	1/31,680	4.01	0.27	3.70	37.13	1.23	nd	10.81	3.04	1/96,307	67.11	7.92
78	bCmo	1/40,000	6.40	0.22	4.50	72.00	1.27	0.43	8.90	3.40	1/136,000	70.60	10.00
79	bBmo	1/25,000	2.50	0.26	3.85	24.06	1.34	0.19	10.39	3.10	1/77,500	67.70	6.25

SRI MAP NUMBER	TYPE	MEASURABLE ATTRIBUTES RpFr	MiLeLaAr	DeArDn	AvDeAr	AvLaAr	DeLnDn	SmDeAr	DeLeQ	AvLeRdFa	AvLeSc	AvLeId	MaxLoAc
80	bDmu	1/126,720	64.23	0.35	2.86	459.26	1.07	0.19	13.99	2.67	1/338,342	62.55	31.68
81	bAmu	1/10,000	0.40	0.18	5.56	5.56	0.73	0.99	7.19	3.73	1/37,300	73.19	2.50
82	bBmo	1/20,000	1.60	0.33	3.03	12.12	1.20	0.05	13.20	2.75	1/55,000	63.64	5.00
83	bBmo	1/25,000	2.50	0.19	5.26	32.88	1.00	nd	7.60	3.63	1/90,750	72.45	6.25
84	bCmo	1/63,360	16.06	0.39	2.56	102.77	1.08	0.13	15.63	2.53	1/162,202	60.94	15.84
85	bCmu	1/50,000	10.00	0.40	2.50	62.50	1.10	0.21	16.00	2.50	1/125,000	60.00	12.50
86	aDmo	1/126,720	64.23	0.65	1.54	247.29	1.70	0.05	25.17	1.96	1/248,371	48.98	31.68
87	cAmo	1/10,000	0.40	0.14	7.14	7.14	0.54	1.73	5.60	4.22	1/42,200	76.30	2.50
88	dAmo	1/5,000	0.10	0.05	20.00	5.00	0.50	7.82	2.00	7.07	1/35,350	85.86	1.25
89	cAmo	1/10,000	0.40	0.09	11.10	11.10	0.65	1.97	3.60	5.30	1/53,000	81.10	2.50
90	bCmu	1/50,000	10.00	0.28	3.57	89.25	0.70	nd	11.20	2.99	1/149,500	66.56	12.50
91	aDmo	1/125,000	62.50	0.68	1.47	229.69	1.66	0.17	27.21	1.92	1/240,000	47.92	31.25
92	bCmo	1/50,000	10.00	0.27	3.70	92.50	1.29	0.16	10.80	3.00	1/150,000	66.70	12.50
93	bDmu	1/100,000	40.00	0.55	1.82	182.00	1.53	0.06	21.98	2.13	1/213,000	53.05	25.00
94	bDmu	1/100,000	40.00	0.49	2.04	204.00	1.49	0.28	19.68	2.26	1/226,000	55.75	25.00
95	cAmo	1/10,000	0.40	0.13	7.69	7.69	0.86	1.15	5.20	4.38	1/43,800	77.17	2.50

SRI MAP NUMBER	TYPE	MEASURABLE ATTRIBUTES RpFr	MiLeLaAr	DeArDn	AvDeAr	AvLaAr	DeLnDn	SmDeAr	DeLeQ	AvLeRdFa	AvLeSc	AvLeId	MaxLoAc
96	bCmo	1/50,000	10.00	0.42	2.40.	60.00	1.33	0.20	16.70	2.40	1/120,000	58.31	12.50
97	eAmo	1/2,400	0.023	0.02	50.00	2.88	0.18	10.81	0.80	11.18	1/26,832	91.06	0.60
98	dAmo	1/10,000	0.40	0.04	25.00	25.00	0.52	14.30	1.60	7.91	1/79,100	87.36	2.50
99	bBmo	1/20,000	1.60	6.20	5.00	20.00	0.76	0.59	8.00	3.50	1/70,000	71.4	6.25
100	bBmo	1/20,000	1.60	0.29	3.40	13.60	1.03	0.30	11.80	2.90	1/58,000	65.50	5.00
101	bBmo	1/20,000	1.60	0.22	4.50	18.00	1.00	0.32	8.90	3.40	1/68,000	70.60	5.00
102	cAmo	1/2,000	0.02	0.08	12.50	0.50	0.52	0.67	3.20	5.59	1/11,180	82.11	0.50
103	bCmo	1/63,360	16.06	0.41	2.44	97.95	1.16	0.09	16.39	2.47	1/156,499	59.51	15.84
104	bCmo	1/50,000	10.00	0.33	3.03	75.75	1.30	nd	13.20	2.75	1/137,500	63.64	12.50
105	bEmu	1/200,000	160.00	0.59	1.69	676.00	2.01	0.21	23.67	2.06	1/412,000	51.46	50.00
106	aEmu	1/200,000	160.00	0.69	1.45	580.00	2.15	0.29	27.59	1.90	1/380,000	47.37	50.00
107	bCmu	1/30,000	3.60	0.36	2.78	25.02	1.03	0.21	14.39	2.64	1/79,200	62.12	7.50
108	bDmu	1/100,000	40.00	0.43	2.33	233.00	1.20	nd	17.17	2.41	1/241,000	58.51	25.00
109	aDmu	1/100,000	40.00	0.66	1.52	152.00	1.94	0.05	26.32	1.95	1/195,000	48.72	25.00
110	bCmu	1/50,000	10.00	0.34	2.94	73.50	1.36	0.22	13.61	2.71	1/135,000	63.10	12.50
111	dAmo	1/2,500	0.025	0.04	25.00	1.56	0.45	11.63	1.60	7.91	1/19,775	87.36	0.63

SRI MAP NUMBER	TYPE	RpFr	MiLeLaAr	DeArDn	AvDeAr	AvLaAr	DeLnDn	SmDeAr	DeLeQ	AvLeRdFa	AvLeSc	AvLeId	MaxLoAc
		MEASURABLE ATTRIBUTES											
112	bBmo	1/25,000	2.50	0.19	5.26	32.88	0.96	nd	7.60	3.63	1/90,750	72.45	6.25
113	bBmu	1/15,840	1.00	0.17	5.88	14.75	0.80	0.32	6.80	3.83	1/60,667	73.89	3.96
114	bDmu	1/100,000	40.00	0.37	2.70	270.00	1.17	0.25	14.81	2.60	1/260,000	61.54	25.00
115	bDmu	1/100,000	40.00	0.34	2.94	294.00	1.46	0.10	13.61	2.71	1/271,000	63.10	25.00
116	bDmo	1/100,000	40.00	0.54	1.85	185.00	1.81	0.06	21.62	2.15	1/215,000	53.49	25.00
117	bCmu	1/50,000	10.00	0.34	2.94	73.50	1.26	nd	13.61	2.71	1/135,500	63.10	12.50
118	bDmu	1/100,000	40.00	0.41	2.44	244.00	1.39	nd	16.39	2.47	1/247,000	59.51	25.00
119	bEmu	1/500,000	1,000.00	0.61	1.64	4,100.00	1.60	0.14	24.40	2.02	1/1,010,000	50.50	125.00
120	dAmo	1/5,000	0.10	0.04	25.00	6.25	0.40	8.86	1.60	7.90	1/39,500	87.30	1.25
121	aFmu	1/1,000,000	4,000.00	0.78	1.30	13,000.00	1.78	0.06	30.80	1.80	1/1,800,000	44.40	250.00
122	bCmo	1/50,000	10.00	0.32	3.10	77.50	1.38	0.13	12.90	2.90	1/145,000	65.50	12.50
123	bCmo	1/50,000	10.00	0.37	2.70	67.50	1.41	nd	14.81	2.60	1/130,000	61.54	12.50
124	bCmo	1/50,000	10.00	0.34	2.94	73.50	1.30	nd	13.61	2.71	1/135,500	63.10	12.50
125	bCmo	1/50,000	10.00	0.34	2.90	72.50	1.30	0.36	13.80	2.70	1/135,000	63.00	12.50
126	dAmo	1/9,000	0.32	0.06	16.70	13.50	0.53	2.44	2.40	6.50	1/58,500	84.60	2.25
127	bBmo	1/25,000	2.50	0.39	2.56	16.00	1.30	0.37	15.63	2.53	1/63,250	60.47	6.25

SRI MAP NUMBER	TYPE	MEASURABLE ATTRIBUTES RpFr	MiLeLaAr	DeArDn	AvDeAr	AvLaAr	DeLnDn	SmDeAr	DeLeQ	AvLeRdFa	AvLeSc	AvLeId	MaxLoAc
128	dAmu	1/10,000	0.40	0.06	16.67	16.67	0.52	5.18	2.40	6.46	1/64,600	84.52	2.50
129	bBmo	1/25,000	2.50	0.28	3.57	22.31	1.19	nd	11.20	2.99	1/74,750	66.56	6.25
130	bBmu	1/20,000	1.60	0.18	5.56	22.24	0.76	0.24	7.19	3.73	1/74,600	73.19	5.00
131	bAmo	1/8,000	0.26	0.20	5.00	3.20	0.90	0.24	8.00	3.54	1/28,320	71.75	2.00
132	bBmo	1/15,840	1.00	0.45	2.22	5.57	1.50	0.52	18.02	2.36	1/37,382	57.63	3.96
133	bBmu	1/24,000	2.30	0.43	2.30	13.20	1.18	0.13	17.40	2.40	1/57,600	58.30	6.00
134	bBmu	1/24,000	2.30	0.48	2.10	12.10	1.18	0.20	19.00	2.30	1/55,200	56.50	6.00
135	bBmu	1/24,000	2.30	0.50	2.00	11.50	1.14	0.23	20.00	2.20	1/52,800	54.50	6.00
136	bBmu	1/24,000	2.30	0;47	2.10	12.10	1.18	0.17	19.00	2.30	1/55,200	56.50	6.00
137	bBmu	1/24,000	2.30	0.46	2.20	12.70	1.14	0.11	18.20	2.30	1/55,200	56.50	6.00
138	bBmo	1/20,000	1.60	0.44	2.27	9.08	1.47	0.11	17.62	2.38	1/47,600	58.00	5.00
139	aFmu	1/1,000,000	4,000.00	0.71	1.40	14,000.00	1.84	0.10	28.60	1.90	1/1,900,000	47.40	250.00
140	bBmu	1/15,840	1.00	0.53	1.89	4.74	1.67	0.28	21.16	2.17	1/34,373	53.92	3.96
141	bBmu	1/15,840	1.00	0.23	4.30	10.80	1.00	0.32	9.30	3.30	1/52,272	69.70	3.96
142	bCmo	1/62,500	15.63	0.52	1.90	72.20	1.42	0.17	21.10	2.20	1/137,500	54.50	15.60
143	bBmo	1/15,840	1.00	0.47	2.13	5.34	1.53	0.24	18.78	2.31	1/36,590	56.71	3.96

SRI MAP NUMBER	TYPE	MEASURABLE ATTRIBUTES RpFr	MiLeLaAr	DeArDn	AvDeAr	AvLaAr	DeLnDn	SmDeAr	DeLeQ	AvLeRdFa	AvLeSc	AvLeId	MaxLoAc
144	bBmo	1/15,840	1.00	0.48	2.08	5.22	1.66	0.14	19.23	2.28	1/36,115	56.14	3.96
145	bBmo	1/20,000	1.60	0.42	2.38	9.52	1.43	0.10	16.81	2.44	1/48,800	59.02	5.00
146	bBmu	1/15,840	1.00	0.49	2.04	5.12	1.66	0.22	19.61	2.26	1/35,798	55.75	3.96
147	bBmo	1/20,000	1.60	0.50	2.00	8.00	1.53	0.12	20.00	2.24	1/44,800	55.40	5.00
148	bBmo	1/15,840	1.00	0.31	3.20	8.03	1.13	0.29	12.50	2.80	1/44,352	65.90	3.96
149	bBmo	1/15,840	1.00	0.48	2.08	5.22	1.54	0.34	19.23	2.28	1/36,115	56.14	3.96
150	bBmu	1/15,840	1.00	0.41	2.44	6.12	1.42	0.24	16.39	2.47	1/39,125	59.51	3.96
151	bBmu	1/15,840	1.00	0.48	2.08	5.22	1.53	0.26	19.23	2.28	1/36,115	56.14	3.96
152	cBmo	1/20,000	1.60	0.11	9.10	36.40	1.07	0.16	4.40	4.80	1/96,000	79.20	5.00
153	bBmu	1/20,000	1.60	0.29	3;45	13.80	1.12	0.12	11.59	2.94	1/58,800	65.99	5.00
154	bBmo	1/15,840	1.00	0.43	2.33	5.85	1.64	0.19	17.17	2.41	1/38,174	58.51	3.96
155	bBmo	1/20,000	1.60	0.51	1.96	7.84	1.55	0.08	20.41	2.21	1/44,200	54.75	5.00
156	bBmu	1/24,000	2.30	0.22	4.55	26.21	0.99	0.14	8.79	3.37	1/80,800	70.33	6.00
157	bBmo	1/15,840	1.00	0.43	2.33	5.85	1.50	0.38	17.40	2.40	1/38,016	58.33	3.96
158	bBmu	1/15,840	1.00	0.41	2.44	6.12	1.44	0.20	16.39	2.47	1/39,125	59.51	3.96
159	bBmo	1/15,840	1.00	0.39	2.56	6.42	1.52	0.25	15.63	2.53	1/40,075	60.47	3.96
160	bBmo	1/13,500	0.73	0.18	5.56	10.13	0.69	nd	7.19	3.73	1/50,355	73.19	3.38

SRI MAP NUMBER	TYPE	MEASURABLE ATTRIBUTES											
		RpFr	MiLeLaAr	DeArDn	AvDeAr	AvLaAr	DeLnDn	SmDeAr	DeLeQ	AvLeRdFa	AvLeSc	AvLeId	MaxLoAc
161	aDmu	1/100,000	40.00	0.74	1.40	140.00	1.64	0.19	28.60	1.90	1/190,000	47.40	25.00
162	bAmo	1/10,000	0.47	0.20	5.00	5.00	0.72	0.29	8.00	3.54	1/35,400	71.75	2.50
163	bBmo	1/25,000	2.50	0.29	3.40	21.30	1.10	0.17	11.80	2.90	1/72,500	65.50	6.25
164	aEmu	1/500,000	1,000.00	1.00	1.00	2,500.00	2.44	0.11	40.00	1.58	1/790,000	36.71	125.00
165	dAmo	1/5,000	0.10	0.04	25.00	6.25	0.47	7.74	1.60	7.91	1/39,550	87.36	1.25
166	bCmu	1/50,000	10.00	0.33	3.03	75.75	1.30	0.23	13.20	2.75	1/137,500	63.64	12.50
167	cAmo	1/2,000	0.02	0.12	8.33	0.33	0.64	0.33	4.80	4.56	1/9,120	78.07	0.50
168	bDmu	1/100,000	40.00	0.57	1.75	168.00	1.68	0.11	23.81	2.05	1/205,000	51.20	25.00
169	aDmu	1/100,000	40.00	0.66	1.52	152.00	1.89	0.05	26.32	1.95	1/195,000	48.72	25.00
170	bBmu	1/15,000	0.90	0.29	3.45	7.76	1.10	nd	11.59	2.94	1/44,100	65.99	3.75
171	bCmu	1/63,360	16.06	0.37	2.70	108.39	1.24	0.15	14.81	2.60	1/164,736	61.54	15.84
172	bBmu	1/15,000	0.99	0.26	3.85	8.66	1.00	0.20	10.39	3.10	1/46,500	67.74	3.75
173	bCmo	1/50,000	10.00	0.35	2.86	71.50	1.13	0.39	13.99	2.67	1/133,500	62.55	12.50
174	bDmo	1/100,000	40.00	0.32	3.10	310.00	1.61	0.31	12.90	2.80	1/280,000	64.30	25.00
175	bBmo	1/25,000	2.50	0.32	3.13	19.56	1.15	nd	12.78	2.80	1/70,000	64.29	6.25
176	bCmu	1/50,000	10.00	0.20	5.00	125.00	1.32	0.56	8.00	3.50	1/175,000	71.40	12.50

nd : not determined

APPENDIX 4. TABLE OF CORRELATION COEFFICIENTS

(Cochran, 1969)

CORRELATION COEFFICIENTS AT THE 5% AND 1% LEVELS OF SIGNIFICANCE

Degrees of Freedom	5%	1%	Degrees of Freedom	5%	1%
1	.997	1.000	24	.388	.496
2	.950	.990	25	.381	.487
3	.878	.959	26	.374	.478
4	.811	.917	27	.367	.470
5	.754	.874	28	.361	.463
6	.707	.834	29	.355	.456
7	.666	.798	30	.349	.449
8	.632	.765	35	.325	.418
9	.602	.735	40	.304	.393
10	.576	.708	45	.288	.372
11	.553	.684	50	.273	.354
12	.532	.661	60	.250	.325
13	.514	.641	70	.232	.302
14	.497	.623	80	.217	.283
15	.482	.606	90	.205	.267
16	.468	.590	100	.195	.254
17	.456	.575	125	.174	.228
18	.444	.561	150	.159	.208
19	.433	.549	200	.138	.181
20	.423	.537	300	.113	.148
21	.413	.526	400	.098	.128
22	.404	.515	500	.088	.115
23	.396	.505	1,000	.062	.081

APPENDIX 5. ADEQUACY EVALUATION OF MAP LEGEND AND SRI REPORT (An example)

SRI serial no.: 157

SRI title: Soil survey of Shawano County, Wisconsin, USA. USDA-SCS (1982)
In coooperation with the Research Division of the College of Agricultural and Life Sciences, University of Wisconsin.

SRI map scale: 1/15,840

Intended land use objective: Multi-purpose

Land use for which legend and SRI report are being evaluated: Corn production

Total number of different mapping units: 90

Counts	Mapping unit symbols		No. of grid points counted for the sampled mapping units	
1	ObA		1	
	RoB		1	
	Mk		5	
	ObA		1	
	KaC		2	
	Sd		4	
	RoB		3	
	KaB		1	
	ObA		2	
2	RoC	RoB	1	2
	CrD		6	
	RoB		1	
	ScA		1	
	CtA		2	
	RoC		1	
	KaB		1	
	RoB		2	
	Mk		3	
3	ScA	CrC	2	1
	ObA	ObA	1	1
	KaC		1	
	KaB		1	
	CrC		1	
	RoB		2	
	Mu		5	
	ObA		2	
	Sd		3	
4	Mu	Mk	1	1
	RoB		1	
	ObA		2	
	Sd		1	
	Mu		5	
	ObA		1	
	ScA		2	
	ObA		2	
	Lx		3	
5	RoB	RoC ✓	1	1
	EcE	Sd ✓	1	1
	RoC	RoB ✓	1	1
	Sb	EcE ✓	2	1
	RoB	RoD ✓	1	1
	RoB		1	
	RoC		1	
	RoB		5	
	RoC		1	

List of the different mapping units	No. of grid points counted for each different mapping unit	% proportion of each mapping unit (Mi)	Mapping unit composition class (§52.1.2)	Missing data in the case composition class is unknown	Mapping unit adequacy coefficient (Ci)
ObA	17	8.54	U-L		1
RoB	27	13.57	U-S		1
Mk	21	10.55	U-L		1
KaC	17	8.54	X	CEC, BS and OM	0
Sd	13	6.53	U-L		1
KaB	8	4.02	X	CEC, BS and OM	0
RoC	6	3.02	U-S		1
CrD	6	3.02	U-S		1
ScA	15	7.54	U-S		1
CrC	2	1.01	U-S		1
Mu	14	7.04	U-L		1
Lx	2	1.01	U-L		1
EcE	2	1.01	U-L		1
Sb	2	1.01	X	Inclusions & their %, CEC, BS and OM	0
RoD	1	0.50	U-S		1

APPENDIX 5 cont.

6	Ba KaC KaB KaC KaD RoB KaC	1 10 1 1 4 2 1
7	KaB KaD ScA BuA Mk KaD KaC KaB ScA	2 3 2 6 1 2 2 2 2
8	Mu Sd ScA RoB ObA Mk RrD RoB	3 1 6 2 2 3 1 2
9	OeC2 Mk SoA OeB SoA Ba Sd SoA	2 2 1 6 3 1 3 2
10	SoA OeB SoA Mk	4 8 2 6

Ba	2	1.01	U-L	CEC, BS and OM	1
KaD	9	4.52	X		0
BuA	6	3.02	U-S		1
RrD	, 1	0.50	U-L		1
OeC2	2	1.01	U-S		1
SoA	12	6.03	U-L		1
OeB	14	7.04	U-S		1
	199	100			

Other remarks:
Readability of information in the SRI report is very high; the text is well written and presented.

% OVERALL LEGEND DESCRIPTION ADEQUACY (OLDA)=ΣMiCi x 100

APPENDIX 6. PERCENT OVERALL LEGEND DESCRIPTION ADEQUACY (OLDA) VALUES OF THE STUDIED SRIs IN FUNCTION OF THREE DIFFERENT LAND USES

SRI No.	Land uses		
	Corn production	Oil palm production	Production of *E. deglupta*
5	0	0	0
7	0	0	0
8	0	0	0
14	0	0	0
20	37.5	37.5	52.6
23	0	0	0
29	0	0	0
30	0	0	0
35	0	0	0
38	0	0	0
57	0	0	0
58	0	0	0
60	79.5	79.5	98
61	100	100	100
64	0	0	0
65	0	0	0
67	0	0	0
77	0	0	0
79	0	0	0
81	100	100	100
87	0	0	0
88	0	0	0
89	0	0	0
95	0	0	0
97	0	0	0
98	0	0	0
102	0	0	0
107	77	77	100
111	0	0	0
112	0	0	0

APPENDIX 6 cont.

SRI No.	Land uses		
	Corn production	Oil palm production	Production of *E. deglupta*
113	0	0	0
120	0	0	0
126	84.1	84.1	87.9
127	74.3	74.3	97
128	0	0	0
129	100	100	100
130	0	0	0
131	82.5	82.5	84
132	0	0	0
133	0	0	0
138	54.1	54.1	54.1
140	0	0	0
141	0	0	0
143	0	0	0
144	3.5	3.5	38
145	50.5	50.5	60.9
146	0	0	0
147	89.5	89.5	100
148	60.2	60.2	95.5
149	100	100	100
150	99.5	99.5	100
151	99	99	100
152	48.6	48.6	49.7
153	100	100	100
154	100	100	100
155	70.1	70.1	100
156	47.5	47.5	100
157	81.9	81.9	99
158	100	100	100

APPENDIX 6 cont.

SRI No.	Land uses		
	Corn production	Oil palm production	Production of *E. deglupta*
159	100	100	100
163	0	0	0
165	0	0	0
167	0	0	0
170	0	0	0
172	97.7	97.7	97.7
175	0	0	0

APPENDIX 7. DENSITY OF BASE MAP INFORMATION OF SOME S

Serial No. of SRI	SRI map scale	AvBmLnInDn (§52.1.3)	AvBmArInDn (§52.1.3)
5	1/15,840	0.8	1.3
7	1/20,000	6.1	7.3
8	1/25,000	1.8	2.3
14	1/20,000	6.3	7.0
20	1/15,000	4.6	5.5
23	1/12,500	4.0	4.6
29	1/5,000	5.1	5.7
30	1/20,000	4.3	4.7
35	1/32,000	3.6	4.1
38	1/22,000	4.6	5.1
57	1/5,000	6.0	8.5
58	1/20,000	6.5	7.3
60	1/15,840	1.0	1.0
61	1/25,000	4.5	4.9
64	1/20,000	4.3	4.7
65	1/5,000	4.7	6.5
67	1/10,000	3.4	5.2
77	1/31,680	2.7	3.9
79	1/25,000	4.5	5.0
81	1/10,000	5.4	7.0
87	1/10,000	1.7	1.3
88	1/5,000	0.0	0.0
89	1/10,000	1.0	2.0
95	1/10,000	5.1	5.6
97	1/2,400	0.0	0.0
98	1/10,000	2.0	2.8
102	1/2,000	1.0	2.5
107	1/30,000	5.7	5.3
111	1/2,500	5.3	8.1
112	1/25,000	3.4	2.4
113	1/15,840	3.7	5.9
120	1/5,000	2.6	3.0
126	1/9,000	4.3	5.0

APPENDIX 7 cont.

Serial No. of SRI	SRI map scale	AvBmLnInDn	AvBmArInDn
127	1/25,000	4.3	5.1
128	1/10,000	4.0	4.8
129	1/25,000	4.4	5.0
130	1/20,000	6.3	5.0
131	1/8,000	7.5	6.0
132	1/15,840	5.0	5.8
133	1/24,000	4.7	4.0
138	1/20,000	3.0	4.0
140	1/15,840	3.5	5.3
141	1/15,840	3.7	5.2
143	1/15,840	5.1	5.7
144	1/15,840	4.9	5.5
145	1/20,000	3.4	4.4
146	1/15,840	4.3	5.1
147	1/20,000	3.7	5.0
148	1/15,840	3.5	5.1
149	1/15,840	5.0	5.5
150	1/15,840	4.5	5.3
151	1/15,840	4.3	5.5
152	1/20,000	3.0	4.0
153	1/20,000	3.0	3.4
154	1/15,840	4.4	5.5
155	1/20,000	3.9	3.8
156	1/24,000	3.4	3.5
157	1/15,840	4.0	4.3
158	1/15,840	5.2	5.8
159	1/15,840	4.6	5.0
163	1/25,000	5.4	6.2
165	1/5,000	4.0	5.5
167	1/2,000	0.4	0.4
170	1/15,000	4.0	4.5
172	1/15,000	5.3	6.1
175	1/25,000	2.9	4.3

*Based on 66 SRIs

APPENDIX 8.1. PREDICTIVE ADEQUACY SCORES OF THE STUDIED SRIs FOR CORN PRODUCTION

	CARTOGRAPHIC			MAP LEGEND	BASE MAP			
Attributes / SRI No.	AvLeId at least 50% (§52.1.1)	Color distinguishable in at least 85% of cases (§52.1.1)	Symbols clear and symbol elements readable in at least 85% of cases (§52.1.1)	OLDA at least 60% (§52.1.2)	Base map accuracy standards given (§52.1.3)	AvBmLnInDn 2 - 25 (§52.1.3)	Base map information distinct from soils information in at least 85% of cases (§52.1.3)	SRI Predictive Adequacy Score (SPAS) (§52.2.4)
5	+	+	+	−	−	−	+	−
7	+	+	+	−	−	+	+	−
8	+	+	+	−	−	−	+	−
14	+	+	+	−	+	+	+	−
20	+	N.A.	+	−	+	+	+	−
23	+	N.A.	+	−	−	+	+	−
29	+	N.A.	+	−	−	+	+	−
30	+	N.A.	+	−	−	+	+	−
35	+	+	+	−	−	+	+	−
38	+	N.A.	+	−	−	+	+	−
57	+	+	+	−	−	+	+	−
58	+	+	+	−	−	+	+	−
60	+	+	+	+	+	−	+	−
61	+	+	+	+	+	+	+	−
64	+	N.A.	+	−	−	+	+	+
65	+	N.A.	+	−	−	+	+	−
67	+	N.A.	+	−	+	+	+	−

APPENDIX 8.1. cont.

Attributes / SRI No.	CARTOGRAPHIC: AvLeId at least 50%	CARTOGRAPHIC: Color distinguishable in at least 85% of cases	CARTOGRAPHIC: Symbols clear and symbol elements readable in at least 85% of cases	MAP LEGEND: OLDA at least 60%	BASE MAP: Base map accuracy standards given	BASE MAP: AvBmLnInDn 2 - 25	BASE MAP: Base map information distinct from soils information in at least 85% of cases	SRI Predictive Adequacy Score (SPAS)
77	+	+	+	−	+	+	+	−
79	+	+	+	−	−	+	+	−
81	+	+	+	+	+	+	+	+
87	+	N.A.	+	−	+	−	+	−
88	+	N.A.	+	−	−	−	+	−
89	+	N.A.	+	−	−	−	+	−
95	+	N.A.	+	−	−	+	+	−
97	+	+	+	−	−	−	+	−
98	+	+	+	−	−	+	+	−
102	+	N.A.	+	−	+	−	+	−
107	+	+	+	+	+	+	+	+
111	+	N.A.	+	−	+	+	+	−
112	+	N.A.	+	−	−	+	+	−
113	+	N.A.	+	−	+	+	+	−
120	+	N.A.	+	−	−	+	+	−
126	+	N.A.	+	+	−	+	+	−
127	+	+	+	+	+	+	+	+
128	+	N.A.	+	−	−	+	+	−
129	+	+	+	+	+	+	+	+
130	+	N.A.	+	−	+	+	+	−
131	+	+	+	+	+	+	+	+

APPENDIX 8.1. cont.

Attributes / SRI No.	CARTOGRAPHIC: AvLeId at least 50%	CARTOGRAPHIC: Color distinguishable in at least 85% of cases	CARTOGRAPHIC: Symbols clear and symbol elements readable in at least 85% of cases	MAP LEGEND: OLDA at least 60%	BASE MAP: Base map accuracy standards given	BASE MAP: AvBmLnInDn 2 - 25	BASE MAP: Base map information distinct from soils information in at least 85% of cases	SRI Predictive Adequacy Score (SPAS)
132	+	N.A.	+	-	+	+	+	-
133	+	N.A.	+	-	+	+	+	-
138	+	N.A.	+	-	+	+	+	-
140	+	N.A.	+	-	+	+	+	-
141	+	N.A.	+	-	+	+	+	-
143	+	N.A.	+	-	+	+	+	-
144	+	N.A.	+	-	+	+	+	-
145	+	N.A.	+	-	+	+	+	-
146	+	N.A.	+	-	+	+	+	-
147	+	N.A.	+	+	+	+	+	+
148	+	N.A.	+	+	+	+	+	+
149	+	N.A.	+	+	+	+	+	+
150	+	N.A.	+	+	+	+	+	+
151	+	N.A.	+	+	+	+	+	+
152	+	N.A.	+	-	+	+	+	-
153	+	N.A.	+	+	+	+	+	+
154	+	N.A.	+	+	+	+	+	+
155	+	N.A.	+	+	+	+	+	+

APPENDIX 8.1. cont.

	CARTOGRAPHIC			MAP LEGEND	BASE MAP			
Attributes / SRI No.	AvLeId at least 50%	Color distinguishable in at least 85% of cases	Symbols clear and symbol elements readable in at least 85% of cases	OLDA at least 60%	Base map accuracy standards given	AvBmLnInDn 2 - 25	Base map information distinct from soils information in at least 85% of cases	SRI Predictive Adequacy Score (SPAS)
156	+	N.A.	+	-	+	+	+	-
157	+	N.A.	+	+	+	+	+	+
158	+	N.A.	+	+	+	+	+	+
159	+	N.A.	+	+	+	+	+	+
163	+	+	+	-	-	+	+	-
165	+	N.A.	+	-	+	+	+	-
167	+	+	+	-	+	-	+	-
170	+	+	+	-	+	+	+	-
172	+	+	+	+	+	+	+	+
175	+	N.A.	+	-	-	+	+	-

+ Pass score

\- Fail score

N.A. Not applicable (Pass score)

APPENDIX 8.2. PREDICTIVE ADEQUACY SCORES OF THE STUDIED SRIs FOR OIL PALM PRODUCTION

	CARTOGRAPHIC			MAP LEGEND	BASE MAP			
Attributes / SRI No.	AvLeId at least 50% (§52.1.1)	Color distinguishable in at least 85% of cases (§52.1.1)	Symbols clear and symbol elements readable in at least 85% of cases (§52.1.1)	OLDA at least 60% (§52.1.2)	Base map accuracy standards given (§52.1.3)	AvBmLnInDn 2 - 25 (§52.1.3)	Base map information distinct from soils information in at least 85% of cases (§52.1.3)	SRI Predictive Adequacy Score (SPAS) (§52.2.4)
5	+	+	+	-	-	-	+	-
7	+	+	+	-	-	+	+	-
8	+	+	+	-	-	-	+	-
14	+	+	+	-	+	+	+	-
20	+	N.A.	+	-	+	+	+	-
23	+	N.A.	+	-	+	+	+	-
29	+	N.A.	+	-	-	+	+	-
30	+	N.A.	+	-	-	+	+	-
35	+	+	+	-	-	+	+	-
38	+	N.A.	+	-	-	+	+	-
57	+	+	+	-	-	+	+	-
58	+	+	+	-	-	+	+	-
60	+	+	+	+	+	+	+	-
61	+	+	+	+	+	-	+	-
64	+	N.A.	+	-	-	+	+	+
65	+	N.A.	+	-	-	+	+	-
67	+	N.A.	+	-	+	+	+	-

APPENDIX 8.2. cont.

	CARTOGRAPHIC			MAP LEGEND	BASE MAP			
Attributes / SRI No.	AvLeId at least 50%	Color distinguishable in at least 85% of cases	Symbols clear and symbol elements readable in at least 85% of cases	OLDA at least 60%	Base map accuracy standards given	AvBmLnInDn 2 - 25	Base map information distinct from soils information in at least 85% of cases	SRI Predictive Adequacy Score (SPAS)
77	+	+	+	-	+	+	+	-
79	+	+	+	-	-	+	+	-
81	+	+	+	+	+	+	+	+
87	+	N.A.	+	-	+	-	+	-
88	+	N.A.	+	-	-	-	+	-
89	+	N.A.	+	-	-	-	+	-
95	+	N.A.	+	-	-	+	+	-
97	+	+	+	-	-	-	+	-
98	+	+	+	-	-	+	+	-
102	+	N.A.	+	-	+	-	+	-
107	+	+	+	+	+	+	+	+
111	+	N.A.	+	-	+	+	+	-
112	+	N.A.	+	-	-	+	+	-
113	+	N.A.	+	-	+	+	+	-
120	+	N.A.	+	-	-	+	+	-
126	+	N.A.	+	+	-	+	+	-
127	+	+	+	+	+	+	+	+
128	+	N.A.	+	-	-	+	+	-
129	+	+	+	+	+	+	+	+
130	+	N.A.	+	-	+	+	+	-
131	+	+	+	+	+	+	+	+

APPENDIX 8.2. cont.

Attributes / SRI No.	CARTOGRAPHIC: AvLeId at least 50%	CARTOGRAPHIC: Color distinguishable in at least 85% of cases	CARTOGRAPHIC: Symbols clear and symbol elements readable in at least 85% of cases	MAP LEGEND: OLDA at least 60%	BASE MAP: Base map accuracy standards given	BASE MAP: AvBmLnInDn 2 - 25	BASE MAP: Base map information distinct from soils information in at least 85% of cases	SRI Predictive Adequacy Score (SPAS)
132	+	N.A.	+	-	+	+	+	-
133	+	N.A.	+	-	+	+	+	-
138	+	N.A.	+	-	+	+	+	-
140	+	N.A.	+	-	+	+	+	-
141	+	N.A.	+	-	+	+	+	-
143	+	N.A.	+	-	+	+	+	-
144	+	N.A.	+	-	+	+	+	-
145	+	N.A.	+	-	+	+	+	-
146	+	N.A.	+	-	+	+	+	-
147	+	N.A.	+	+	+	+	+	+
148	+	N.A.	+	+	+	+	+	+
149	+	N.A.	+	+	+	+	+	+
150	+	N.A.	+	+	+	+	+	+
151	+	N.A.	+	+	+	+	+	+
152	+	N.A.	+	-	+	+	+	-
153	+	N.A.	+	+	+	+	+	+
154	+	N.A.	+	+	+	+	+	+
155	+	N.A.	+	+	+	+	+	+

APPENDIX 8.2. cont.

Attributes / SRI No.	CARTOGRAPHIC: AvLeId at least 50%	CARTOGRAPHIC: Color distinguishable in at least 85% of cases	CARTOGRAPHIC: Symbols clear and symbol elements readable in at least 85% of cases	MAP LEGEND: OLDA at least 60%	BASE MAP: Base map accuracy standards given	BASE MAP: AvBmLnInDn 2 - 25	BASE MAP: Base map information distinct from soils information in at least 85% of cases	SRI Predictive Adequacy Score (SPAS)
156	+	N.A.	+	-	+	+	+	-
157	+	N.A.	+	+	+	+	+	+
158	+	N.A.	+	+	+	+	+	+
159	+	N.A.	+	+	+	+	+	+
163	+	+	+	-	-	+	+	-
165	+	N.A.	+	-	+	+	+	-
167	+	+	+	-	+	-	+	-
170	+	+	+	-	+	+	+	-
172	+	+	+	+	+	+	+	+
175	+	N.A.	+	-	-	+	+	-

+ Pass score

\- Fail score

N.A. Not applicable (Pass score)

APPENDIX 8.3. PREDICTIVE ADEQUACY SCORES OF THE STUDIED SRIs FOR PRODUCTION OF Eucalyptus deglupta

Attributes / SRI No.	CARTOGRAPHIC: AvLeId at least 50% (§52.1.1)	CARTOGRAPHIC: Color distinguishable in at least 85% of cases (§52.1.1)	CARTOGRAPHIC: Symbols clear and symbol elements readable in at least 85% of cases (§52.1.1)	MAP LEGEND: OLDA at least 60% (§52.1.2)	BASE MAP: Base map accuracy standards given (§52.1.3)	BASE MAP: AvBmLnInDn 2 - 25 (§52.1.3)	BASE MAP: Base map information distinct from soils information in at least 85% of cases (§52.1.3)	SRI Predictive Adequacy Score (SPAS) (§52.2.4)
5	+	+	+	-	-	-	+	-
7	+	+	+	-	-	+	+	-
8	+	+	+	-	-	-	+	-
14	+	+	+	-	+	+	+	-
20	+	N.A.	+	-	+	+	+	-
23	+	N.A.	+	-	-	+	+	-
29	+	N.A.	+	-	-	+	+	-
30	+	N.A.	+	-	-	+	+	-
35	+	+	+	-	-	+	+	-
38	+	N.A.	+	-	-	+	+	-
57	+	+	+	-	-	+	+	-
58	+	+	+	-	-	+	+	-
60	+	+	+	+	+	-	+	-
61	+	+	+	+	+	+	+	-
64	+	N.A.	+	-	-	+	+	+
65	+	N.A.	+	-	-	+	+	-
67	+	N.A.	+	-	+	+	+	-

APPENDIX 8.3. cont.

Attributes / SRI No.	CARTOGRAPHIC: AvLeId at least 50%	CARTOGRAPHIC: Color distinguishable in at least 85% of cases	CARTOGRAPHIC: Symbols clear and symbol elements readable in at least 85% of cases	MAP LEGEND: OLDA at least 60%	BASE MAP: Base map accuracy standards given	BASE MAP: AvBmLnInDn 2 - 25	BASE MAP: Base map information distinct from soils information in at least 85% of cases	SRI Predictive Adequacy Score (SPAS)
77	+	+	+	-	+	+	+	-
79	+	+	+	-	-	+	+	-
81	+	+	+	+	+	+	+	+
87	+	N.A.	+	-	+	-	+	-
88	+	N.A.	+	-	-	-	+	-
89	+	N.A.	+	-	-	-	+	-
95	+	N.A.	+	-	-	+	+	-
97	+	+	+	-	-	-	+	-
98	+	+	+	-	-	+	+	-
102	+	N.A.	+	-	+	-	+	-
107	+	+	+	+	+	+	+	+
111	+	N.A.	+	-	+	+	+	-
112	+	N.A.	+	-	-	+	+	-
113	+	N.A.	+	-	+	+	+	-
120	+	N.A.	+	-	-	+	+	-
126	+	N.A.	+	+	-	+	+	-
127	+	+	+	+	+	+	+	+
128	+	N.A.	+	-	-	+	+	-
129	+	+	+	+	+	+	+	+
130	+	N.A.	+	-	+	+	+	-
131	+	+	+	+	+	+	+	+

APPENDIX 8.3. cont.

Attributes / SRI No.	CARTOGRAPHIC: AvLeId at least 50%	CARTOGRAPHIC: Color distinguishable in at least 85% of cases	CARTOGRAPHIC: Symbols clear and symbol elements readable in at least 85% of cases	MAP LEGEND: OLDA at least 60%	BASE MAP: Base map accuracy standards given	BASE MAP: AvBmLnInDn 2 - 25	BASE MAP: Base map information distinct from soils information in at least 85% of cases	SRI Predictive Adequacy Score (SPAS)
132	+	N.A.	+	-	+	+	+	-
133	+	N.A.	+	-	+	+	+	-
138	+	N.A.	+	-	+	+	+	-
140	+	N.A.	+	-	+	+	+	-
141	+	N.A.	+	-	+	+	+	-
143	+	N.A.	+	-	+	+	+	-
144	+	N.A.	+	-	+	+	+	-
145	+	N.A.	+	+	+	+	+	+
146	+	N.A.	+	-	+	+	+	-
147	+	N.A.	+	+	+	+	+	+
148	+	N.A.	+	+	+	+	+	+
149	+	N.A.	+	+	+	+	+	+
150	+	N.A.	+	+	+	+	+	+
151	+	N.A.	+	+	+	+	+	+
152	+	N.A.	+	-	+	+	+	-
153	+	N.A.	+	+	+	+	+	+
154	+	N.A.	+	+	+	+	+	+
155	+	N.A.	+	+	+	+	+	+

APPENDIX 8.3. cont.

	CARTOGRAPHIC			MAP LEGEND	BASE MAP			
Attributes / SRI No.	AvLeId at least 50%	Color distinguishable in at least 85% of cases	Symbols clear and symbol elements readable in at least 85% of cases	OLDA at least 60%	Base map accuracy standards given	AvBmLnInDn 2 - 25	Base map information distinct from soils information in at least 85% of cases	SRI Predictive Adequacy Score (SPAS)
156	+	N.A.	+	+	+	+	+	+
157	+	N.A.	+	+	+	+	+	+
158	+	N.A.	+	+	+	+	+	+
159	+	N.A.	+	+	+	+	+	+
163	+	+	+	-	-	+	+	-
165	+	N.A.	+	-	+	+	+	-
167	+	+	+	-	+	-	+	-
170	+	+	+	-	+	+	+	-
172	+	+	+	+	+	+	+	+
175	+	N.A.	+	-	-	+	+	-

\+ Pass score
\- Fail score
N.A. Not applicable (Pass score)

APPENDIX 9. **THE QUESTIONNAIRE TO SOIL SURVEYORS**

GEOLOGISCH INSTITUUT
--
LABORATORIUM
voor
ALGEMENE BODEMKUNDE
—
Dir. Prof. Dr. Ir. J. B. AMERIJCKX
E. assist. Dr. R. LANGOHR
—

GENT.
[illegible]
Tel. (091) [illegible]

Re: QUESTIONNAIRE TO PEOPLE WHO HAVE BEEN MAKING SOIL SURVEYS FOR THE PURPOSE OF PRODUCING SOIL MAPS

Dear Sir/Madam,

SUBJECT: Nature of the existing soil resource inventories(SRIs) and the methodologies that were used to produce them

We have the honour to send you this questionnaire and we would like in advance to apologize for the fact that it may take some of your precious time in answering it.

We are doing research on the subject "CHARACTERIZATION OF SRIs AND EVALUATION OF THEIR ADEQUACY FOR VARIOUS LAND USE OBJECTIVES". In the course of this study, need has arisen to know some facts about the nature of the existing SRIs and the methodologies that were used to produce them. We have thus selected you as one of the people specialized in one or more fields of earth science to receive this questionnaire, with full confidence that you will be willing to to communicate your experience to us regarding the mentioned subject. We consider that your views are very important for the success of this investigation.

As far as this questionnaire is concerned, a soil resource inventory includes a soil map and its report except in the case of site evaluations. The latter could simply be reports on site informations gathered mostly from experimental plots.

If you have had several jobs in your career, or you have been working for different institutions, please answer for the most recent one, otherwise make copies and specify for each job/institution.

From our side, we are very much willing to inform you of the results of this research. If you desire to have the results sent to you, please fill in the section on application for results of the research. Otherwise if you would like anonymity to be maintained you should leave this section blank.

Looking forward to receiving your completed questionnaire as soon as possible.

Yours sincerely,

Dr. R. LANGOHR
(Scientific supervisor)

BALTHAZAR M. MSANYA
(Doctorate student)

QUESTIONNAIRE TO PEOPLE WHO HAVE BEEN MAKING SOIL SURVEYS FOR THE PURPOSE OF PRODUCING SOIL MAPS

APPLICATION FOR RESULTS OF THE RESEARCH

Full name (block letters) :

Nationality :

Mailing address :

1. Specify your field(s) of specialization. Mark with X.

☐ soil physics ☐ soil chemistry ☐ soil microbiology

☐ soil survey/classification ☐ agronomy ☐ geology ☐ geography

☐ geomorphology ☐ research soil scientist

☐ other(s) (specify)---

2. What institutions are you working for? Mark with X.

☐ university or other institution of higher teaching

☐ research institute or experimental station separate from university

☐ government soil survey institute ☐ private soil survey consultancy firm

☐ ministry or department of agriculture ☐ ministry or department of forestry

☐ other(s) (specify)---

3. Following the standards in your country, what is your professional level? Mark with X.

☐ senior ☐ mid-career ☐ junior

Indicate here if for the following questions you would like to give answers for your institution ☐ or for yourself ☐ . Mark with X.

4. For how long has your institution /have you been involved in soil surveys up to date? Fill in number of years. ☐

5. What type of soil resource inventories (SRIs) have been carried out? Indicate publication scale or range of scales and mark with A(always), F(frequently), C(commonly), O(occasionally) and N(never).

Types of SRI	Site evaluations	Detailed	Semi-detailed	Reconnaissance	Exploratory
scale:					
frequency:					

6. In soil surveys who/what has been determining the scale and content of the legends? Mark with A(always), F(frequently), C(commonly), O(occasionally), N(never) and ?(you don't know).

	Types of SRI				
	Site evaluations	Detailed	Semi-detailed	Reconnaissance	Exploratory
.decision of your institution/yourself					
.person/agency paying for the SRIs					
.political decisions					

7. In the surveys, what was the (a) source of funding and (b) staff? Mark with A(always), F(frequently), C(commonly), O(occasionally), N(never) and ?(you don't know).

a. ☐ funding from abroad ☐ funding from within the country

☐ funding from both abroad and within the country

b. ☐ only foreign staff were involved ☐ only local staff were involved

☐ both foreign and local staff were involved

8. Who have been the immediate users of the SRIs ? Mark with A(always), F(frequently), C(commonly), O(occasionally) and ?(you don't know).

	Types of SRI				
	Site evaluations	Detailed	Semi-detailed	Reconnaissance	Exploratory
.ministry of agriculture and/or related departments					
.ministry of natural resources including forestry and/or related departments					
.road and building construction engineers and/or elated engineering departments					
.private farmers and land owners					
.state farms					
.military authorities					
.others (specify) -------------------					

9. Have any attempts been made to assess the utility of SRIs ie. to monitor if users are satisfied with them or not? Mark with A(always), F(frequently), C(commonly), O(occasionally), N(never) and ?(you don't know).

Types of SRI				
Site evaluations	Detailed	Semi-detailed	Reconnaissance	Exploratory

10. If attempts have been made to assess utility of SRIs, how was it done? Mark with A(always), F(frequently), C(commonly), O(occasionally), N(never) and ?(you don't know).

	Types of SRI				
	Site evaluations	Detailed	Semi-detailed	Reconnaissance	Exploratory
.by sending questionaires to users					
.by having permanent extension staff in the field					
.by sending occasional extension staff to the field					
.by monitoring sales & new orders of SRIs					
.other means (specify) -------------------- --------------------					

11. In terms of field soil mapping procedure, how were the observations made? Mark with A(always), F(frequently), C(commonly), O(occasionally) and N(never).

	Types of SRI				
	Site evaluations	Detailed	Semi-detailed	Reconnaissance	Exploratory
.fixed-grid surveys					
.free-hand surveys					
.combined fixed-grid & free-hand surveys					
.other types (specify) -------------------- --------------------					

12. In the soil surveys, was the purity of mapping units determined? Mark with A(always), F(frequently), C(commonly), O(occasionally) and N(never).

Types of SRI				
Site evaluations	Detailed	Semi-detailed	Reconnaissance	Exploratory

13. If the purity of mapping units was being determined, what percentage was aimed at? Specify the percentage eg. 75%.

Types of SRI				
Site evaluations	Detailed	Semi-detailed	Reconnaissance	Exploratory

14. If the purity of mapping units was being determined, was this information included in the soil survey reports? Mark with A(always), F(frequently), C(commonly), O(occasionally) and N(never).

Types of SRI				
Site evaluations	Detailed	Semi-detailed	Reconnaissance	Exploratory

15. If the purity of mapping units was not being determined, what is the reason? Mark with X.

☐ determination is too costly ☐ purity of mapping units is not so important

☐ time is too limiting ☐ it is a habit not to determine purity of mapping units

☐ other reasons (specify)____

____

16. From your experience, how do you consider soil maps are being used in your country? Mark with A(always), F(frequently), C(commonly), O(occasionally) and N(never).

	Types of SRI				
	Site evaluations	Detailed	Semi-detailed	Reconnaissance	Exploratory
.directly					
.indirectly thru interpretation maps					

17. If soil maps are not being made in your country, what do you think are the reasons? Mark with X.

☐ the needed information can be obtained from other sources (specify)

____

☐ there is enough soil information, so there is no need

☐ people generally consider soil maps as not being useful

☐ soil maps are too complicated and there are too few soil scientists and/or extension staff for their interpretation

☐ other reasons (specify)____

____

18. If soil maps in your country are not being used anymore despite their availability, what are the reasons? Mark with X.

- [ ] soil maps are too complicated and there are too few soil scientists and/or extension staff for their interpretation
- [ ] people have no sufficient knowledge about their existence
- [ ] people don't trust soil maps because previous ones were faulty and useless
- [ ] the needed soil information can better be obtained from other sources (specify)____
____
- [ ] other reasons (specify)____
____

19. Has there been any publicity about the existence of soil maps and reports in order to increase their use? Mark with A(always), F(frequently), C(commonly), O(occasionally), N(never) and ?(you don't know).

Types of SRI				
Site evaluations	Detailed	Semi-detailed	Reconnaissance	Exploratory

20. Out of the total number of soil surveys that have been made, give an estimation of how many were printed for public use. Fill in numbers.

$$\frac{\text{no. of surveys printed}}{\text{total no. of surveys made}} = \_\_\_\_$$

21. Out of the total number of surveys that have been printed, give an estimation of how many copies were sold. Fill in numbers.

$$\frac{\text{no. of copies sold}}{\text{total no. of copies printed}} = \_\_\_\_$$

22. If you have any further comments you would like to make about soil maps and their reports, you can put them in this section.

Please mail the completed questionnaire preferably by air to:

Mr. Balthazar M. MSANYA
State University Ghent
Department of General Pedology
Krijgslaan 281, S8
B-9000 Ghent
BELGIUM

APPENDIX 10. THE QUESTIONNAIRE TO USERS OF SOIL SOIL MAPS AND REPORTS

GEOLOGISCH INSTITUUT

LABORATORIUM
voor
ALGEMENE BODEMKUNDE

Dir. Prof. Dr. Ir. J. B. AMERIJCKX
Werkleider Dr. R. LANGOHR

GENT
[illegible]
[illegible]
[illegible]

Re: QUESTIONNAIRE TO USERS OF SOIL MAPS AND REPORTS

Dear Sir/Madam,

We are doing research on the subject of "CHARACTERIZATION OF SOIL RESOURCE INVENTORIES AND THE EVALUATION OF THEIR ADEQUACY FOR VARIOUS LAND USE OBJECTIVES", and we have the honour to send you a questionnaire through which we can get information relevant to this research.

We have selected you as one of the scientists to receive this questionnaire, with the confidence that you will be willing to communicate your experience to us regarding the use of soil maps and their reports. Your views are important for the success of this study.

From our side, we are very much willing to inform you of the results of the research. If you desire to have the results sent to you, please fill in the section on application for results of the research. Otherwise if you would like anonymity to be maintained, you should leave this section blank.

Looking forward to your kind cooperation and immediate response.

Yours sincerely,

R. Langohr

Dr. R. LANGOHR
(Scientific supervisor)

BALTHAZAR M. MSANYA
(Doctorate student)

QUESTIONNAIRE TO USERS OF SOIL MAPS AND REPORTS

APPLICATION FOR RESULTS OF THE RESEARCH

Full name (block letters) :

Mailing address :

Nationality :

---

1. Specify your profession using the following key (mark with X; several answers if applicable).

☐ Agronomy ☐ Horticulture ☐ Forestry

☐ Animal breeding & production ☐ Soil science

☐ Civil engineering ☐ Electrical engineering

☐ Land reform (redistribution of land) ☐ Tax assessment

☐ Environmental science/ecology ☐ Research in _________________

☐ Extension services for ____

☐ Other (specify)____

NB. In case of more than one profession, please specify the one for which you would like to answer this questionaire. Mark with an extra X in the appropriate square above.

2. What institution are you working for ? (mark with X; several answers if applicable).

☐ ministry of agriculture and/or related departments

☐ ministry of natural resources including forestry and/or related departments

☐ ministry of land planning and/or related departments

☐ ministry of public works and/or related departments

☐ private company (specify specialization)--------------------------

----

☐ other (specify)____

For all the following questions, please fill in all cases by using the following frequency code : A=always, F=frequently, C=commonly, O=occasionally and N=never

3. Do you use soil maps in your work ? (answer by A, F, C, O or N)

☐

If the answer is "Never", please answer questions 4, 15 and 16.

4. In your work do you use interpretation maps completely ☐ or partly ☐ derived from soil maps ? (answer by A, F, C, O or N).

5. If you have been using soil maps, for what purpose exactly ? (answer by A, F, C, O, or N).

☐ to locate suitable areas for professional productions and/or estimations and/or informations

☐ for the sake of getting loans or financial assistance from banks or government

☐ other reasons (specify) --

----

6. If you use soil maps, who produces these maps ? (answer by A, F, C, O or N

☐ your own institution ☐ government soil survey institutions

☐ private soil survey institutions ☐ other institutions (specify)

----

7. If you use soil maps, they are produced (answer by A, F, C, O or N).

☐ specifically and only for your objectives

☐ as general base maps for multiple uses

☐ for specific objectives different from yours

8. If you use soil maps produced by other institutions, (answer by A, F, C, O or N).

- [ ] you still have to make complementary prospection
- [ ] all the necessary information can be found on the maps
- [ ] other situations (specify)------------------------------------

----

9. If you have been using soil maps, how did you know of their existence ? (answer by A, F, C, O or N).

- [ ] from education in college/university
- [ ] from colleagues
- [ ] through extension services
- [ ] through publicity in the radio, on television, in newspapers
- [ ] other means (specify)------------------------------------

----

10. When you decided to use soil maps, how easy was it to know if they were existing or not ? (answer by A, F, C, O or N).

- [ ] very difficult
- [ ] difficult
- [ ] easy
- [ ] very easy

11. When you decided to use soil maps, were you free to select those which were good for your objectives ? (answer by A, F, C, O or N).

- [ ] (specify if not A)------------------------------------

----

12. When using soil maps, did you need any help from a soil surveyor or soil scientist to interpret for you ? (answer by A,F,C,O or N).

- [ ]

13. When using soil maps, what problems have you been facing ? (answer by A, F, C, O or N).

- [ ] problems related to location
- [ ] problems related to legibility (readability)
- [ ] problems related to terminology (specify; mark with X)
  - [ ] too complicated
  - [ ] too vague
- [ ] no problems
- [ ] other problems (specify)------------------------------------

----

14. If you have been using soil maps in relation to your profession as quoted under 1, what comments can you make on them ? (answer by A, F, C, O or N).

- [ ] soil maps are an absolute necessity in your projects
- [ ] soil maps are completely useless in your projects
- [ ] soil maps are only good when you have soil experts to interpret them
- [ ] other comments (specify)------------------------------------

----

15. If you don't use soil maps at all in relation to your profession as quoted under 1, why ? (answer by A, F, C, O, or N).

- [ ] you have more useful information for your needs from interpretation maps (specify)____
- [ ] from your past experience you don't trust soil maps anymore (specify)____
- [ ] soil maps are too complicated to use and you don't have the technical ability to interpret them
- [ ] soil maps are useful for you, but there are no maps of the areas you are working in
- [ ] other reasons (specify)____

16. If you have any further comments that you would like to make about soil maps and their reports, you can put them in this section.

Mail preferably by air to: Mr. Balthazar M. MSANYA
General Pedology - State University Ghent
Krijgslaan 281 - S8
B-9000 Ghent
BELGIUM

APPENDIX 11. REVISED QUESTIONNAIRE TO USERS OF SOIL MAPS AND REPORTS

GEOLOGISCH INSTITUUT

LABORATORIUM
voor
ALGEMENE BODEMKUNDE

Dir Prof Dr Ir. J. B. AMERIJCKX
Werkleider Dr R LANGOHR

GENT

Krijgslaan 281 - S 8 - B 9000 GENT (België)
Tel (09) 22 57 15 - Ext 2761 - 2760
Telex RUGENT 12 754

Re: REVISED QUESTIONNAIRE TO USERS OF SOIL MAPS AND REPORTS

Dear Sir/ Madam,

We are doing research on the subject "CHARACTERIZATION OF SOIL RESOURCE INVENTORIES AND EVALUATION OF THEIR ADEQUACY FOR VARIOUS LAND USE OBJECTIVES", and we have the honour to send you a questionnaire through which we believe we can get information relevant to this work. In fact this questionnaire is an improved version of a previous one which was distributed to various scientists world-wide. If you already received the first questionnaire, kindly bear with us the fact that some questions are repeated in the present one.

We have selected you as one of the scientists to receive this questionnaire, with the confidence that you will be willing to communicate your experience to us regarding the use of soil maps and reports. Moreover we consider that your views are very important for the success of this research.

Looking forward to receiving your completed questionnaire as soon as possible.

Yours sincerely,

Dr. Roger LANGOHR
Scientific Supervisor.

Balthazar M. MSANYA
Doctorate student.

REVISED QUESTIONNAIRE TO USERS OF SOIL MAPS AND REPORTS

NOTE: Please read the instructions given after the questions. In some, you have to answer using the frequency code: A=always, F=frequently, C=commonly, O=occasionally and N=never. A question left unanswered will be taken as being not applicable to you.

---

1. Fill in the following particulars.

   Full name in block letters (optional):

   Mailing address (optional):

   Nationality:

---

2. Specify your field of specialization using the following key (mark with x; several answers if applicable).

- [ ] Agronomy
- [ ] Horticulture
- [ ] Forestry
- [ ] Soil science
- [ ] Animal breeding and production
- [ ] Civil engineering
- [ ] Electrical engineering
- [ ] Land reform (redistribution of land)
- [ ] Tax assessment
- [ ] Environmental science/ecology
- [ ] Research in ____
- [ ] Extension services for ______________________________
- [ ] Others (specify) ___________________________________

3. What institution are you working for? (mark with x; several answers if applicable).

- [ ] Ministry of agriculture and/or related departments
- [ ] Ministry of natural resources including forestry and/or related departments
- [ ] Ministry of land planning and/or related departments
- [ ] Ministry of public works and/or related departments
- [ ] Private company (specify) ____________________________
- [ ] Others (specify) ____________________________________

4. According to the professional standards in your country, how would you consider yourself? (mark with x).

- [ ] Senior
- [ ] Mid-career
- [ ] Junior

5. What percent of your work is done:

- [ ] In the field
- [ ] In the office

6. Do you use soil maps and reports in your work? (answer by A, F, C, O or N).

- [ ]

7. Do you use soil maps and reports more often (mark with x):

- [ ] In the field
- [ ] In the office

8. How many soil maps do you have at present?

- [ ]

9. Do you normally wish to obtain (mark with x):

- [ ] Soil maps only
- [ ] Soil maps and reports
- [ ] Reports only

10. If you have been using soil maps and reports, in which areas of land management do you find them useful in making decisions?

____

____

11. Which do you find most useful? (mark with x).

- [ ] Soil maps
- [ ] Soil reports
- [ ] Both are equally useful

12. Do you use interpretation maps? (answer both cases by A, F, C, O or N).
(a) Interpretation maps completely derived from soil maps

☐

(b) Interpretation maps partly derived from soil maps

☐

13. Which do you find most useful? (mark with x).

☐ Interpretation maps ☐ Soil maps ☐ Both are equally useful

14. Who produced the soil maps and reports you have been using? (answer all cases by A, F, C, O or N).

☐ Government soil survey institutions
☐ Private soil survey institutions
☐ Other institutions (specify)________________________________

15. For how long have you used soil maps and reports? (indicate number of years)

☐

16. Have you been trained to use soil maps and reports? (mark with x).

☐ Yes ☐ No

17. If you have been using soil maps and reports, how did you know of their existence? (answer all cases by A, F, C, O or N).

☐ Through education in school
☐ Through extension services
☐ From colleagues
☐ Through publicity in the radio, tevevision and/or newspapers

☐ Other means (specify)____

18. When using soil maps and reports, did you need help from anyone else? (answer by A, F, C, O or N).

☐ (specify)____

19. When using soil maps and reports, what problems related to the documents per se did you encounter? (answer all cases by A, F, C, O or N).

☐ Problems of location on the map
☐ Poor legibility (readability) of the map
☐ Problems of incomplete definition of mapping units
☐ Problems of incomplete analytical data
☐ Problems of mapping errors
☐ Problems of terminology (specify; mark with x).

☐ too complicated
☐ too vague

☐ Others (specify)____

20. What type of base map would you prefer soil information printed on? (answer all cases by A, F, C, O or N)

☐ A topographic map ☐ An aerial photograph

☐ Others (specify)____

21. If you have been using soil maps and reports, what comments can you make about their significance? (answer all cases by A, F, C, O or N).

☐ These documents are an absolute necessity in your projects

☐ They are completely useless in your projects

☐ They are only good when there are soil experts to interpret them

☐ They are a valuable addition to other information

☐ Other comments (specify)_______________________________________

____

22. If you have any further comments that you would like to make about soil maps and reports, you can put them in this section.

Please mail the completed questionnaire preferably by air to:

Mr. Balthazar M. MSANYA
State University Ghent
Department of General Pedology
Krijgslaan 281, S8
B-9000 Ghent
BELGIUM

APPENDIX 12. LIST OF ABBREVIATIONS

1. ADDS : Applied Digital Data Systems, Inc. (§41.3.2)
2. API : Air photo interpretation (§22.4)
3. AvBmArInDn : Average base map areal information density (§43.3)
4. AvBmLnInDn : Average base map linear information density (§43.3)
5. AvDeAr : Average delineation area (§41.1.10)
6. AvLaAr : Average land area (§41.1.10)
7. AvLeId : Average legibility index (§41.1.16)
8. AvLeRdFa : Average legible reduction factor (§41.1.14)
9. AvLeSc : Average legible scale (§41.1.15)
10. CNRA : Centre National de Recherches Agronomiques - France (§31.4)
11. CPCS : Commision de Pédologie et Cartographie des Sols - France (§42.3.4)
12. De : Delineation (§41.1.5)
13. DeArDn : Delineation areal density (§41.1.8)
14. DeBoCo : Delineation boundary complexity (§41.1.19)
15. DeBoRo : Delineation boundary roundness (§41.1.19)
16. DeLeQ : Delineation legibility quotient (§41.1.13)
17. DeLnDn: Delineation linear density (§41.1.9)
18. DSIR : Department of Scientific and Industrial Research - New Zealand (§31.3, §42.3.5)
19. E : Survey effort (§22.4)
20. FAO : Food and Agriculture Organization of the United Nations (§42.3.4)
21. I : Intricacy of soil pattern (§22.4)
22. INEAC : Institut National d'Etude Agronomique du Congo (table 4.9)
23. INRA : Institut National de la Recherche Agronomique - France (§42.3.5)
24. ISRIC : International Soil Reference and Information Centre - Wageningen (§31.1)
25. Le : Legibility (§41.1.1)

APPENDIX 12 cont.

26. LnRdFa : Linear reduction factor (§41.3.3)
27. LRDC : Land Resources Development Centre - Britain (§31.7)
28. MaIt : Mapping intensity (§41.1.12)
29. MaxLoAc : Maximum location accuracy (§41.1.17)
30. MiLeDeAr : Minimum legible delineation area (§41.1.6)
31. MiLeLaAr : Minimum legible land area (§41.1.7)
32. OLeDeAr : Optimum legible delineation area (§41.1.14)
33. OLDA : Overall legend description adequacy (§52.1e)
34. ORSTOM : Office de la Recherche Scientifique et Technique Outre-Mer - France (§31.5)
35. PSc : Publication scale (§41.1.3)
36. RpFr : Representative fraction (§41.1.3)
37. RV : Relative variance (§23.4)
38. SCS : Soil Conservation Service - of the United States Department of Agriculture (§24.3; fig. 4.19)
39. ScFa : Scale factor (§41.1.4)
40. SIL : Survey intensity level (§22.3)
41. SmDeAr : Smallest delineation area (§41.1.11)
42. SPAS : SRI predictive adequacy score (§52.2.4)
43. SRI : Soil resource inventory (§11)
44. STIBOKA : Stichting voor Bodemkartering (Netherlands Soil Survey Institute) - Wageningen (§31.6)
45. Unesco : United Nations Educational, Scientific and Cultural Organization (§42.3.4)
46. USDA : United States Department of Agriculture (§31.2; §42.3.4)

APPENDIX 13. GUIDELINES FOR ASSESSING THE QUALITY AND ADEQUACY OF A SRI FOR SITE-SPECIFIC LAND USES

A. CARTOGRAPHIC ATTRIBUTES

1. *Estimate average legible scale (AvLeSc) of the SRI map using the formula in §41.1.15.*

2. *Using the formula in §41.1.16, calculate the average legibility index (AvLeId) of the map.*

3. *The requirement is, AvLeId should be at least 50 (§52.1.1). If so, assign (+) score and if not (-) score (respectively meaning pass or fail), and proceed.* ☐

4. *If the SRI map is colored, estimate color legibility using the method described in §52.1.1.*

5. *The requirement is, colors should be distinguishable in at least 85% of cases (§52.1.1). If so, assign (+) score and if not (-) score and proceed.* ☐

6. *If the SRI map is not colored, assign N.A. (not applicable) equivalent to (+) score, and proceed.* ☐

7. *Estimate map symbol legibility using the method described in §52.1.1.*

8. *The requirement is, symbols should be clear and readable in at least 85% of cases (§52.1.1). If so, assign (+) score and if not (-) score, and proceed.* ☐

B. MAP LEGEND ATTRIBUTES

1. *Prepare suitability table outlining the limiting soil properties in function of the land use under consideration (see §52.1.2a)*

2. *If the SRI map has 20 or more different mapping units, sample part of them and estimate the % proportion (Mi) of each using the procedure described in §52.1.2c. If the number of different mapping units is less than 20, all have to be used in the evaluation. % areal proportions of mapping units are those given in the SRI. If % proportions are not given in the SRI, then sampling is necessary even when the number of mapping units is less than 20, to be able to estimate them.*

3. *Control the information given in the SRI on the mapping units against the requirements stipulated for the land use, and define the composition classes of the units (§52.1.2d).*

4. *To each mapping unit, assign the mapping unit description adequacy coefficient (Ci) in function of its composition class, and calculate the percent overall legend description adequacy (OLDA) using the formula given in §52.1.2e.*

4. *The requirement is, % OLDA should be at least 60 (§52.1.2f). If so, assign (+) score and if not (-) score, and proceed.* ☐

APPENDIX 13 cont.

C. <u>BASE MAP ATTRIBUTES</u>

1. *Check in the SRI if <u>base map accuracy standards</u> are specified (§52.1.3). If so, assign (+) score and if not (-) score, and proceed.* ☐

2. *Using the method described in §43.3. estimate the density of base map information.*

3. *<u>The requirement is</u>, the average base map linear information density - AvBmLnInDn (§43.3) should be between 2 and 25, or alternatively the base map areal information density - AvBmArInDn (§43.3) should be between 2 and 30. If so, assign (+) score and if not (-) score, and proceed.* ☐

4. *Using the procedure given in §52.1.3, check if base map information is clearly separated from soils information.*

5. *<u>The requirement is</u>, base map information should be clearly separated from soils information in at least 85% of cases. If so, assign (+) score and if not (-) score, and proceed.* ☐

D. <u>PREDICTIVE ADEQUACY OF THE SRI</u>

1. *Assign to the document, the SRI Predictive Adequacy Score - SPAS (§52.2.4) in function of scores made in the preceeding individual attributes. All the attributes used in the assessment are considered equally important. Hence the document will have a (+) score only when all the individual attributes have scored (+). Otherwise (-) score when even one of them has (-) score. Assign the respective score and proceed.* ☐

2. *Proceed to ground truth checking <u>ONLY</u> when the SRI has a (+) score at the "SPAS" level.*

APPENDIX 14. AUTOBIOGRAPHY

SOKOINE UNIVERSITY OF AGRICULTURE CURRICULUM VITAE

1. PERSONAL HISTORY

1 1. Full name : Balthazar Msanya
1 2. Date of birth : 13.01.1953
1 3. Place of birth : Moshi
1 4. Nationality : Tanzanian
1 5. Marital status : married
1 6. Number of children : one

2. ACADEMIC QUALIFICATIONS

	Qualifications (and when obtained)	University/college attended
2 1.	BSc (Agric.) (Hons) - 1977	University of Dar es Salaam
2 2.	MSc (Soil Science) - 1980	Ghent State University Belgium
2 3.	Cert. (Remote Sensing) - 1981	Regional Centre for Services in Surveying & Mapping, Nairobi
2 4.	Cert. (Animation techniques & conducting of meetings) - 1984	General Administration for Development Cooperation, Brussels
2 5.	Cert. (French language - elementary level) - 1985	Provincial Institute for Commerce and Languages, Ghent.

3. PROFESSIONAL QUALIFICATIONS (including memberships in professional societies)

Qualifications (and when obtained)

3 1. Member of the Belgian Society of Soil Science (Pedologie) since 1980
3 2. Member of the International Society of Soil Science (ISSS) since 1979
3 3. Member of the East African Soil Science Society (EASSS) since 1982
3 4. Member of the Africa Association of the State University of Ghent since 1986

4. POSTS HELD AT THE UNIVERSITY

	Posts	Dates
4 1.	Tutorial Assistant	May 5, 1977 - June 30, 1979
4 2.	Assistant Lecturer	July 1, 1979 - June 30, 1982
4 3.	Departmental coordinator for students' field practicals	Febr. 1981 - September 1982
4 4.	Lecturer	July 1, 1982 - June 30, 1986
4 5.	Senior Lecturer	July 1, 1986 up to date

5. PREVIOUS WORKING EXPERIENCE

	Posts	Dates
5 1.	Teaching and supervision of students' class and field practicals	May 1977 - September 1978, Jan. 1981 - September 1982
5 2.	Research in the field of soil science	May 1977 up to date
5 3.	Coordinating students' field practicals in the Dept. of Soil Science	Febr. 1981 - September 1982

6. EXTRACURRICULAR AND OTHER ACTIVITIES

6 1. Secretary General of the International Student Association of Ghent (ISAG) - 1983/84.
6 2. Chairman of ISAG Publication Committee and Editorial Board - 1983/84.
6 3. Participation in training course on animation techniques and running of meetings and seminars; obtained a certificate .
6 4. Secretary of the African Student Association of Ghent (ASAG) - 1984/85.

7. AWARDS AND HONORS

7 1. BSc (Agric.) (Dar) - qualified with honors.

7 2. Best final year student in soil science option 1977, awarded the Tanzania Fertilizer Company prize for best student in soil science.

7 3. MSc (Soil Science) (Ghent) - qualified with distinction.

8. PUBLICATIONS

8 1. Papers

8 1.1 Pedological and edaphological properties of the soils of two soil associations in the Morogoro area, Tanzania by J.P. MOBERG, B.M. MSANYA & M. KILASARA. Tropical Agric. (Trinidad) vol. 59 nr. 2 : 139 - 148, 1982.

8 1.2 Mineralogy of some soils developed on metasedimentary rocks of Morogoro Region, Tanzania by B.M. MSANYA & J.J.T. MSAKY. Beiträge trop. Landwirtsch. Veterinärmed. vol. 21 nr. 2 : 181-189, 1983.

8 1.3 The effect of some organic acids on phosphorus solubility in soils by MSAKY, J.J.T. and B.M. MSANYA. Med. Fac. Landbouwwet. Rijksuniversiteit Gent, vol. 50 nr. 1 : 21-28, 1985.

8 1.4 Inter-relationships among important soil properties based on data of some Typic Paleudults by LOPULISA, C.F. and B.M. MSANYA. Med. Fac. Landbouwwet. Rijksuniversiteit Gent, vol. 50 nr. 1 : 41-47, 1985.

8 1.5 A questionnaire to users of soil maps in different countries : Responses and implications for future soil inventories by B.M. MSANYA, R. LANGOHR and C. LOPULISA. Trans. XIII Cong. Int. Soc. Soil Sci. III : 1215-1216, 13-20 August 1986, Hamburg, West Germany.

8 1.6 Analysis on the use of U.S. Soil Taxonomy (1975) for the classification of soils in the Tropics, with special reference to the Tropept suborder by C. LOPULISA, R. LANGOHR and B.M. MSANYA. Trans. XIII Cong. Int. Soc. Soil Sci. III : 1196-1197, 13-20 August 1986, Hamburg, West Germany.

8 1.7 The effect of organic acids on micronutrients solubility in soils by J.J.T. MSAKY and B.M. MSANYA. Med. Fac. Landbouwwet. Rijksuniversiteit Gent, vol. 51 nr. 1, 79-93, 1986.

8 1.8 The use of rock phosphate as a source of phosphorus on a slightly acid clayey soil in Tanzania by J.J.T. MSAKY, B.M. MSANYA and A.P. URIYO. Afrika Focus 2(2) : 127-138, 1986.

8 1.9 Adequacy of the existing pedon data of organic soils for the classification among the Histosols (USDA SOIL TAXONOMY, 1975) by C. LOPULISA, R. LANGOHR and B.M. MSANYA. Proc. Int. Peat Society Symposium on Tropical Peat and Peatlands for Development, Jogyakarta, Indonesia, February 9-14, 1987.

8 1.10 Testing and improvement of a questionnaire to users of soil maps by B.M. MSANYA, R. LANGOHR and C. LOPULISA. Soil Survey and Land Evaluation 7 (1) : 33-42, 1987.

8 2. Papers accepted for publication

8 2.1 Preliminary study on the adequacy of existing soil resource inventories (SRIs) for the prediction of potential soil erosion hazards by B.M. MSANYA, R. LANGOHR and C. LOPULISA. Comprehensive Summary. Proc. XIII Cong. Int. Soc. Soil Sci., 13-20 August 1986, Hamburg, West-Germany.

8 3. Other research papers and writings

8 3.1 Evaluation of the adequacy of soil resource inventories - cartographic attributes by B.M. MSANYA. Seminar paper presented at the International Training Centre, Ghent State University, as progress report on doctorate research. February, 1984. Internal Papers, Department of General Pedology.

8 3.2 Evaluation of the adequacy of soil resource inventories - cartographic and legend attributes by B.M. MSANYA. Seminar paper presented at the International Training Centre Ghent, State University, as progress report on doctorate research. January, 1985. Internal Papers, Department of General Pedology.

ERRATA

Page 8:
- Line 24: Survey instead of Suvey
- Line 36: define instead of defined

Page 12:
- Line 3: unstandardized instead of understandardized

Page 17:
- Line 11: boundaries instead of boudaries

Page 25:
- Line 33: composition instead of compostion

Page 35:
- Line 37: Finally instead of finally

Page 36: under QUESTIONNAIRE TO SOIL SURVEYORS AND TO USERS OF SOIL MAPS AND REPORTS.

Notations:
- A=always=100% of cases
- F=frequently=more than 50% of cases
- C=commonly=less than 50% of cases
- O=occasionally=less than 20% of cases
- N=never=0% of cases

Page 51:
- Line 2: variation instead of correlation

Page 101:
- Line 33: suitable instead of limiting

Page 119:
- Line 9: $\geq$

Page 155:
- Line 2: assess instead of asses
- Line 21: greater instead of great

Page 157:
- Line 26: inevitable instead of enevitable