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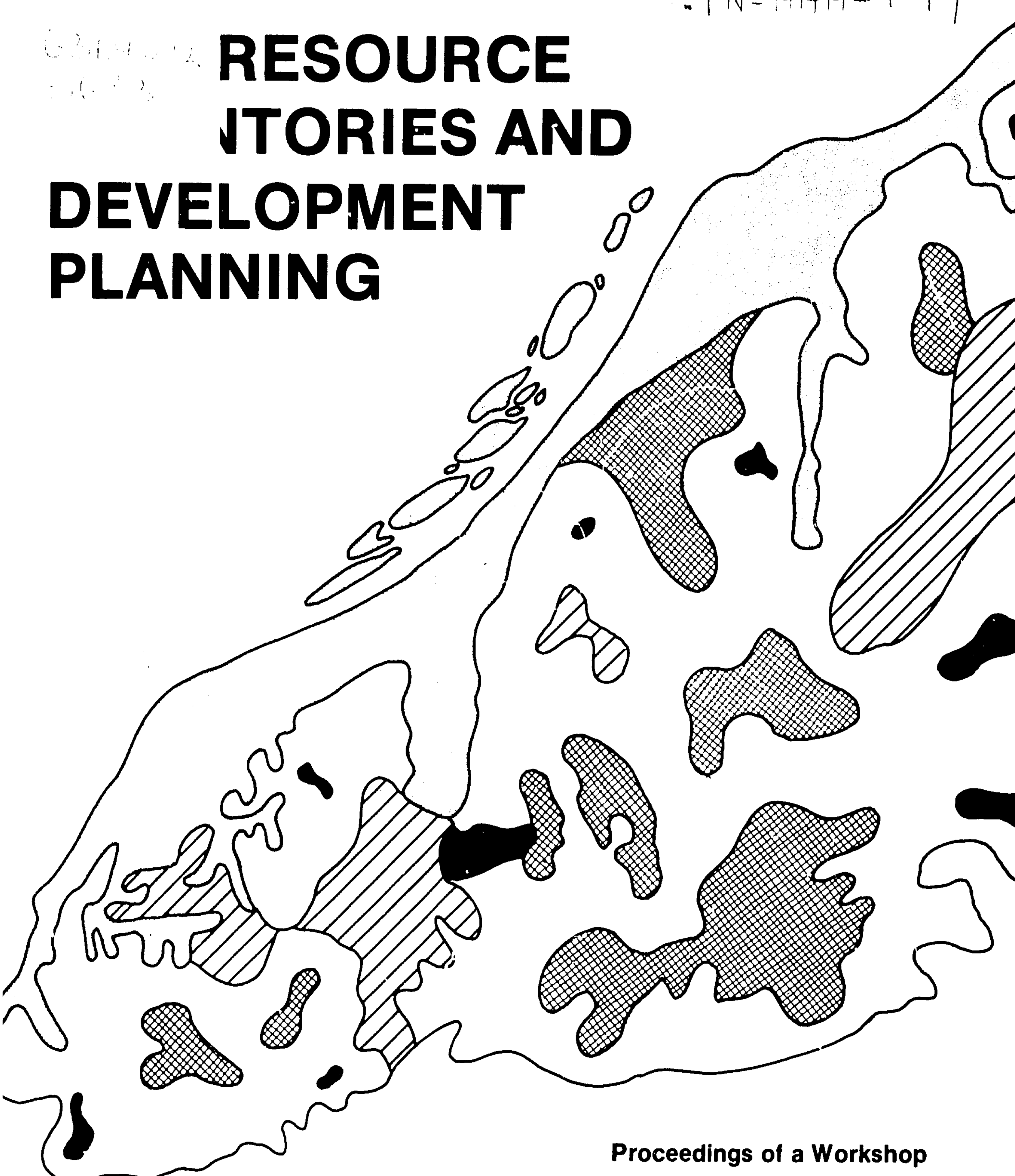
RESOURCE NTORIES AND DEVELOPMENT PLANNING



Proceedings of a Workshop held at Cornell University December 11-15, 1978

SOIL RESOURCE INVENTORIES

AND

DEVELOPMENT PLANNING

Proceedings of a Workshop
Organized by the Soil Resource Inventory
Study Group at Cornell University
December 11-15, 1978

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for the

SOIL RESOURCE INVENTORIES AND DEVELOPMENT PLANNING WORKSHOP

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CONTENTS

OPENING SESSION

Chairman: R. Lucey

Speakers

M. G. Cline - Objectives and Rationale of the Cornell Study of Soil Resource Inventories

OBJECTIVES AND RATIONALE OF THE CORNELL STUDY OF SOIL RESOURCE INVENTORIES

M. G. Cline[1]

The participants in this workshop are well aware that soil resource inventories vary enormously in approaches, detail, and quality. Probably all also appreciate the fact that neither the agencies which make soil inventories nor the institutions and individuals which use them have developed comprehensive methods to evaluate their usefulness for the varied purposes to which they are applied.

The problem is especially serious in the developing nations. Many of the soil survey programs are relatively new, and experience with both making and using soil inventories is limited. Resources for the work, including qualified soil scientists, are commonly limited. Administrative authorities responsible for policy and allocation of funds rarely appreciate what is needed to conduct a soil survey and to achieve and maintain quality. Funds for correlation, even within countries, for example, are rarely available, and quality control is severely restricted. This is not to imply that soil inventories in developing nations are necessarily poorly planned and executed. Many excellent surveys have been made. But the obstacles are very great, indeed, and the usefulness of many soil inventories has suffered as a result. The utility of many of these is not enhanced by the fact that they are made without clearly defined applied objectives beyond the general idea that knowing what kinds of soil exist is important for a nation's development. Too commonly, soil inventories are treated essentially as ends in themselves, assuming that they can be used in some way for practical purposes.

It was against this background that soil scientists who work in the international area at Cornell and representatives of the Agency for International Development concluded that some method should be developed to appraise the usefulness of soil surveys and similar soil inventories. They were particularly concerned because people who are not expert in soil science are among the more important audiences for whom soil inventories are made. Yet these people have little or no basis for judging whether or not inventories important for their purposes are, indeed, suited to their objectives. Soil scientists have the expertise to make such judgments, but even they have developed no standardized method of appraisal.

Initially the objective of the project was to develop a method suitable for people who should use soil inventories but do not have expertise to appraise them. It quickly became evident that the theory and principles on which a sound method should be based had not been articulated. Consequently, much of the effort to date has focused on principles and theory. This workshop will concentrate more on the primary objective.

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SCOPE OF THE STUDY

In earlier discussions with individuals and groups, it has been evident that the objective of appraising the utility of soil inventories is easily confused with soil survey interpretations for evaluating suitability of soils for use. It must be clearly understood that this study is concerned strictly with whether or not a soil inventory provides soils information in an amount and form that permits evaluation of suitability of the inventory for land use objectives. The actual prediction of soil performance and suitability for use from soil inventories is a separate and distinct operation.

The study has focused on the utility of soil resource inventories of developing nations. The principles involved, however, should also apply to the inventories of developed countries. Consequently, the study has drawn on data derived from soil inventories in developed as well as developing nations. The criteria for appraisal of soil inventories should apply to both, with appropriate modification in detail for differences in land use objectives.

The study has concentrated on the use of soil inventories (1) for predicting soil performance in the production of plants for food and fiber, and (2) for land use planning in which food and fiber production is a major element. Many of the principles involved in appraising the usefulness of soil inventories for these kinds of land use objectives should, however, be valid for diverse purposes, such as appraising utility for urban development planning and understanding ecology of the environment. Different kinds of information would have to be considered, but the principles should be the same.

Soil resources constitute only one of several factors that determine land use potentials. Accessibility, cultural factors, economic considerations, and others are also primary determinants of the feasibility of a given kind of land use. The SRI study has been confined to the appraisal of soil inventories as the basis for evaluating only the soil factor in land use potentials, deliberately avoiding confounding the soil factor with other factors on which final land use decisions must also be based.

RATIONALE OF THE STUDY

The following pages abstract the primary ideas that determined the course of the study. Relevant lines of reasoning are indicated, but details of the study's accomplishments to date are beyond the scope of this paper.

The study treats soil resource inventories primarily as documents that record the geographic distribution of unique kinds of natural soil bodies on maps and identify the sets of properties which characterize them in accompanying legends and texts. It does not exclude inventories that identify areas defined in terms of single soil properties or inferred attributes, but it does not emphasize them. It focuses on inventories that identify soils in terms of some soil taxonomy, but it does not exclude others.

Soil resource inventories are, at best, incomplete records of the soil conditions that exist within land areas. Their potential usefulness depends on the degree to which they identify the soil conditions that are critical for given land use objectives and accurately show their geographic distribution on maps. Their actual utility also depends on presentation of this information in a form that can be used effectively. Starting from these relatively obvious truisms, the study addressed two questions: (1) What would one need to determine in an on-site appraisal to predict soil performance? (2) What attributes of soil maps and associated legends and texts must be appraised to determine the degree to which a soil inventory provides that information in a form that will satisfy land use objectives?

The study identified five kinds of information that would be necessary to predict soil performance in an on-site appraisal:

1) The land use objective for which soil resources are to be evaluated.

2) The level of detail of information that would be required to evaluate soil resources for that objective.

3) The soil properties that would be critical for the projected land use.

4) The degree of limitations which critical soil properties would impose on that use.

5) The effects of the geographic distribution of limiting soil conditions on the projected use.

It is necessary to identify land use objectives of item 1 to establish requirements of items 2 through 5. In an on-site investigation, an appraiser tests soil conditions in the field against use limitations of items 3 through 5 in the detail that land use objectives dictate to be necessary for item 2.

The information required to predict soil performance from inventories is, obviously, the same as that required for on-site investigations. A major part of the appraisal of utility of soil inventories consists of testing the adequacy of information they give for items 3 through 5 as listed above and the detail of item 2 against those requirements for each land use objective. In addition, however, the ease or difficulty of extracting soil inventory information and its reliability relative to actual field conditions are potent factors affecting the usefulness of any inventory. Thus, the study has addressed three additional criteria:

6) Quality of the base map, including ground control.

7) Legibility of the map.

8) Reliability of the recorded data of both the map and the associated text.

The perspective in which the study has considered these eight elements is discussed briefly in the following pages.

Land Use Objectives

Land use objectives for which soil resource inventories are used differ widely in both kinds and levels of generalization. Both affect the information a soil inventory must provide. For example, some objectives require prediction of soil performance for specific plants, such as maize, rice, or cacao. Others require prediction of soil suitability for general land use classes, such as cropping, grazing, or forestry. Still others require evaluation of soil resources for alternative uses in land use planning. Different kinds of land use objectives, such as these, require different kinds or amounts of information about soils and their geography.

To complicate the problem further, some kinds of land use objectives require site-specific predictions for small areas, such as individual fields. Others require broad generalizations about extensive areas hundreds or thousands of square kilometers in size. Such differences in scale dictate different levels of detail or generalization of the information about soils and their distribution. The study has concluded that there is no viable alternative to identifying minimum requirements of kinds, amounts, and detail of soil information for each contrasting kind and level of generalization of land use objectives, against which the information of soil inventories may be tested for appraisal of their usefulness.

Detail of Information

This element includes both (1) the number and size of delineations on a soil map, and (2) the detail in which soils of mapping units are identified and described in the legend and text. Both must be appraised in terms of the degree to which they satisfy requirements of the land use objective for which a soil inventory is appraised.

Map scale is one criterion of map detail, but it is not infallible. Some soil maps are at scales larger than necessary to present the information they contain. Others are at scales too small to present the information legibly. The study proposes that the smallest scale at which map data can be presented legibly is a more useful criterion than the scale of publication. It determines the minimum size of legible delineations and, therefore, the smallest land area about which predictions can be made. It and related criteria developed by the study do not measure how much of the geographic pattern of soils in the field is represented on the map. That can be inferred from the character of mapping units identified in the legend, although field investigations may be needed for precise estimates.

Kinds of mapping units, the level of detail of soil classification in the legend, and the detail in which mapping units are described in the text have as much impact on usefulness of a soil inventory as the detail of the soil map. Many soil inventories of developing nations do not give enough information about the map units to realize the full potential of the map. The study has identified four criteria of the legend and text that should be used in conjunction with scale when appraising the level of detail of a soil inventory:

1) Kinds of mapping units. Are they defined as predominantly one kind of soil or as mixtures of two or more kinds? This is a criterion of the detail of information on the map relative to soil pattern in the field. It controls detail of geographic location of soils.

2) Taxonomic level of taxa used to identify map units. This identifies the level of detail or generalization of information about soils in delineated areas. It controls the detail of predictions about the soils.

3) Phase and other qualifying terms in names of map units. These add definitive criteria and increase the potential detail and precision of predictions about the soils of map units.

4) Soil properties and inferred attributes described in the text. The extent to which the text amplifies information which can be implied about map units from the legend is an important criterion of the detail of information a soil inventory provides. Both soil descriptions and the amount and character of inclusions in map units rank high among the kinds of information which should be provided in the text.

Soil Properties

Ideally, the text of a soil inventory should describe the properties which have been observed or measured for each kind of soil. These descriptions provide the basic data from which soil limitations and suitabilities for use can be deduced. Many soil inventories provide inadequate soil descriptions. Some give none at all.

In the absence of adequate soil descriptions, the names of mapping units can be used to deduce sets of soil properties in combination. These names commonly identify taxa in some taxonomic system. In some systems, the names imply specifically defined ranges of properties. In others, the names suggest only very general concepts of soils related to assumed genesis or factors of soil formation.

A high level of expertise in soil science is required to deduce information about soil properties from taxonomic names. If people who are not expert in soil science are to appraise the usefulness of soil inventories, there appears to be no alternative to compiling lists of the soil properties implied by the names of taxa of each major taxonomic system likely to be encountered. This should not be an impossible task, especially within a single country where only one system may be used. Phase or similar qualifying terms used with names of soil taxa add important information about soils and commonly are self-explanatory.

In some soil inventories, the names of map units stand for sets of properties unrecognized in any taxonomy. In others, the map units are named in terms of physiography, vegetation or other features that are soil-related but not consistently diagnostic of soil properties. Unless the soil properties associated with such terms are described, even soil scientists are unlikely to deduce consistently useful information from them with a high degree of confidence.

Soil Limitations

The utility of a soil inventory depends heavily on the extent to which it permits one to identify those soil attributes that limit soil performance. These are sometimes called "performance attributes." Some of these attributes are observed or measured soil properties, which should be recorded in soil descriptions. Soil depth, acidity, and slope are such properties. Others must be inferred from descriptions of soil properties. Periodic wetness and available moisture capacity, for example, are commonly inferred though not observed directly.

Ideally, the text of a soil inventory should describe such potentially limiting attributes for each kind of soil. This kind of information is commonly incomplete in soil inventories of developing nations. If potentially limiting attributes are not identified, the expertise of a soil scientist is usually necessary to deduce those which must be inferred from soil descriptions. For those who lack that expertise but need to know whether or not the information can be extracted from a soil inventory, it should be feasible to compile a list of common limiting soil attributes showing the soil properties from which they can be inferred.

Each land use objective has a set of limiting soil attributes that are critical. These differ in both kind and level of detail among uses. The study has developed checklists of limiting soil attributes for eight types of land use objectives. The information provided by soil inventories can be compared to these lists to determine deficiencies. Similar checklists could be developed for most land use objectives.

Geographic Distribution of Limiting Soil Attributes

For some purposes, the geographic pattern of contrasting soils is equally as important as limiting attributes or the area affected by them. Five percent of wet soil in a field otherwise well suited to mechanized farming, for example, may be no more than a nuisance if it is all in one place. It can control choice of crops, cultural operations, and timeliness of work if it is distributed in small parcels throughout the field.

The study has considered this topic in terms of criteria for judging how well the soil map segregates and describes the geography of the total soil variation of an area.

Map units characterized as single kinds of soil-consociations. Although such units contain inclusions of other soils, their performance attributes that can be identified should be uniform enough that predictions based on them should apply to entire delineations for practical purposes. Any contrasting inclusions that would affect such predictions should be identified and described in terms of amount and pattern of distribution.

Map units characterized as mixtures of contrasting soils - associations and complexes. Such units permit predictions about performance of each o: the constituent soils as accurately as if the soils were delineated separately. They do not show precisely where those predictions apply within delineations. They are suitable for estimating amounts of soils that perform differently if the units are properly defined in terms of proportions. They can be evaluated in terms of general suitability for land use objectives that are not site-specific. Description of the pattern of constituent soils and of inclusions adds predictive value.

The remaining soil variation that is not identified in map unit definitions. Map units identified in terms of taxa of higher categories of a taxonomy, for example, tell little about the geography of limitations imposed by properties that are criteria of lower categories. Predictions that depend on them cannot be made.

Beyond these criteria, anyone appraising the usefulness of a soil inventory should search the text for information that describes the geography of soil-related conditions which may not be recorded for map units. Description of the variation of rainfall or temperature within an area, for example, is a good indicator of soil moisture and temperature regimes.

Quality of the Base Map

A soil 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. The study has considered in great detail the amount and accuracy of ground control for soil maps at various scales. Guidelines for appraising the adequacy of base maps have been developed.

Legibility of the Map

Legibility is a primary factor determining the ease with which a soil map can be used and, indeed, whether it will be used at all. The study has investigated a number of factors that influence legibility on existing maps, including:

- Size of delineations
- Number of delineations per unit area
- Color or other devices to distinguish among delineations or to present interpretive groupings
- Amount and legibility of ground control of the base map
- Quality of reproduction

The study has developed a number of criteria for appraising legibility.

Reliability of the Information

The value of a soil inventory for any use obviously depends on how accurately the information it provides represents actual soil conditions in the field -- called "ground truth." Few soil inventories are totally unreliable, but many contain information that should be questioned. An appraisal of the utility of a soil inventory should include an estimate of the reliability of both the cartography and the identification and definition of soils. This is emphasized, for if the apparent quality of a soil inventory based on a study of maps, legends, and texts in the office does not, in fact, reflect faithful characterization of ground truth, the information is not only useless but deceptive and potentially harmful.

The ultimate test of reliability is determination of ground truth in the field. The study has investigated methods for determining ground truth in considerable detail, including statistical bases for sampling designs and for interpreting results.

In lieu of field testing, potential reliability can be inferred from the methods used to collect the information. Generally, potential reliability decreases in the order in which inventory methods are listed below (the methods as defined in the 1951 Soil Survey Manual of the U.S. Department of Agriculture):

1) Detailed field methods with remote sensing support.
2) Detailed field methods without remote sensing support.
3) Reconnaissance field methods with remote sensing support.
4) Reconnaissance field methods without remote sensing support, or Remote sensing with field checking.
5) Exploratory field methods, without remote sensing support, or Remote sensing without field checking.
6) Schematic compilations without field work.

Any information given in an inventory about procedures, such as density of traverses and sampling intensity, is a valuable criterion. None of these criteria, however, measure human error.

Poor reliability related to human error, incompetence, or dishonesty is difficult to establish without determination of ground truth. Experienced soil scientists can detect evidence of poor reliability from the map and text. Such evidence as identification of soils in places where they are not likely to be found, boundaries that do not conform to diagnostic landscape features, and statements or soil descriptions in the text which are inconsistent with known facts indicate human error or incompetence. If they are numerous, the reliability of the entire inventory must be questioned. Existing geological surveys, topographic maps, and other information about an area can be used to detect inconsistencies in comparison with soil maps and texts.

APPLICATIONS OF THE STUDY

Development of a comprehensive method by which people without expertise in soil science can appraise soil resource inventories remains the primary objective of the study. Much remains to be done to translate the principles which have been developed into methodology that can be understood and can be applied empirically by this important group of people. This appears to be a goal that can be attained. As the foregoing discussion would imply however, such methodology will have to be based on a much simplified interpretation of the principles developed, and it will undoubtedly lose precision and scope in the simplification. Nevertheless, it should be an enormous improvement over no basis at all.

Given widespread circulation of the results and interpretations of them, the impact of the study on soil scientists may be more significant than the appraisal method, per se. It should organize ideas about soil inventory utility in one comprehensive treatment for soil scientists generally and for those in developing nations in particular. It should spur some soil scientists to scrutinize their own inventories critically. It could inspire soil scientists of some developing countries to develop methods for evaluating their soil inventories, methods that could be designed for the local environment and could be much simpler than a comprehensive system. This may well be the best way to reach people who lack expertise in soils in some countries.

Finally, and perhaps most important, the study pinpoints attributes of soil inventories that detract from their usefulness. Those who scrutinize the documents which come from the study should recognize in them the bases for guidelines for designing new soil surveys. Guidelines of various kinds have been developed, but this study focuses on the consequences of poor design and execution. It should affect the scrutiny to which new soil survey plans are subjected by both soil scientists and the administrative officers responsible for allocating funds.

QUESTIONS/COMMENTS (by P.H.T. Beckett):

Soil entities that belong to a soil class certainly share its keying characters, or should share its definitive characters. We hope they share some useful characters, because if they do not we do not gain or benefit from identifying the class to which a soil belongs. If so, then it seems important to check, for any soil map, that (a) all members of typical taxonomic classes share certain characters that are relevant to one or several land users and (b) all members of the mapping units defined to contain these taxonomic classes share these characters, too.

ANSWERS:

One must certainly agree that soil maps should be thoroughly field-checked not only to determine whether the information they record is a faithful representation of soil conditions but also to determine whether they record information that is relevant to applied objectives. This is a task for soil scientists before the map is published for the general public. Actually, relevance should be checked while the legend is being prepared and before the mapping is done. Given a published soil inventory, one should be able to deduce from the publication a great deal about whether it does or does not provide relevant information. The deficiencies are fixed for practical purposes. Field checking at this stage can determine whether the relevant information given is reliable.

SESSION I

AN OVERVIEW OF PAST SOIL RESOURCE INVENTORY ACTIVITIES

Chairman: H. Ikawa

Speakers

A. Van Wambeke - Summary of Cornell's Soil Resource Inventory Workshop 1977

R. W. Arnold - Introduction to Guidelines on Soil Resource Inventories

SUMMARY OF CORNELL'S SOIL RESOURCE INVENTORY WORKSHOP 1977

A. Van Wambeke[1]

It has been our experience that the subject matter which will be discussed at this workshop is not a topic with which many people are very familiar. Although Marlin Cline described the objectives of our study in the previous paper, some additional information on what has been done before is thought to be useful.

The Soil Resource Inventory group at Cornell has been working for more than two years on the evaluation of soil surveys. They organized a first workshop in April 1977 to compile a state of the art on the assigned research objectives. The concerns then dealt with all aspects of soil resource inventories. The quality of existing inventories was only a part of the overall objectives of the study, which included among other topics: soil survey operations, methodology of interpretation, strategies for institution building, etc.

The participants at the first workshop mainly tried to arrive at a better understanding of the qualities of soil maps and surveys, and to identify the characteristics associated with them.

AGENDA OF 1977 SRI WORKSHOP

The workshop analysed seven major areas of interest.

Orders of Soil Surveys

Two papers described the USDA system for classifying soil surveys. One paper explained the approach adopted by the Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM), France. It was obvious that the kinds of soil surveys as they were recognized by different schools did not provide a consistent basis for comparing their qualities at the international level. No system provided objective criteria to evaluate their usefulness with sufficient precision. It is worth noting that all forms of soil resource information were considered, and that the study was not restricted to the standard soil surveys in the sense of the Soil Conservation Service of USDA.

The discussions related primarily to map scale as a parameter for recognizing different kinds of surveys. Scale was unanimously accepted as one of the most important criteria to evaluate their usefulness. Obviously, scale may restrict the degree of detail which may be shown on a map. Scale is important both to evaluate existing soil maps and to plan future ones. Costs of producing maps are directly related to their scale.

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It was felt however that scale should not be the only criterion; if it were, enlargements of soil maps would shift maps from one class to another. This concern, and the need to include mapping intensities in the evaluation, oriented the group to search for objective criteria to measure this property. Smyth (1977) related the adequacy of mapping intensities to planning objectives, and introduced the concept of a "minimum area of planning interest." He proposed that the scale of a map should be such that the area in which the planner is interested could be shown on the map by a delineation at least 1 or 2 cm^2 large.

Evaluation of Soil Surveys and Maps

This section was an attempt to select the various components of soil resource inventories which have to be considered to evaluate their usefulness.

It had been previously argued whether it was desirable, or even worthwhile, to analyze existing surveys. Many participants felt instead that work on the methodology for making new surveys would be more rewarding. It was assumed that soil scientists on the one hand knew quite well the deficiencies of most soil resource inventories; on the other hand, outsiders would not believe in an evaluation of soil surveys done by the soil surveyors themselves. The implication was that the evaluation should be done by "laymen" and the first ideas were to write guidelines for non-agronomists to estimate the adequacy of soil resource information. It was further accepted that an objective evaluation could have considerable value for appraising commercial maps.

Among the properties which were discussed were reliability, legibility, structure of the legend, density of observations, amount of information, artistic appeal, and quality of base maps.

Legibility was among the factors which received most attention. It was described by Forbes (1977) as the ease with which a map user can read the information recorded on a soil map. The degree of legibility was estimated by comparing the size of map delineations with an area of 0.4 cm^2, which is accepted by most people as the minimum size for a legible delineation. This minimum size delineation or the equivalent area on the ground became the basis for the calculation of a series of map indices, which combined legibility and mapping intensities into one figure.

Soil Survey Methodologies

This section started with descriptions of soil survey procedures used in Tanzania, Colombia, and Mexico. Only a few conclusions from these case studies are mentioned here. The authors stressed the need for early publication of results. In project-oriented operations, soil correlation was considered to be an important factor for continuity. In many cases, the scales of the maps were considered too small to allow interpretation of data at the farm level.

Several base map documents and types of imagery were examined as components of soil resource maps.

The discussions on methodologies inevitably dealt with strategies: multipurpose maps with long-term utility versus single-value surveys with direct but short-term effects; project-oriented operations against nation-wide systematic soil surveys; integration of old inventories into new approaches.

Cost-benefit ratios were considered when comparing single-purpose with comprehensive surveys. The advantages of grid surveys were measured against free surveys. Some people said we should not become slaves to statistics, but the same people perhaps failed to indicate other standards of comparison. Soil surveyors would waste a lot of time during field mapping if they could only test soil boundaries against probability distributions.

Legends which accompany maps were examined as to content and structure. The naming of map units according to a taxonomic system was highly advocated, but was not considered sufficient. The USDA Soil Taxonomy was not universally accepted, and the criteria it uses were not always considered relevant.

Names given to map units retained much attention. The "What's in a name" question quickly becomes a "What's in a map unit" question: how uniform and how reliable is the information? This leads to control of map unit composition, ground truth and purity concepts.

Reliability was considered the most important criterion when looking at the quality of a soil map. Its evaluation has to be done in the field. It is not an office operation. Reliability is the key factor in all aspects of soil surveys, particularly in matters related to communication with others. Once a farmer has had a bad experience with a map, he will probably not consult other maps. The same may apply to planners. Improving the procedures for producing better soil surveys is therefore the major objective of this study.

Map Characteristic Evaluation

This part of the workshop focused mainly on methods to measure the average size of delineations on soil maps; they will be explained in more detail in the following paper.

Soil Properties Important for Given Land Uses

This section turned away from internal structures of soil surveys, dimensions of planning areas and map delineations, and scales of maps. The emphasis was placed on information content. The section addressed problems which people face when making decisions about land use. To what extent is a soil resource inventory supplying the information which planners and other users need?

An attempt to condense soil information into a manageable number of crop production factors was described by Beek (1977). The "land quality" concept is a major component in FAO's Framework for Land Evaluation (FAO, 1975). Land qualities are composite factors derived from soil properties, which are used as independent variables in crop production functions. They are considered to be excellent tools for introducing soil factors in the economic analysis of agricultural development.

It was accepted, however, that much remains to be done in the quantitative measurements of land qualities. In addition, different planning interests call for different land qualities. This variability was illustrated by a presentation on the use of soil survey information in trace element studies; a second paper discussed soil factors which influence the growth of tropical crops; a third studied the limitations of Soil Taxonomy in providing adequate data for land use alternatives in northern and western Africa.

Soil limitations or "negative qualities" offer another approach to achieve capability groupings or define suitability classes for soils. The definitions of soil potential and soil performance were discussed. Lack of knowledge about crop requirements was considered to make soil survey interpretation a difficult task; the wide range in the soil requirements of different crops reduces the usefulness of a general suitability classification.

It was accepted that the adequacy of soil resource inventories can only be measured with respect to specific objectives. Each intended use calls for another evaluation. The "guidelines" on the assessment of the usefulness of soil resource inventories would therefore concentrate, as a first phase, on adequacy studies for specific land uses.

Soil Data Presentation

Some have stated that a wealth of information can be worthless. Soil resource inventories often contain too much information for general uses, and too little for specific objectives. Access to the latter is often cumbersome. Different methods of extracting specific knowledge from soil surveys were presented at the workshop. Special attention was given to the methodology for reaching small farmers in less developed countries.

The optimum number of mapping units, the appropriate terminology in naming soils, the use of colors on maps, and the inclusion of analytical data and detailed descriptions in reports were parts of the discussions.

Role of Soil Surveys

According to the participants, the role of soil surveys in development planning should not be a passive one, satisfied by only providing information to users. Although soil surveyors are told to be user-friendly, this aspect is not considered enough. Development planners should be warned about the serious hazards of the deterioration of natural resources when land is used above its capacity.

The workshop recommended more interactions between pedologist and planners, and an exchange of more relevant, more precise, and more quantitative information between the two groups.

PROPOSED WORK PLAN FOR CORNELL'S RESOURCE INVENTORY GROUP

The tasks set aside for the soil resource inventory group at the end of the workshop can be summarized as follows:

(1) Develop methods to measure the adequacy of existing soil surveys. The critical analysis of the soil resource inventories would highlight the factors which are important for increasing the effectiveness of future soil survey operations.

(2) Relate the evaluation of soil resource inventories to well-defined objectives.

(3) Identify differentiation of properties of soil resource inventories which indicate how complete the information is with respect to actual soil variability in the field, and with respect to soil factors limiting development.

(4) Prepare a methodology, or describe existing methods to evaluate ground truth, and check the reliability of soil information.

(5) Suggest ways to improve communications between planners and soil scientists.

(6) Describe strategies for more effective soil survey operations.

Points one to four have formed the subject matter of the "guidelines." A first draft has been circulated to approximately one hundred reviewers. It will briefly be discussed during the first two sessions of this workshop.

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INTRODUCTION TO GUIDELINES ON SOIL RESOURCE INVENTORIES

R. W. Arnold[1]

The early drafts of guidelines were developed by having individuals wr'te sections for discussion. We came from many backgrounds and often had "jargon" problems. For example, soil potential was a concept each of us had but the details and acceptable terminology varied widely. Other phrases also presented difficulties - such as suitability, reliability, accuracy, land use planning, and utility.

Our group consisted of a core at Cornell - Marlin Cline, Matt Drosdoff, Armand Van Wambeke, Gerry Olson, Terence Forbes, and myself. Visiting scientists who wrote draft sections included Hari Eswaran from Belgium and Malaysia, Mike Laker from South Africa, Carlos Scoppa from Argentina, and Alan Stobbs from England. Many concepts and ideas came from participants at the 1977 Workshop. Graduate students have assisted in many ways and we appreciate the efforts of Elizabeth Bui, Pam Piech, Juan Perez-Oraa, and Anibal Rosales. Visitors to the campus and correspondents have also influenced our thinking and approaches.

From an early idea of a Handbook we matured and now hope to propose guidelines rather than a definitive Handbook. Such guidelines are suggestions of methods to be modified and adapted as deemed appropriate.

Our preliminary draft was assembled earlier this year and about 100 copies sent out for review. We have received lots of comments and suggestions - for reorganizing, for resolving conflicts of terminology, for improving the readability, and so forth. We truly appreciate the efforts of those who have reflected on the subject and given of their time and talent.

Based on responses and perhaps our own opportunity to stand-off-a-bit, our current effort has been to reorganize, to add explanatory notes, and to flesh out or mention weaknesses. As both Dr. Cline and Dr. Van Wambeke have indicated, the value of guidelines likely will be encouraging other soil scientists to be more active in evaluating soil resource inventories and to interact with other specialists in the planning process.

Let's look briefly at the draft of the guidelines for Appraisal of Soil Resource Inventories.

GUIDELINES FOR SOIL RESOURCE INVENTORY CHARACTERIZATION

Chapter I. Introduction

1. Soil resource inventories and agricultural development
2. The need for guidelines to characterize SRI
3. Questions that can be answered by soil maps and soil surveys
4. SRI in relation to other inventories
5. How to use the handbook

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Chapter II. Kinds of SRI documents and their use

1. Kinds of SRI documents
   - 1.1 Soil maps
   - 1.2 Soil surveys
   - 1.3 Soil survey base maps
   - 1.4 Soil survey reports and other documents

2. Uses of SRI documents
   - 2.1 Outline of principles of planning
   - 2.2 Kinds of planning
     - 2.21 Master planning
     - 2.22 Project planning
     - 2.23 Operational planning

3. Areas relevant to the planning process

Chapter III Characterization of existing SRI maps

1. Rationale for map characterization

2. Characterization methodology
   - 2.1 Relevant attributes of soil maps and legends
   - 2.2 Map unit composition
     - 2.21 Definition of limiting or suitable soils
     - 2.22 Classes of map unit composition
     - 2.23 Examples of map unit composition for an existing survey
   - 2.3 Map pattern analysis
     - 2.31 Map legibility
     - 2.32 Analysis of size, density and distribution of delineations
       - 2.32.1 Size of delinations
       - 2.32.2 Patterns of delineations
       - 2.32.3 Density of delineations
     - 2.33 Map reduction
       - 2.33.1 Map index of maximum reduction
       - 2.33.2 Minimum scale of reduction
     - 2.34 Enlarging soil maps
   - 2.4 Soil boundary analysis
     - 2.41 Boundary representation in relation to other map parameters
     - 2.42 Line thickness
     - 2.43 Boundary error in relation to delineation size
   - 2.5 A classification of soil maps
   - 2.6 Features of base maps
     - 2.61 Accuracy of location of ground control information
     - 2.62 Amount of ground control information

3. Nature, properties and function of soil legend
4. Soil survey reports
5. Soil survey checklist

Chapter IV. Field evaluation of SRI

1. The need for quantitative field checks

2. Concept of ground truth and ground truth analysis
   2.1 Accuracy and precision of estimates
   2.2 Types of mapping errors
   2.21 Locational errors
   2.22 Boundary errors
   2.23 Classification errors
   2.3 Sampling techniques for ground truth evaluation
   2.31 Estimate of number of observations
   2.31.1 Number of observations in cases with no classification errors
   2.32 Analyzing transect data

Chapter V Evaluation of SRI for planning purposes

1. Uses of SRI

2. Some concepts relating SRI information to planning
   2.1 Soil performance
   2.2 Limiting attributes of soil maps and legends
   2.3 Inventories of soil performance
   2.31 For site specific purposes
   2.32 For non-site specific purposes
   2.4 Relation of performance to planning

3. Other inputs needed for planning purposes

Chapter VI Summary and conclusion

Chapter I. Introduction

Sections emphasize the philosophy mentioned by Dr. Cline. A lack of systematic procedures led to this attempt of providing guidelines. They are a starting point rather than an end in themselves. Soil surveys are expected to predict soil performance when particular uses are undertaken, and inabilities to do so readily become apparent. Sometimes the lack of use is due more to presentation than lack of information.

Soil information is one part, but commonly a critical part, of resource information needed or used in planning and development, and the role of soils in a larger decision-making process is noted. The introduction will also suggest how to use these guidelines.

Dr. Eswaran will go through the methodology in more detail later.

Chapter 2. Kinds and Uses of Soil Resource Inventory Documents

The sections discuss kinds of soil maps and point out that soil survey maps are those based on field techniques. Types of base maps are mentioned because of the importance of ground-control reference points.

A goal of SRI is to have soil information used in a meaningful way in planning, particularly in the development of agriculture. Some concepts we have used to approach adequacy and utility of existing surveys will be mentioned in more detail by Dr. Van Wambeke. There still may be differences of opinion about "semantics" but we hope for consensus about the need for concepts in areas related to performance, management, and planning relevant to objectives.

Chapter 3. Characterization of Existing Soil Resource Inventory Maps

Dr. Cline noted that for a given land use objective it is necessary to recognize critical soil properties associated with that use, and also the degree to which those critical properties affect the use. We ha· organized this chapter into the following areas:

Map unit composition refers mainly to assessments of a legend and text to the extent that limiting soil properties for a given use are provided. Map units may be accurately described, yet not adequately cover relevant information for particular uses.

Pattern analysis includes map texture or fabric and outlines a circle count method to estimate sizes of delineations which can be related to legibility, scales of reduction and unit composition.

Soil boundary analysis discusses concepts of boundaries on maps such as line width and effects of misplacement on sizes of areas and composition. Obviously more potential errors are associated with small delineations.

Map classification utilizes the average size of delineations and indices of reduction to group soil maps for comparison purposes.

Features of base maps outlines concepts for checking the locational accuracy and amount of ground control information that may affect the usefulness of base maps for reporting soil information. We conclude that most soil maps are used for relative location rather than for cadastral accuracy.

Soil legends and Soil survey reports are sections being prepared to help stress inadequacies of some existing surveys and alert people to the significance of properly described and documented information as previously pointed out by Dr. Cline.

Soil survey checklist is a section that describes our effort to catalog the available information of a Soil Resource Inventory. It often provides clues to unstated objectives and methods of survey. Mr. Forbes will go over this checklist with us later.

Chapter 4. Field Evaluation of Soil Resource Inventories

Some suggestions of methodologies to evaluate inventories relative to ground conditions are offered. Although several types of errors may exist they commonly are grouped together as classificational errors. We have used binomial statistics to provide some insight into minimum numbers of observations to take, and have developed graphical solutions for statistical statements of map unit composition. Such estimates give upper and lower confidence limits for several levels of probability and have been based on transect observations.

Chapter 5. Evaluation of Soil Resource Inventories for Planning Purposes

The sections of this chapter attempt to bring together the pieces of map characterization and show how they relate to planning. Soil performance is a major goal but predictions can be limited by the maps and legends produced. Objectives of inventories commonly dictate what can be done, consequently the importance of interacting early in the planning process.

We are cognizant of the limited role of soil inventories in some development planning and that economics of alternatives as well as social, cultural and political considerations are ultimately involved.

Chapter 6. Summary and Conclusions

We have tried to assemble concepts and principles used by pedologists and hope they aim us at the larger goal of offering assistance to non-soil scientists and have a positive effect on land use decisions.

The next draft of guidelines are expected in early 1980 and again we will welcome your comments and suggestions.

QUESTIONS/COMMENTS (by. P.H.T. Beckett):

There may be some advantages in describing the texture of the soil map in terms of "length of soil boundary/area" which can be measured quite easily by counting the number of boundaries crossed per unit length of random linear traverse (see J. Soil Sci. 26:144-154; 1975). Indeed the ratio of average delineation area to average boundary density might indicate the average form (long or circular) of the soil delineations.

ANSWERS:

SESSION II

SOIL RESOURCE INVENTORY METHODOLOGY

Chairman: R. S. Murthy

Speakers

A. Van Wambeke - Planning Objectives and the Adequacy of Soil Resource Inventories

H. Eswaran - Evaluation of Soil Resource Inventories

T. R. Forbes and H. Eswaran - Soil Survey Report and Map Checklist

PLANNING OBJECTIVES AND THE ADEQUACY OF SOIL RESOURCE INVENTORIES

A. Van Wambeke[1]

The adequacy of a soil resource inventory for development planning can only be appraised in a meaningful way when the information given by the survey is matched against the requirements of specific planning objectives.

During the course of the study of soil resource inventories and development planning, it soon became obvious that planners deal with many aspects of development, which vary greatly in kind, degree, and precision. The concerns of planners relate to the questions "What? How? Where?" concerning the presence, performance, response to management, and feasibility of resource development. The inquiries may be for inventory purposes or may be action oriented. For each answer to their questions, planners require reliability and precision.

Soil scientists provide information through soil surveys. The simplest analysis of soil maps would start with lines and symbols or colors. Lines should answer questions about location, or "where?" Symbols and colors should lead to information about "what?" or "how." For this reason soil survey characteristics are discussed under two headings: location and information requirements.

LOCATION REQUIREMENTS

Areas of Interest to Planners

Most but not all descriptions of soil resources include maps which indicate the location of specific soils. Planning often involves siting or the assignment of objects or operations to well-defined areas. These areas are of interest to planners because they are uniform in either topography or soil properties, respond uniformly to management, or present the same development needs.

In this paper, the term "area" refers to actual land areas on the ground. When they are represented to scale on maps, the boundaries enclose "delineations."

The "planning area" is the entire land surface for which a plan is made. This may be a region in which a land use plan shows that different parts are best used for different purposes. It may be a tract of cropland in which different parts need different management. Conceivably some planning areas are homogeneous enough that the plan would assign the same use or even the same management to all parts.

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The term "operational area" is proposed for tracts of land where specific sets of activities related to land use will be conducted.

Individuals or groups of individuals may reserve certain areas for use by economic units functioning under the same operational control. It may be the area which is utilized by one farm, or the land cropped by a farmers' community, or the domain controlled by a plantation.

The term "operational area" is used as a general designation for parts of a planning area which will be administered as one economic or social unit. In this context operational areas by definition cannot be larger than the planning area. In certain cases a minimum-size operational area may be recognized. It is the operational area of land which for practical considerations cannot be reduced in size without loss of profits or other advantages. For example, an oil palm factory needs a minimum supply of palm nuts to achieve maximum efficiency. In a land use plan designed to identify areas suitable for farming the "minimum operational area" might be the smallest parcel that would realistically support a farm unit. The minimum operational area is equivalent to Smyth's (1977) minimum area of planning interest.

The term "management area" is used for areas identified on the basis of the type of soil management which is applied to them. A field planted to corn receiving the same treatment is a management area. Operational areas and management areas may not, and usually do not, coincide with soil patterns. Many factors other than soil may dictate their size and shape for practical land use and management.

The term "performance area" is used for tracts within which one may predict relatively uniform soil performance under a single system of management for a given use. The boundaries of performance areas generally coincide with soil boundaries, although those boundaries may enclose areas of two or more kinds of soil that perform alike for a given use. Performance areas may vary for different uses.

The term "soil performance" is used for the yield or other output obtained from a soil in response to management under a given land use. A soil having properties good for a given use has the qualities to "perform" well in that use. If a critical soil property severely limits a given use, the soil would "perform" poorly. The term not only describes the land use quality of a soil as it is found in nature but also takes into account the qualities resulting from soil changes imposed by men.

Performance for growth of plants is expressed in terms of actual or average yields per unit area; it is related to the concept of potential by the equation: potential equals performance minus costs to produce the performance yield, expressed in monetary units.

The sizes of all of the kinds of areas discussed above are expressed in units of land measurement, such as hectares of square kilometers. Delineations are usually measured in square centimeters on the map. To avoid confusion, one should refer to planning delineations, operational delineations, management delineations, and performance delineations when referring to maps. A set of equations to convert the sizes of land to sizes of delineations on maps as a function of map scale are given below:

m	:	linear distance on map in cm
a	:	area on map in sq cm
g	:	linear distance on ground in cm
Ah	:	area on ground in ha
Ak	:	area on ground in sq km
s	:	scale denominator (1:s)
G	:	g in meters = g/100
		$g = sm$
		$G = \frac{sm}{100}$

Conversion of area on map (cm^2) to area on ground (ha) or vice versa

$$Ah = \frac{a\ s^2}{10^8} \qquad \text{and} \qquad a = \frac{Ah \cdot 10^8}{s^2}$$

Conversion of area on map (cm^2) to area on ground (km^2) or vice versa

$$Ak = \frac{a\ s^2}{10^{10}} \qquad \text{and} \qquad a = \frac{Ak \cdot 10^{10}}{s^2}$$

Scale as a function of the ratio between areas on ground (ha or km^2) and area on map (sq cm)

$$s = 10^4 \sqrt{\frac{Ah}{a}} \qquad \text{and} \qquad s = 10^5 \sqrt{\frac{Ak}{a}}$$

Relation Between Map Scale and Size of Area of Interest

There are economic reasons to reduce scales of soil maps as much as possible; costs of surveys are proportional to the square of the scale. However, there is a limit for the reduction of maps: the delineations of areas in which planners are interested should remain legible; this is achieved as long as most delineations are larger than 0.4 sq cm (Soil Resource Inventory Group, 1977); optimally the average size should be larger than ± 1.5 sq cm.

The adequacy of scales can be checked against the size of the delineations of planning interest on the map. The minimum scale of a map is defined by the size of the smallest area of interest the planner wishes to identify on the map: it is the smallest of either the operational, the management, or the performance delineation which will first reach the 0.4 sq cm size limit when maps are reduced.

An example may help to clarify the concepts and illustrate the use of areas of interest in adequacy appraisals. Assume a territory of one million hectares. An agency is asked to select the best locations for rural communities which would need 10,000 ha each. Each farmer in a community would need 50 ha of land to be subdivided into fields no smaller than 2 ha. Soil maps at 1:100,000 are available on which the performance delineations are on average 2.3 sq cm large. There are aerial photographs at a scale 1:40,000.

According to the adequacy standards explained above, the map at 1:100,000 is adequate for selecting the best sites for the communities since the critical performance delineation is larger than the conventional 0.4 sq cm set for legibility; the performance delineation (2.3 sq cm) is in this case the delineation which corresponds to the smallest area of interest (2.3 is smaller than 100).

The siting of the 50 ha plots within the community lands would need additional maps. Indeed, the critical area of interest, which is now represented by the operational delineation (the operational area of 0.5 is smaller than the performance area of 2.3 sq cm) is close to the 0.4 sq cm limit, and far below the optimal size of 1.5 sq cm requested for legibility. For making farm plans which would indicate the location of the 2 ha fields, the management delineations on the aerial photographs at 1:40,000 scale would be 1.25 sq cm, slightly below the optimum size for map delineations. If the performance of the crops to be planted in the fields could be predicted as uniform in each farm, the 1:40,000 aerial photographs would be adequate to indicate the location of the 2 ha fields.

INFORMATION REQUIREMENTS

Once the soil data that are recorded in surveys are given to planners, their main concerns relate to two kinds of information: (1) the extent to which the inventory permits identification of limiting factors for the intended land uses, and (2) the variability of these limiting factors within each map unit.

To respond to these concerns, a precise understanding of the types of land uses which will be introduced in the planning area is needed. Alternatives should be discussed with agronomists or other resource development specialists, but specific soil limitations to the projected land use should be recognized. They form the third set of data needed to assess the adequacy of information provided by soil resource inventories.

The three components are briefly discussed below:

Diagnosis of Land Use Requirements

The judgment of an agronomist or soil scientist familiar with plant requirements and management systems is critical. For each specific objective a list of limiting soil properties must be compiled, and their relation to crop production or feasibility of development assessed as closely as possible.

The degree of detail needed varies with the degree of specialization of the development objectives. As an example the limiting soil properties for oil palm are given in Table 1. A table such as this sets critical limits for suitability within a particular project and serves two purposes in the adequacy study of soil resource inventories: (1) it gives the soil properties which should be described in the soil survey report, and (2) it

Table 1. Limiting soil properties for tropical tree crops (oil palm example). (Sys, 1976)

Properties to be evaluated	Critical limits
1. Topography (slope)	Not more than 30% slope
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%
6. Effective soil depth	Not less than 50 cm
7. Cation exchange capacity	Not less than 16 meq/100 g of clay; no net positive charge
8. Base saturation	Not less than 15% in the surface horizons
9. Organic matter	Not less than 0.8%

permits an evaluation of the percentage of suitable land in the planning area.

Usually, this type of information is not easily found in the literature; most frequently the critical limits have to be defined for each project.

Information on Limiting Factors

There are several ways to check the presence of data related to limiting factors in soil resource inventories. Many surveys, but not all, either have condensed the information in soil classification systems, or in interpretative tables. These procedures may facilitate the identification of properties which have to be taken into account in the feasibility or suitability evaluation. In most instances, however, the adequacy study will have to check each description of each individual map unit for relevance to specific objectives.

In the soil resource adequacy study proposed by Cornell's group, all soils for which no information on required limiting factors is given are categorized as "unknown." The soil units or parts of them which have all qualities above the critical level are called "suitable." All others are termed "limiting."

Information on Map Unit Composition

The planner should be informed as to whether uniform responses to the development actions can be expected in each map unit. The soil resource inventory should provide an estimate of the within-boundary variability of limiting factors. As in the previous section, in some survey procedures, the name of the mapping unit may give some indications about its composition. In many cases however, even when all reported data are true, the internal variability may not be reported.

The Soil Resource Inventory group at Cornell proposes to categorize soil units about which no information on variability is given, or which contain more than 40% undescribed inclusions, as "unknown." Those which contain less than 15% inclusions of dissimilar soils are qualified as "uniform." All others were considered "non uniform."

There are three components in the assessment procedures of map unit composition: (1) the adequacy of the information given in the survey report about the variability of limiting factors within each unit. This does not need ground checking; (2) the evaluation of the map unit composition in the field either by additional, more detailed mapping, or statistical sampling and, (3) the correspondence of soil information as given in the survey and the actual occurrence of soil properties in the field.

Adequacy of Soil Resource Information, an Example

The combination of the uniformity and suitability concepts, explained above, with the "unknown" parts of mapped areas, can be used to define appraisal classes. The soil resource inventory group at Cornell has been testing five classes of areas described briefly as follows:

Uniform-limiting (U-L), Uniform-suitable (U-S), Non uniform-predominantly suitable (N-PS), Non uniform-predominantly limiting (N-PL), and Unknown (U).

The U-L and U-S areas correspond to the performance areas previously defined in this text. A methodology to estimate the percentages of these classes on a map has been described by Forbes (1977).

The use of these classes in adequacy studies can be illustrated by an example in which the following results of area estimates were obtained:

U-L:	Uniform - Limiting: 26%	(1)
U-S:	Uniform - Suitable: 16%	(2)
N-PS:	Non uniform - predominantly suitable: 37%	(3)
N-PL:	Non uniform - predominantly limiting: 13%	(4)
U:	Unknown: 8%	(5)

It would mean that the information given by the map, provided it were accurate (no field checking done yet), is adequate in 42% of the planning area (1 + 2); it would be necessary to conduct an additional survey in 45% of the area (3 + 5). It would not be worthwhile to investigate the composition of the soil units in 13% of the area (4), because most of the land in this part is unsuitable for the intended land use.

SUMMARY AND CONCLUSION

The two examples given in this paper illustrate the use of objective criteria in the evaluation of the adequacy of soil surveys. They only considered two components: scale and map unit composition. A complete evaluation should also include the quality of base maps, ground truth, etc.

The criteria regarding location requirements determine for given standards of base maps how well the question "where" is answered. This type of adequacy is important for siting an area on the ground, or identifying a delineation on the map.

How well the question "what limitations?" can be answered, is covered by the information criteria. It also gives an indication of the amount of additional surveys which would be needed to arrive at a complete diagnosis of the planning area.

The methodology, which is only a part of a complete soil resource inventory evaluation, is applicable where a specific objective for utilizing the survey has been selected and when the critical soil properties for that particular land use are known. When more than one objective for utilization is involved in one evaluation, the criteria for defining sets of limiting factors still has to be worked out. Suitability scales for soils in multipurpose projects cannot be used in the adequacy study, since all soils are suitable for something.

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QUESTIONS/COMMENTS:

In your example in Table I on Limiting Soil Properties for oil palm, 9 properties are listed. Are these of equal value or are they on a scale of most important to least important? Are not some limiting properties more significant than others?

ANSWERS:

In this example all the properties have the same value. They are not on a scale. However, if the information is available and it is important and advantageous to list the limiting factors on a scale from the most to least significant, it would be desirable to do so.

EVALUATION OF SOIL RESOURCE INVENTORIES

Hari Eswaran[1]

Maps are primarily instruments for arranging, storing, transmitting, and analyzing information about the spatial distribution of attributes (Varnes, 1974). According to Cherry (1966), what people value in a source of information (i.e. what they are prepared to pay for) depends upon its exclusiveness and prediction power. Exclusiveness implies the selection of that one particular recipient out of the population, while the prediction value of information rests upon the power it gives the recipient to select his future action, out of a whole range of prior uncertainty as to what action to take.

A soil resource inventory (SRI) is exclusive in terms of its information content. It may or may not have a predictive value, as this frequently requires one additional stage of reasoning. From the point of view of the user, the quality of the SRI is judged largely from its predictive value or the alternatives that are presented to make a choice. The technical language of an SRI is, to the user, a coded language. To increase the predictive value, the scientist must decode the information and present it in a form palatable to the user.

Soil resource inventories, like any inventories, may be evaluated from different points of view. To evaluate an SRI objectively, one has to relate it to the needs of the user. However, there is an inherent problem for SRIs: in many instances (more so in less developed countries), the user is frequently not completely aware of his needs. The user knows that he requires some detailed information to facilitate his decision-making process, but he is generally uninformed of the kind of information that is needed. This complicates the situation as it puts the burden on the scientist; he must not only provide the user with the information but also sort out the relevant information and organize it in a manner suitable to the user.

The three basic aspects of evaluation of SRIs used by scientists are: (a) relevance to the stated objective, (b) adequacy to the stated objective, and (c) reliability to the stated objective. The user - in this case a planner - evaluates it slightly differently. He wants answers to the questions: (a) What can I do with the area? (b) What are the alternatives? (c) What are the risks? and (d) How much flexibility do I have? If the SRI provides him with these answers, he considers the inventory satisfactory; if not, he bases his decision on other considerations. The user is not concerned with how the inventory was made or the limitations (quality) of the inventory. As a result, the evaluation of an SRI is made from two basic points of view: 1) the technical aspect, and 2) the practical aspect.

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THE TECHNICAL ASPECT

From the technical point of view, the SRI is evaluated with respect to its relevance, adequacy and reliability. In Figure 1 the relation of this kind of evaluation to the objectives, the elements of SRI, and the methods of characterizatio of the SRI are shown schematically. The following discussion adheres to this scheme, which is described in detail in the earlier parts of the Handbook.

Relevance

As stated earlier, the evaluation is made with respect to a stated objective. As shown in Figure 1, the evaluation procedure starts anew for a different objective.

Prior to making an evaluation it is necessary to determine the objective or objectives for which the SRI was made. To develop an SRI is an expensive exercise and so the scientist is encouraged to report in detail and put in as much information as possible. In a new area, the soil surveyor may be one of the few people who has traversed the land and his report may be the only document available until the land is settled. As a result, even though a survey is made for a specific objective, it should contain information that could be used for other purposes. Consequently, a secondary evaluation may be made to test the usefulness of the SRI for other possible objectives.

Evaluation in Relation to Kinds of Planning

In Figure 1 and a section of the Handbook, three major categories of objectives were considered: master planning, project planning, and operational planning. Each of these kinds of planning involves a different scale of operation and a different degree of informational detail. The requirements in terms of relevance, adequacy, and reliability consequently vary.

Table 1 lists the characteristics of SRI for evaluation. More aspects could be added to the list if necessary. The evaluation is made for specific objectives. In the first column, it is determined if the information is available. If not available, boxes 'a' or 'b' are checked depending on whether the information is considered necessary or not. If the information is available, then its relevance, adequacy, and reliability are determined wherever applicable and the respective boxes in the columns are checked.

Table 1 when complete presents a summary sheet of the quality of the SRI for the objective. The process is started again for a new objective. Although the three columns - relevance, adequacy, and reliability - are provided for each of the criteria, it may not be necessary to make a judgment for all three columns. In the obvious cases, the unnecessary columns are eliminated.

Table 1, when used in conjunction with the checklist in the Handbook, will make a complete assessment of the SRI.

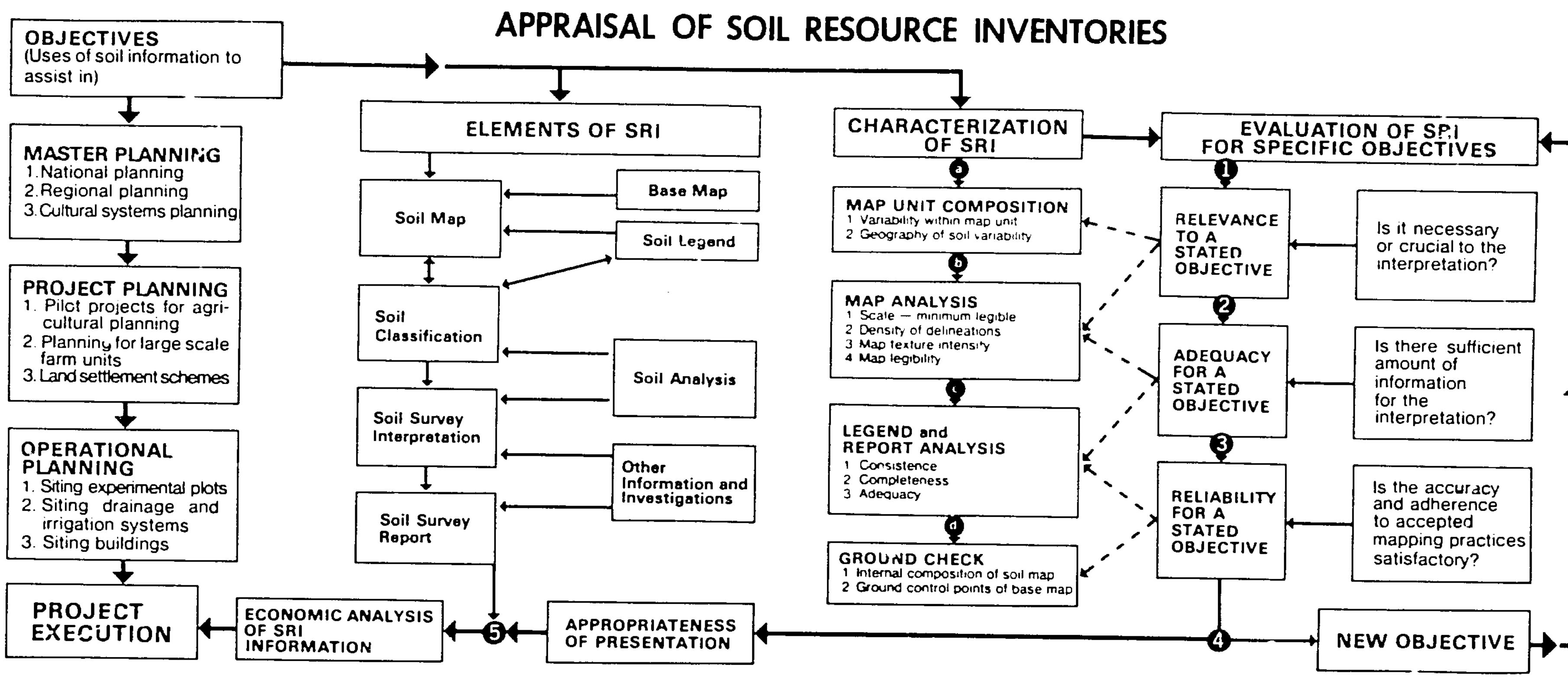

Fig. 1. Flow chart of characterization methodology.

Evaluation of site-specific objectives

The SRI requirements listed in Table 1 change and sometimes become more detailed as the objectives become more site specific. This is particularly so in the third kind of planning - operational planning. Operational planning requires site-specific information. Some aspects, such as soil analysis, become more critical and sometimes require special data. In some instances, the routine soil survey has to be supplemented with extra observations, such as deep borings. Figure 2 taken from Miller (1978) illustrates an example of such a consideration.

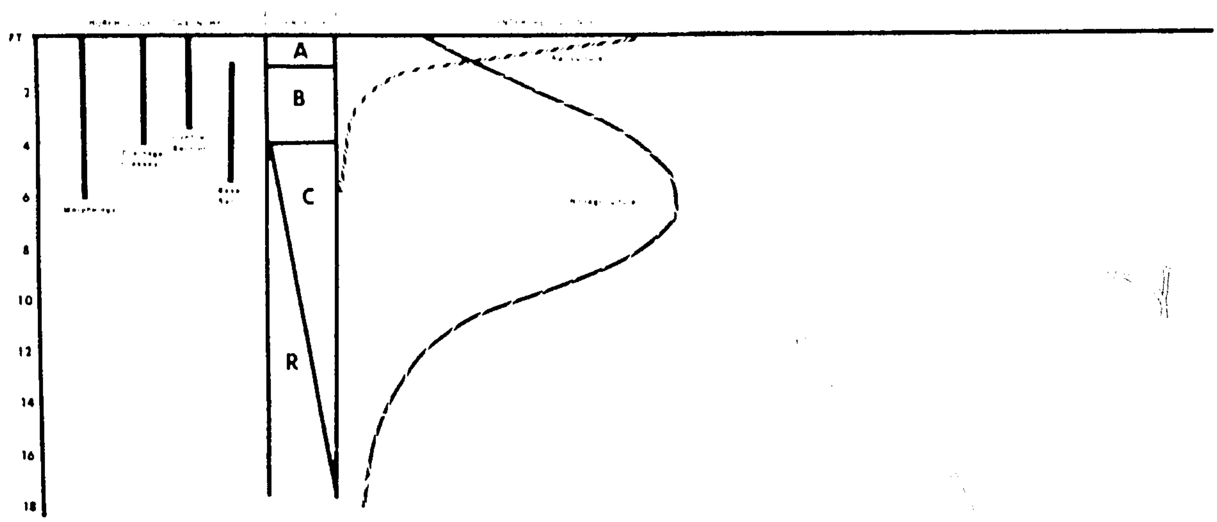

Fig. 2. Frequency of requests for soil interpretations at various depth limits of several diagnostic soil taxonomy criteria.

In such situations where the objectives call for specific data, a new checklist has to be prepared to evaluate the SRI. The list in Table 1 is definitely inadequate to evaluate a report, for example, on an irrigation project. To illustrate, an irrigation survey report may meet all the requirements in Table 1, but if it does not mention the presence of gypsum at 10 to 20 feet, the project may be doomed to failure.

In conclusion, in the evaluation of the technical aspects of the SRI the objective is to test the usefulness of the report. Only a competent soil scientist can make such an assessment. This begs the question of who makes the evaluation and for what reasons.

When soil surveys are contracted, the verification or adherence to specification calls for such an evaluation. In such cases, the verification can only be done in relation to specifications stipulated prior to commencement of the survey. If the specifications were vague or there were no specifications, the evaluation has little legal meaning.

The evaluation methodology also serves, indirectly, as guidelines for quality control in a national SRI program. A standard practice could be adopted whereby a survey is evaluated by colleagues after its completion. This provides a 'check' mechanism within the organization to maintain or improve its standards. Occasionally, a third party could be invited for a review. Efforts of this kind are necessary to maintain quality and are part of the quality control mechanisms within the organization.

THE PRACTICAL ASPECT

The criteria used in the technical evaluation discussed above are generally quite different from those employed by planners or users. An SRI report may be technically excellent but may be disregarded by the planner because of poor presentation or use of a coded language.

Users of SRI information vary in their interests and experience. In the Western world, even a farmer with a few hundred hectares of land might want to consult with the SRI report or a scientist. In less developed countries (LDCs) this is less frequent and users of SRI are mainly officials of government agencies. The planner or user in this context is considered as one who has little or no technical background, who is generally an administrator, who frequently has to make decisions in a short time, who has little or no time to spend on determining the pros and cons of a suggestion and who, as a result, relies completely on the advice of the technical man. Consequently, the technical man has a tremendous responsibility on his shoulders. (Usually, this responsibility is much less, as many decisions are socio-political with the technical considerations being of secondary importance.) How does a planner evaluate a report, or in other words, what does he expect in a report?

The first point is the psychological impact of the report. This encompasses a whole range of aspects, some of which might appear ridiculous to the scientist who only evaluates it from the point of view of its information content.

Appearance of the Report

One of the reasons for the success of Playboy magazine (apart from its content) is its presentation. The presentation makes it a status symbol and gives it a certain degree of refinement. If the magazine had been published on poor quality paper and sold for ten cents, it would have been considered trash. SRI reports should also strive to attain such perfections in presentation. The comparison may seem frivilous but I think it is relevant.

Presentation of Information

Use of tables, graphs and other visual aids are equally necessary. Planners have little time to go through pages of technical data. Critical data has to be summarized and tabulated or presented in graphical forms. Apart from the soil map, an attempt must be made to present derivative maps for the objectives. The latter maps should be simple and have three or at the most five classes so that the planner can locate at a glance the areas good for the objective and the areas to be avoided. Such a derivative map, when well presented, can have the same impact as the centerfold of Playboy.

Presentation of maps. Maps are always wanted by planners. These are the basic materials, apart from other diagrams, which planners use in their discussions and meetings. The clarity of the map is critical. Ground control should be well indicated so the planner can locate himself. Towns, villages, roads, and rivers must be prominent. Colored maps are preferred to black and white maps. As stated before, legend must be simple - not to exceed five units.

Presentation of other data. Most planners can read histograms, so these can be used effectively. Presenting the past, present, and anticipated future situations is usually attractive to the planner, e.g. yield data for the past ten years and anticipated production during the next ten years. Diagrams or maps to show alternative choices (with preferences) and if possible, inclusion of socio-political considerations and indications of risks and flexibilities are frequently well appreciated by planners.

The psychological impact of SRI reports are as important as the information content. Many soil scientists ignore this aspect or pay less attention to it than they should. It is important that we realize that to sell our product -SRI- we have to package it in an attractive form.

Economics

How much will it cost, can I do it cheaper, what is the profit margin, etc., are the questions of prime concern to the planner. The average soil scientist has failed dismally in this respect as he considers the job done on completion of the technical report. In an irrigation project, the fundamental question is what is the increase in the net farm income, followed by, how long can this increase be maintained without further substantial investments. The economic considerations start from the small farmer and the implications are examined up to the national level. Obviously, a soil scientist cannot, with any level of confidence, provide such information. He needs the assistance of an economist. It is necessary that SRI reports carry such economic evaluations. The Bureau of Land Reclamation of the U.S. is already involved in such aspects. Their land classification has an economic parameter.

Planner Education

Much as the technical man strives to find out the needs of the planner, creating an awareness of the planner to technical aspects greatly facilitates the communication and makes the planners' evaluation of SRIs more rational. The enterprising planners frequently desire to know more about the technical aspects, but there are others who need more coaxing. The scientist must attempt to participate more effectively in the planning process.

CONCLUSION

Many national soil survey organizations believe that the quality control mechanisms built into the system are sufficient and as a result a quality apprisal at the end of the survey is superfluous. This attitude may be dangerous, especially when the survey organizations become large bureaucracies. In developing countries which are in the process of setting up national survey organizations, evaluation exercises are essential.

Internal (by the organization) evaluation exercises should be conducted not only to verify the quality of the product, but for other possible advantages such as picking out weaknesses which could be corrected for future inventories, standardizing inventories being developed for different parts of the country or different projects, and serving as a training program for young surveyors. An occasional external review (a third party) helps to bring in new considerations. Every SRI organization perseveres to improve its products and it is towards this goal that evaluation should be considered.

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Miller, F.P. 1978. Soil survey under pressure: The Maryland experience. J. Soil Water Conserv. 33:104-110.

Varnes, D.J. 1974. The logic of geological maps, with reference to their interpretation and use for engineering purposes. U.S. Geol. Surv. Prof. Papers. No. 837.

QUESTIONS/COMMENTS (by P.H.T. Beckett)

Essentially the user of a soil map is not interested in learning the name of the soil at a site or within a management area. He wants to know the useful properties of soils within that area. If, however, the useful information he wants is collated, or categorized under soil names, then he looks at the map to determine the relevant soil name, and then elsewhere to find out information about soils of that name. This information may be in the memoir, or briefly in the map legend as in some of Prof. Eswaran's examples, or in both. Will it not be necessary to consider them together, not separate? The question is then "Do this legend and memoir together make it easy or difficult for the user to find the information he wants about the soil class that it should come first in the memoir and not 5th, as suggested. It would be of very great interest to collect a panel of agronomists, intelligent but not pedologists, present them with copies of the memoirs of a range of soil surveys, and time the rates at which they extracted answers to simple questions such as: (in order of increasing complexity). What are the surface soil textures, pH and phosphorus status of series A, B, & C? Summarize the agronomic potentials and hazards of series D, E, F? Select the three areas on the map, each of 100 ha, that you consider most/least suitable for the production of maize (corn), irrigated vegetables, etc.

ANSWERS:

Comment considered.

Table 1. Evaluation of SRI for stated objectives.

Check boxes as follows:

1. <u>No information</u>

If no information is available, check one of the two boxes 'a' or 'b':

a. If information is necessary.
b. If information is not necessary.

(If one of the boxes is checked, leave the boxes under the other three columns blank).

2. <u>Relevance to stated objectives</u>.

Check if one of the following conditions apply:

a. The information is relevant.
b. The information is not relevant.

3. <u>Adequacy to stated objective</u>.

Check if one of the following conditions apply:

a. The information is adequate.
b. The information is inadequate.

4. <u>Reliability for stated objectives</u>.

Check if one of the following conditions apply:

a. The information is reliable.
b. The information is unreliable.

	No Information	Relevance	Adequacy	Reliability
A. Map unit composition				
1. Information on soil performance for:				
a. All map units				
b. Most map units				
c. Some map units				
d. Few critical map units				
2. Information on map unit composition for:				
a. All map units				
b. Most map units				
c. Some map units				
d. Few critical map units				
B. Map pattern analysis				
1. Publication scale				
2. Map parameters				
a. Average size delineation				
b. Index of max. reduction				
c. Least size delineation				
d. Spot symbols				
e. Map texture intensity				
3. Map legibility				
a. Nature of symbols				
b. Choice of colors				

	No Information		Relevance		Adequacy		Reliability	
C. Legend and report analysis								
1. Descriptive legend								
a. Consistency with theories of soil genesis								
b. Correlation of units with landscape								
c. Mappability of soil units								
d. Consistency of soil identification								
e. Completeness of soil descriptions								
f. Information on non-soil and special soil features								
2. Report								
a. Soil classification								
i. Consistency with an accepted system								
ii. Consistency with descriptive legend								
iii. Compatability with laboratory data								
iv. Consistency with soil interpretations								
b. Soil analysis								
i. All mapping units								
ii. Most mapping units								
iii. Some mapping units								
iv. Critical mapping units								

	No Information	Relevance	Adequacy	Reliability
c. Soil interpretations				
i. For stated objectives				
ii. For other objectives				
iii. Information on susceptibility to deterioration				
iv. Information on soil management				
v. Information on constraints to land use				
d. Other information				
i. Geology				
ii. Climate				
iii. Vegetation				
iv. Land use				
e. Information to planners				
i. For stated objectives				
ii. Planning alternatives				
iii. Economic considerations				
iv. Other constraints				
D. <u>Ground check</u>				
1. Base map				
a. Kind of base map				
b. Number of reference points				
c. Distribution of reference points				
d. Distinctness of cultural features				

	No Information	Relevance	Adequacy	Reliability
e. Information on topographic features				
f. Scale of base map in relation to scale of published soil map				
2. Soil map				
a. Random spot checks made for				
i. Identification of soils				
ii. Location of soil boundaries				
b. Systematic random checks for				
i. Identification of soils				
ii. Location of soil boundaries				
c. Transect checks for				
i. Identification of soils				
ii. Location of soil boundaries				
d. Density of observations reported as				
i. Inset map				
ii. In report				

SOIL SURVEY REPORT AND MAP CHECKLIST

T. R. Forbes and H. Eswaran[1]

The Soil Resource Inventory Study Group has compiled a Soil Survey and Map checklist on which is recorded relevant soils and map data. The checklist is useful from several different points of view.

First, given the large number of different kinds of soils report formats and map presentations, the checklist provides a concise summary of the report and map for later reference. Since the checklist is standardized, the kind of information extracted from the report and map will be the same no matter what the original format. This aspect may be particularly useful to administrators who need a short summary of pertinent facts for land use planning decisions.

Second, a collection of checklists form a useful inventory of existing soil resource inventories for any given continent, country, region or any other desirable geographic subdivision. Many governmental ministries in less developed countries, and funding agencies in developed countries are often overwhelmed with years of project reports, feasibility studies and other materials which may include soil resource inventory information. Rapid and efficient access to these materials is often lacking and in the case of large funding agencies, the volume of materials that need to be researched for any given geographic area or country may be prohibitive. Generally, the final result is an underutilization of valuable reports and studies for assessing the effectiveness of past development projects and for planning effective future development projects. Or it may result in a duplication of work since sponsors of future projects may not be aware that a usable soil resource inventory already exists in a given area. (This is particularly a problem in less developed countries where many soil resource inventories are carried out as a part of a specific project that is not published in a government report).

Third, the checklist can be used as an instrument for soil resource inventory characterization and/or evaluation for specific objectives. The checklist includes a 4-step characterization methodology flowchart (See Figure 1 in "Evaluation of Soil Resource Inventories" by H. Eswaran, this workshop).

CHECKLIST: SUMMARY OF MAJOR SECTIONS OF THE SOILS REPORT

The first section of the checklist summarizes bibliographic and background material which would be useful for report writing and just generally getting an overview of the kinds of materials which the soil survey report contains (see p. 1, Soil Survey Report and Map Checklist at end of this paper).

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The second section of the checklist (pp. 2-4) concerns the objectives of the survey. The first set of objectives includes three major headings of land use planning:

(a) master planning or broad land use planning,
(b) project planning,
(c) operational planning.

Master planning can be subdivided into three categories: national, regional, and cultural systems. Project planning involves the selection of sites for groups of crops based on specific management requirements. The soils information in this case should be specific enough to assess suitability for broad groups of plants in a cultural system. Operational planning designs land management systems within tracts that are assigned to specific uses. Operational plans detail what, how, and when management inputs are needed for satisfactory land use. Elements of soil performance are primary criteria for this kind of planning. General or cross-objectives include those outside specific planning objectives. Such objectives may include scientific advancement, the gathering of data for soil classification or other related scientific disciplines.

The third section of the checklist categorizes the soil survey according to map and legend characteristics (pp. 5-8). Characteristics of the categories of soil surveys are as follows (USDA, 1974):

Exploratory:

(a) compiled without field identification of soils
(b) soil descriptions inferred from limited information on climate, geology, landforms
(c) scale $<$1:650,000
(d) map units defined very broadly or incompletely
(e) no limits on the amount or percentages of inclusions
(f) objectives: compilation of known data for nation or continent on which to base further, more detailed soil studies
(g) topographic or aerial photo base; no topographic or aerial photo base

Macro-reconnaissance survey:

(a) map units identified by limited observations of the soils within the area
(b) no precise location of soil boundaries
(c) scale 1:130,000 to 1:650,000
(d) map units are associations of higher categories or broadly defined taxa
(e) no limits on the amount or percentage of inclusions
(f) minimum-size delineations as small as 250 km^2 (500,000 ha)
(g) planning units as large as 100,000 km^2
(h) objectives: planning for large states, nations, and continents
(i) identification of the soils is mainly based on field data but in some cases supported by laboratory data.

Meso-reconnaissance:

(a) boundaries determined by soils observations
(b) scale 1:65,000 to 1:130,000
(c) minimum-size delineations 100 to 4,000 ha, but usually larger
(d) planning units 1,000 to 10,000 ha or 20,000 to 1,000,000 km^2
(e) no limits on the amount or percent of inclusions
(f) map units are associations of higher categories of taxa (in the USDA system these may include associations of families, subgroups, great groups, etc.)
(g) field methods: random traverses with detailed sampling blocks
(h) objectives: planning for states, small nations or regions; soils delineated for possible use but not management
(i) minimum or least-size delineations are 2 to 100 ha

Macro-detailed surveys:

(a) boundaries determined by soils observations
(b) scale 1:26,000 to 1:65,000
(c) smallest delineations are 10 to 20 times the size of areas that could be delineated at the minimum legible scale
(d) planning units are usually 100 to 10,000 ha or km^2
(e) no limits set on inclusions at smaller scales with limits on inclusions at approximately 30% at larger scales
(f) map units are usually predominantly consociations at the larger scales and associations at the smaller scales (The USDA system may include consociations or associations of series, families and subgroups.)
(g) field methods: traverses to detect minimum-size delineation of contrasting soils (with detailed sampling blocks)
(h) objectives: delineate for medium-sized or extensive operating units (forests, rangeland, large farms), not to site structures or operational planning for intensive uses
(i) smallest delineations are commonly 4 to 5 times the size of areas that could be delineated at the minimum legible scale

Meso-detailed surveys:

(a) scale 1:13,000 to 1:26,000
(b) minimum or least-size delineations are 0.5 to 2 ha (smaller areas use spot symbols)
(c) planning units are usually 5 to 2500 ha
(d) inclusions in map units should be 20%
(e) map units are usually consociations (may also have some complexes or associations)
(f) in some cases the smallest delineations may be two times the size of the areas that can be delineated legibly at the minimum legible scale.
(g) field methods: direct observations with traverses close enough to detect contrasting areas

(h) objectives: covers operational planning for moderate intensively used managment units such as farms and ranches (larger scales), more extensively used units, such as forests, rangelands, etc.; or selection of areas for more detailed surveys for intensive operational units

Ultra-detailed surveys:

(a) scale >1:13,000
(b) minimum or least-size delineations are 0.1 to 0.5 ha (smaller areas of limiting inclusions shown by spot symbols) 0.001 to 0.6 ha
(c) planning units are usually 1 to 500 ha
(d) inclusions in map units should be <20%
(e) map units are consociations (with some complexes at the smaller scales)
(f) field methods: direct examination with field traverses to pick up the limiting areas
(g) objectives: planning and siting for small areas such as experimental areas, truck gardens or housing sites.

Kinds of map units are defined according to United States Department of Agriculture (USDA), Soil Conservation Service (SCS) standards.

The results of the determinations of map pattern and map unit composition analyses are recorded in the last categories of this section. To understand the implications of these results the reader would have to compare them to the appropriate tables given in the handbook of soil resource inventory characterization of the Soil Resource Inventory Study Group (Arnold et al., 1978).

The fourth section of the checklist (pp. 9-10) characterizes the methodology of preparation of the soil survey. These categories should complement or give further information on the kind of soil survey as described in the third section of the checklist. The determination of the number of reference points on a given area of the base map can be made by criteria set forth in the handbook of soil resource inventory characterization by the Soil Resource Inventory Study Group (Arnold et al., 1978).

The fifth section of the checklist (p. 11) covers the results of field checking which may have been completed by the person(s) characterizing or evaluating the soil resource inventory report and map. The theory and methodology of field checking is discussed in the handbook of soil resource inventory characterization by the Soil Resource Inventory Study Group (Arnold et al., 1978).

The sixth and final section of the checklist (p. 12) is a blank page for a narrative characterization or evaluation. This may indeed be the most useful section of the checklist.

In compiling the checklist and characterizing approximately 200 existing soil resource inventories from around the world it was found that much information was not clearly presented and had to be deduced from explanations given in the particular report or map. However, it is suggested that future soil resource inventories clearly state this information somewhere in the body of the text. Results of characterizing over 200 s resource inventories from around the world are given in Table 1.

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Eswaran, H., T.R. Forbes, and M.C. Laker. 1977. Soil map parameters and classification. p. 37-59. In Soil resource inventories: Proceedings of a workshop held at Cornell University, April 4-7, 1977. Agronomy Mimeo 77-23. Dept. of Agronomy, Cornell Univ., Ithaca, NY.

United States Department of Agriculture, Soil Conservation Service. 1974. Soil survey manual, Rev. ed. (4th Draft, 74-75). USDA, SCS, Washington, DC 20000.

GLOSSARY

Association: A grographic mixture of areas of two or more distinctive kinds of soil, or of a soil and a kind of miscellaneous area. The areas of principal components of soil associations can be delineated separately by detailed survey methods at map scales of about 1:20,000 (USDA, SCS, 1974).

Consociation: A mapping unit in which only one identified component of soil (plus allowable inclusions) occurs in each delineation.

Least-size delineation: A delineation which is so small that it cannot contain a two or three digit mapping unit symbol. Features smaller than this, and of importance, are indicated by spot symbols.

Map index of maximum reduction: The factor by which a map may be reduced before it loses legibility. It is computed by the square root of the ratio of average-size delineation to minimum-size delineation.

Map unit composition: Refers to the extent to which limiting soil properties for a specific land use objective are given in descriptions of map units such as profile descriptions, analytical data, land capability classifications, interpretation tables and others.

Minimum-size delineation: The smallest area that still can be legibly indicated on a map. It has an arbitrary area of 0.4 cm^2 on the map.

QUESTIONS/COMMENTS (by P.H.T. Beckett):

It is not unusual that the detail or precision of a soil survey is specified by stating the taxonomic level of the soil classes that are to be mapped as simple map units (perhaps to a specified minimum purity). This being so, it is a very great handicap that there exists no consensus as to the probable or anticipated variability of the soil properties that will affect or limit land use within soil classes at different taxonomic levels. As far as it goes, a short and tentative table of coefficients of variation within series mapping units in Soils & Fertilizers 34. p. 11 (1971) has been confirmed by unit in New Zealand and Britain but the figures in the table for Great Soil Groups and families are derived from too narrow a range to be of any value.

ANSWERS:

Comment considered.

SOIL SURVEY REPORT AND MAP CHECKLIST - page 1

I. General Bibliographic and Background Information

Date of report:

No. of map sheets:

Country:

Title of report:

Report prepared by author(s) (last name, first name):

Map scale:

Area (km^2):

Book reference - (library call no. or other location):

Publisher:

City (publisher):

No. of pages:

Other bibliographic information (report no.; gov't agency, division, etc.):

Report accompanied by the following maps:

Type	No	Yes	Actual Scale		Scale Code*
Geology				G	
Vegetation				V	
Physiography				P	
Climate:				C	
Land use (present)				U	
Land capability/ potential				L	
Irrigation potential				I	
Erosion hazard				E	
Other				O	

Scale code*

1	--		1:12,999
2	1:13,000	-	1:25,999
3	1:26,000	-	1:59,999
4	1:60,000	-	1:129,999
5	1:130,000	-	1:259,999
6	1:260,000	-	1:649,999
7	1:650,000	-	--
8	None indicated		

Report accompanied by the following information:

Type	No	Yes	
Geology			G
Vegetation			V
Physiography			P
Climate			C
Land use (present)			U
Land capability/ potential			L
Irrigation potential			I
Erosion hazard			E
Other (specify)			O

Characterization done by:

Characterization completed on:

II. Objective(s) of Survey 1/

Indicated	Yes	No
Master Planning (broad land use planning)		
National planning and inventory		
Identification of broad development regions for purposes below		
Cropping		
Grazing		
Range lands		
Forestry		
Wildlife and recreation		
Watersheds		
Urban or settlement area		
Others (specify)		
Regional Planning and Inventory		
General (selection of promising areas for a specific purpose)		
Cultural systems general planning including:		
Shifting cultivation		
Wet culture (paddy rice, sugarcane, etc.)		
Rainfed permanent culture		
Irrigation dryland culture		
Other (specify):		
Grazing		
Dryland		
Irrigated		

SOIL SURVEY REPORT AND MAP CHECKLIST - page 3

Rangelands	
Forestry	
Wildlife and recreation	
Settlement areas	
Assess drainage requirements	
Background for soil conservation or reclamation program	
Delineate areas for watershed development	
General location of transport infrastructure, secondary industries or urban development	
Project Planning 2/	
Siting areas of rainfed crops and pastures (based on specific management requirements) - (specify crops or pastures):	
Irrigation feasibility	
Rangelands	
Forestry	
Wildlife and recreation	

1/ Add asterisks (*) to "check mark" if you believe that a particular objective is implied or that the report seems to meet the requirements for that particular objective.

2/ Soils information should be specific enough to assess the suitability for broad groups of plants in cultural systems.

SOIL SURVEY REPORT AND MAP CHECKLIST - page 4

Land settlement sites	
Engineering and urban purposes	
Others (specify):	
Operational Planning 3/	
Irrigation siting (specify crops):	
Siting experiment stations and field plots (specify crops):	
Rainfed crops for which management systems are indicated (specify):	
Engineering and urban uses	
Site roads and pipelines	
Site foundations, sewers, septic tanks	
Landscaping plans	
General or Cross-Objectives	
Scientific advancement	
Provides data for soil classification and genesis	
Provides data for geomorphology, geography or ecology	
Others (specify):	

3/ Soil information should be specific enough to assess the suitability for specific crops under a particular system of management.

SOIL SURVEY REPORT AND MAP CHECKLIST - page 5

III. Kind of Survey, Map and Legend Characteristics	
Exploratory Survey (compiled without identification by original observations in the area. Compiled from limited information on climate, vegetation, geology and landforms)	
Topographic or airphoto base	
No topographic or airphoto base	
Macro-reconnaissance survey (mapping units are identified by observations of the soils within the area, but the soils boundaries are largely compiled from other sources)	
Identification of the soils is mainly based on field data	
Identification of the soils is supported by laboratory data	
Meso-reconnaissance survey	
Macro-detailed survey	
Meso-detailed survey	
Ultra-detailed survey	

Kind of Survey - indicated in report by authors	Yes	No
Specify author's designation:		
Kind of Map Units		
USDA or translated to USDA (if translated by checker, mark with asterisk*)		

	Intensity level 4/		
	1	2	3
Consociations			
Associations			

4/ Asterisks (*) notes the predominant mapping unit

	Intensity level 4/ 1	2	3
Complexes			
Undifferentiated group			
Map Unit Components			
Number of categories			
USDA equivalents	Yes		No
Phases of soil series			
(specify phases):			
Soil series			
Phases of soil families			
(specify phases):			
Soil families			
Phases of subgroups			
(specify phases):			
Soil subgroups			
Phases of great groups			
(specify phases):			
Soil great groups			
Phases of suborders			
(specify phases):			
Soil suborders			
Phases of soil orders			
(specify phases):			
Soil orders			
Other:			
Not comparable			

Taxonomy - Classification System	
Comprehensive	
Non-comprehensive (name):	
"Tailor-made" for study	
No taxonomic system	
Land capability classes	
Soil potential classes	

SOIL SURVEY REPORT AND MAP CHECKLIST - page 8

Map Texture or Pattern	
Average-size delineation (cm^2)	
Average-size delineation (ha)	
Largest size area delineated (estimate, ha)	
Use of spot symbols	
Index of maximum reduction	
Reduced scale	
Actual published scale	
Map Unit Composition	
Objective for background of map unit composition	
List of limiting factors for specific objective:	
Percent uniform-limiting	
Average-size delineation, uniform-limiting	
Percent uniform suitable	
Average-size delineation uniform suitable	
Percent nonuniform-predominantly limiting	
Average-size delineation, nonuniform predominantly suitable	
Percent nonuniform predominantly suitable	
Average-size delineation, nonuniform predominantly suitable	
Percent nonuniform predominantly suitable	
Percent unknown	
Average-size delineation, unknown	

SOIL SURVEY REPORT AND MAP CHECKLIST - page 9

IV. Methodology of Preparation	
Average number of profiles sampled per map unit	
Type of analyses completed for most profiles	
Routine	
Fertility-related properties and routine	
Special properties (salinity, acid sulfate etc.) & routine	
Special properties (mineralogy etc.) and routine	
Other (specify)	
Usefulness of base map for location 2 reference pts. within circle (see Chap.3) — low 2-5 " — moderate 6-8 " — high 9 " — very high Type(s) of base map	
Airphoto	
Topographic	
Other (specify)	
Scales of base map (specify)	
Field Methods Number of observation points per cm^2 on field map, indicated (use code given below) 1 = 1 pt. 2 = 2 pts. 3 = 2-4 pts. 4 = 4-8 pts. 5 = 7-8 pts. 6 = not indicated	

SOIL SURVEY REPORT AND MAP CHECKLIST - page 10

Type of survey	
Rigid grid	
Rigid and with airphotos	
Grid survey with additional observations to locate boundaries	
As above but with aerial photos	
Random survey	
Random survey with airphotos	
If soil map was generalized	
Effective scale (specify)	
Legend determination	
Fixed prior to survey with minor alterations	
Fixed prior to survey with major alterations	
Made during progress of survey	
Not indicated	

SOIL SURVEY REPORT AND MAP CHECKLIST - page 11

V. Field Evaluation

Random spot checks made for

identification of soils

results:

location of soil boundaries

results:

Systematic random checks for

identification of soils

results:

location of soil boundaries

results:

Transect checks for

identification of soils

results:

location of soil boundaries

results:

V. Narrative evaluation and other remarks

Table 1. A survey of 200 SRI's from all over the world.

CHARACTERISTICS and PROPERTIES	Ultra-detailed	Meso-detailed	Macro-detailed	Meso-reconnaissance	Macro-reconnaissance	Exploratory
1 properties						
a Scale	>1:13,000	1:13,000-1:26,000	1:26,000-1:65,000	1:65,000-1:130,000	1:130,000-1:650,000	<1:650,000
b. Basic map units	Phases of consociations	Phases of consociations	Phases of consociations	Associations or consociations	Associations	Associations
c Level of classification of map units	Soil series	Soil series or soil families	Soil families or subgroups	Subgroups or great groups	Great groups or suborders	Suborders or orders
d Average-size delineation (cm^2)	12	4	5	6	6	5
e Average-size delineation (ha)	9	20	130	680	5700	345,000
f. Minimum-size delineation (ha)	1	1-3	3-20	20-70	70-2,000	≥2,000
g Index of maximum reduction	5	3	3	4	4	3
h Map unit composition	U-L or U-S	U-L, U-S, some N-PS but more frequently some N-PL, no X	U-L, U-S, some N-PS but more frequently some N-PL, no X	U-L, U-S, some N-PS and N-PL, some small areas of X	Mostly N-PS and N-PL, some X	Mostly N-PS and N-PL, some unknown
2 methodology of preparation						
a Type of base map	Airphotos, orthophotos, topographic maps	Airphotos aerial mosaics, orthophotos, topographic maps	Airphotos, aerial mosaics topographic maps	Airphotos, aerial mosaics, topographic maps	Airphotos, aerial mosaics, planimetric maps	Airphotos, aerial mosaics, planimetric maps
b Scale of base map	≥1:6,500	≥1:6,500-1:13,000	>1:13,000-1:32,500	>1:32,500-1:65,000	>1:65,000-1:325,000	>1:325,000
c. No. of reference points within circle - $5cm^2$, >1:20,000 - $3cm^2$, ≤1:20,000	Very high ≥9 Low <2	Very high ≥9 Low <2	Very high ≥9 Low <2	Very high ≥9 Low <2	Very high ≥9 Low < [illegible]	Very high ≥9 Low <2
d Approximate average no of observations per km^2 (Vink, 1963)	100-500		1-3	±1	0.5-1	—
e Plotting of soil boundaries continuously verified by						
1 visual observation	✓	✓				
2 verified at closely spaced intervals			✓			
3 plotted by remote sensing with some verification				✓		
4 plotted by remote sensing					✓	✓
f Type of analyses done for most profiles (check indicates necessity)						
1 routine	✓	✓	✓	✓	✓	✓
2 fertility-related and routine	✓	✓	✓			
3 special properties (salinity, acid sulfate etc.) and routine	✓	✓				
4 mineralogy and routine	✓	✓				

Table 1 continued

3 map interpretation potential						
a. indicates susceptibility of soils to deterioration	* * *	* * *	* * *	* *	*	
b. indicates suitability of soils for management and land preparation	* * *	* * *	* *	*	*	
c. indicates response to management	* * *	* * *	* *	*	*	
d. indicates constraints to land use	* * *	* * *	* * *	* *	*	
4 ground-truth						
a. Soil map						
1. internal composition or range in properties of map units	Very narrow	Very narrow	Narrow	Narrow	Broad	Very broad
2. map unit purity	85%	85%	85%	85%	60%	60%
b. Base map						
3. density of ground control points	Moderate-high	High-very high	Moderate-high	Moderate	Moderate-low	Low
5 uses of soil map						
a. Master planning						
1. national planning				*	* *	* * *
2. regional planning			*	* *	* * *	* * *
3. cultural systems planning (generally by regions or large areas)			* *	* * *	* * *	* *
b. Project planning						
1. pilot projects for agricultural development	* * *	* * *	* *	*		
2. planning large-scale farm units	* * *	* * *	* *	*		
3. land settlement schemes	*	* *	* *	* * *	* *	*
c. Operational planning						
1. siting of experimental plots	* * *	* *	*			
2. siting drainage and irrigation systems	* * *	* * *	* *	*		
3. siting of buildings	* * *	* * *	* *	*		

Key:
1) U-S = uniform-suitable, U-L = uniform-limiting, N-PS = non-uniform predominantly suitable, N-PL = nonuniform-predominantly limiting, X = unknown
2) * -minimum, ** - moderate, *** - maximum

SESSION III

USES AND ADEQUACY OF SOIL RESOURCE INVENTORY INFORMATION

Chairman: J. Lizarraga

Speakers

P. Beckett - The Cost-Benefit Relationships of Soil Surveys

S. Somasiri, R. L. Tinsley, C. R. Panabokke and F. R. Moorman - Evaluation of Rice Lands in Mid-country Kandy District, Sri Lanka

THE COST-BENEFIT RELATIONSHIPS OF SOIL SURVEYS

Philip Beckett[1]

It is not always clear why particular soil surveys were carried out. Nevertheless, when soil surveys are justified publicly it is on their practical value, so they should be assessed on their practical value too, that is on how far the existence of a soil map and its supporting documentation has enabled the members of a community to conduct their activities more economically, or to do more things for the same investment, than they could have done without it.

The paymaster of a survey or the users of its results are not necessarily interested in the cost-benefit ratio as such. Usually they are concerned to know the likely minimum cost of achieving a given benefit, or the likely maximum benefit from a given investment, and in either case they want the answer before the survey is commenced, or at least by the end of the reconnaissance stage that should precede mapping, in order to make the crucial decision - "should we do this survey at all, and if so how?"

Obviously the cost-benefit ratio has two components, of which the former is more easily estimated, and I shall discuss them separately.

COSTS

The cost of information increases with its precision and specificity, in soil sciences as anywhere else. Consider one survey area of average complexity, in which the whole range of soil variability in the soil mantle of the survey area can be divided into: 5 soil sub-groups, or 15 soil families, or 40 soil series, or 130 soil phases. We need not here discuss the nature of the criteria on which these divisions are made, except to note that very few of them are directly relevant to current or future land use in the area, and that it is assumed that the classes at each level show a narrower range (or greater "uniformity") of some or all of the relevant soil properties than the classes in the level above. Ideally, all the classes at each level will show approximately equal breadth of concept and equal uniformity in their relevant or useful properties, but this may be very difficult to achieve. Whatever their level of subdivision the soil classes adopted to define the mapped soil units become the basic units of information: the survey cannot specify the soil properties at any place more precisely than they can be specified for the classes adopted for the survey. Since the precision of the information required increases with the intensity of land use, the level of sub-division depends on this too (Figure 1).

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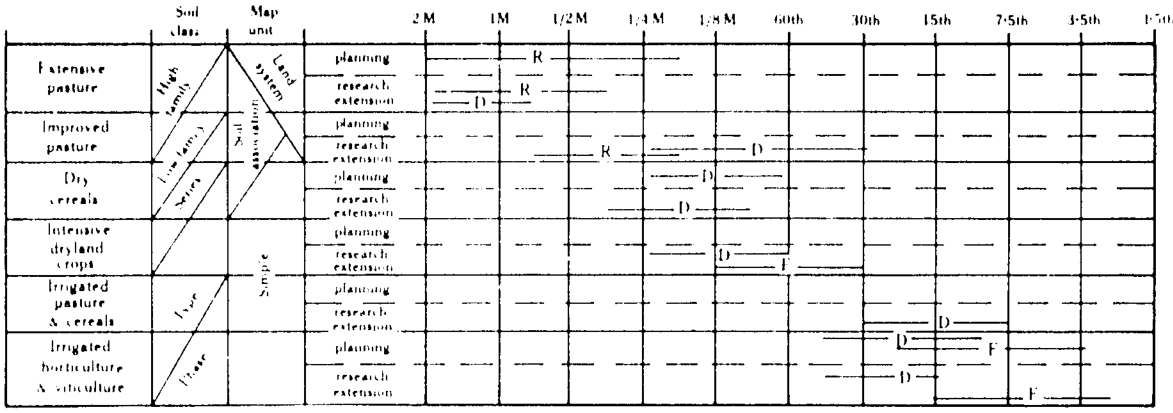


Fig. 1. The level of soil classification is adjusted to the intensity of land use and to the level of decision (R, regional; D, district; F, farm): other interrelations follow from this. (Data from a wide range of Australian soil maps: Beckett and Bie, 1978; reprinted by permission of CSIRO.)

There is little point in defining, and talking about, narrower soil classes than can be represented on the soil map, and the "purity" of the mapped units on a soil map should not vary with the breadth of the classes mapped (or the point of adjusting class breadth to land use will be defeated), so the average distance between the soil boundaries to be mapped must decrease as the classes are defined more narrowly. The average density of boundary on a published soil map should be relatively independent of its scale and purpose (Figure 2), so the publication scale of the soil map should be adjusted to average boundary density (Figure 3). Therefore, soil class and publication scale will also be related (Figure 4). The scale of the base map used in the survey ("field scale") should be about twice publication scale (Table 1). More often than not the constituent series of a soil family are separated by series from other families, so the grouping of series into families, or other higher groupings, may not reduce the length of boundary to be mapped, and at scales of 1:30,000 or smaller the surveyor has to define compound units (Figures 1 and 5, and see Bie and Beckett, 1971a). This makes cost-benefit discussions more complicated, but since it does not alter their basic principles the rest of this paper discusses only large- to medium-scale maps of simple (single-class) mapping units.

The closer the soil boundaries to be mapped, the greater the density of observations that will be needed to locate them, and the greater the effort required per unit area surveyed (Table 2). Also the proportional contribution of air photograph interpretation decreases with map scale (Figures 7 and 8). So the density of soil examinations (Table 3), and the cost of soil survey in effort (Table 4 and Figure 7) or money (Figure 6) increases with map scale. Cost or effort vary considerably with landscape, even within one region (Figure 9).

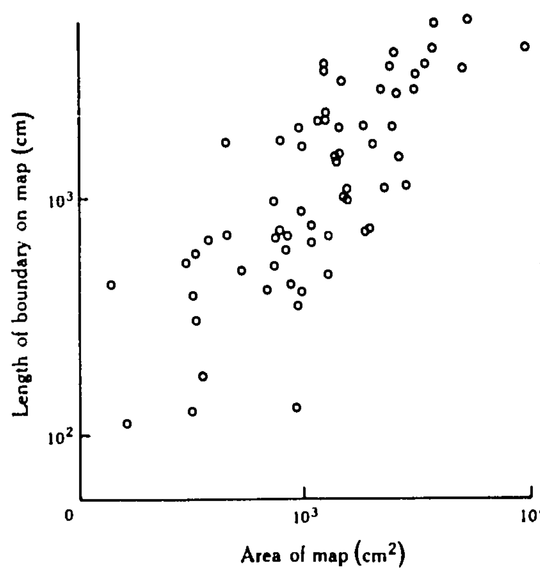


Fig. 2. There is an optimum density of soil boundary on a soil map, not greatly affected by its scale or purpose. (Beckett and Bie, 1978; reprinted by permission of CSIRO.)

Nevertheless, the precision achieved is not necessarily related to the effort applied. Figure 10 averages the fraction (in the range 0-1) of the total variance of topsoil clay content, organic matter, and available magnesium that is successfully described by a range of soil maps of increasing scale, in each of the three areas of Figure 9. (Burrough et al., 1971 give further information). Clearly by these criteria, and in this area, there is little benefit from mapping soil series by conventional free survey or grid survey at scales greater than 1:25-1:20,000. To achieve much increase in precision beyond this scale it will be necessary to produce single-property maps by grid survey.

This is universal: in every landscape there is a certain intensity of survey effort, beyond which the cost of further precision increases sharply and in proportion to the degree of precision already achieved. This is the Law of Diminishing Returns.

Much of the above can be approximately assessed on the reconnaissance that precedes a soil survey. We have explored (Beckett 1967; Beckett and Bie, 1975) the use of auto-correlation plots for predicting the uniformity of the mapping units that would be achieved at different boundary densities and map scales.

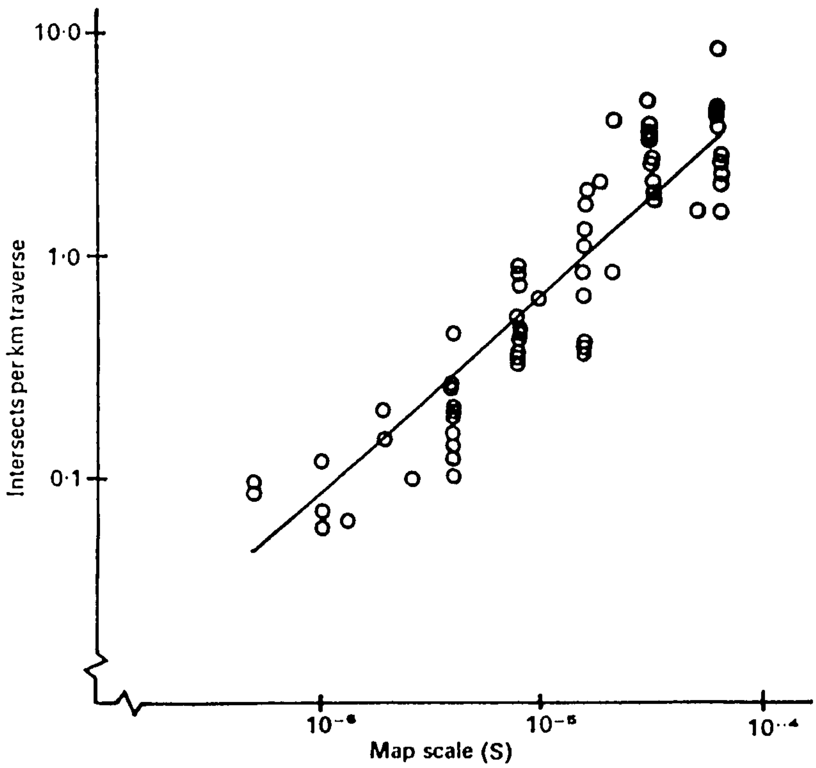


Fig. 3. Map scale is/should be adjusted to the frequency of the soil boundaries to be mapped, in this case estimated as the average number of boundaries crossed per unit length of random linear traverse from a wide range of Australian soil maps: Bie and Beckett, 1971a).

BENEFITS

It is more difficult to assess the benefits from a soil survey. There are plenty of anecdotal claims that this or that school, hospital or housing project incurred unecessary expense because it was built on a flood plain or peat bog that a soil map would have recorded, or conversely that money was saved because they were not built on a peat bog, etc. that a soil map did record. This kind of evidence is highly selective and difficult to evaluate: how many hospitals, etc. were built on suitable sites without the aid of a soil map? How many mapped peat bogs, etc. lay nowhere near a potential building site? How many hospitals, etc. were built on peat bogs, etc. that the soil map had failed to map? Or how many were moved from the site of first choice because the map had hinted at a peat bog, etc. that was not there? If such data are to be used they must be collected in a systematic and unbiased manner: otherwise they are better left for exercises in public relations.

The datum or starting point against which to evaluate the benefits from possessing a soil map is not a state of zero knowledge, but that amount of local knowledge already possessed by the intelligent layman, of which every community possesses at least a few.

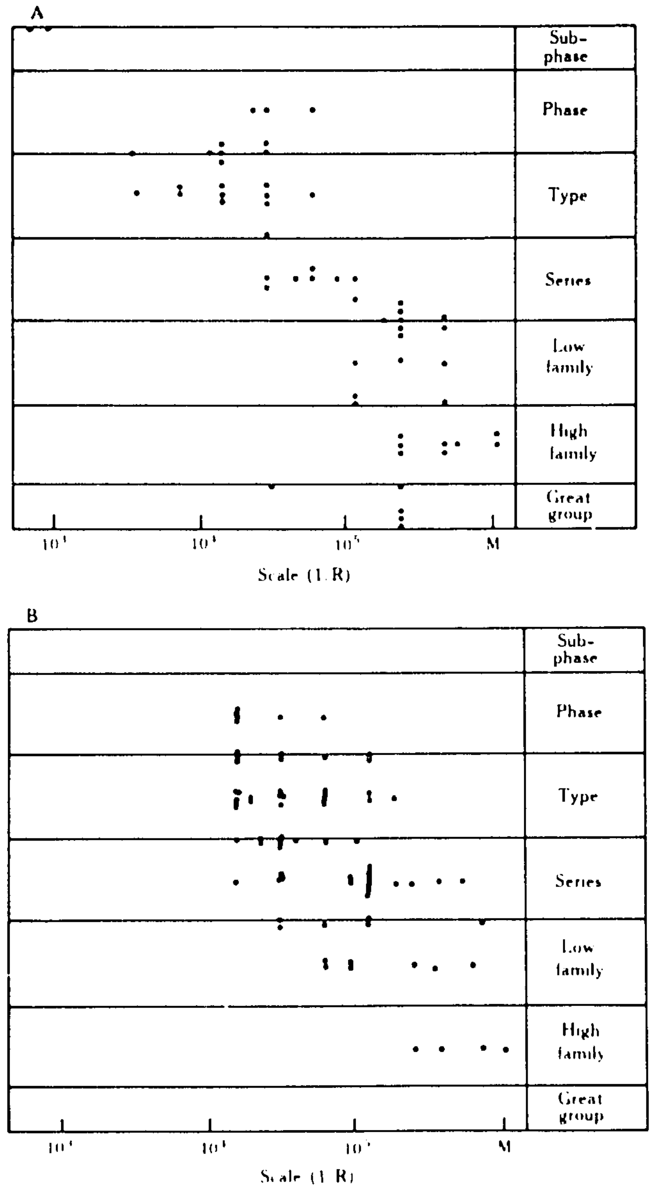


Fig. 4. Map scale and the level of soil classification are interrelated. (Sets of data from (A) Federal and (B) State soil surveys in Australia: Beckett and Bie, 1978; reprinted by permission of CSIRO.)

Table 1. The relationship of field scale to publication scale.

Publication scale	Field scale	Reduction factor	Country
1:2,534	1:2,534	1.00	Eire
1:10,000	1:10,000	1.00	Iraq
1:10,000	1:6,000	1.67	Lesotho
1:20,000	1:15,840	1.26	U.S.A.
1:20,000	1:5,000	4.00	Belgium
1:20,000	1:10,000	2.00	Tanzania
1:20,000	1:20,000	1.00	Fiji
1:20,000	1:6,000	3.33	Lesotho
1:25,000	1:20,000	1.25	Thailand
1:37,500	1:15,000	2.50	Thailand
1:50,000	1:50,000	1.00	Thailand
1:50,000	1:40,000	1.25	Nigeria
1:50,000	1:10,000	5.00	Belgium
1:50,000	1:20,000	2.50	Spain
1:50,000	1:25,000	2.00	Netherlands
1:50,000	1:25,000	2.00	Portugal
1:63,360	1:25,344	2.50	Scotland
1:100,000	1:60,000	1.67	Brunei
1:300,000	1:100,000	3.00	Belgium
1:500,000	1:200,000	2.50	Hungary

(S. Western, 1979)

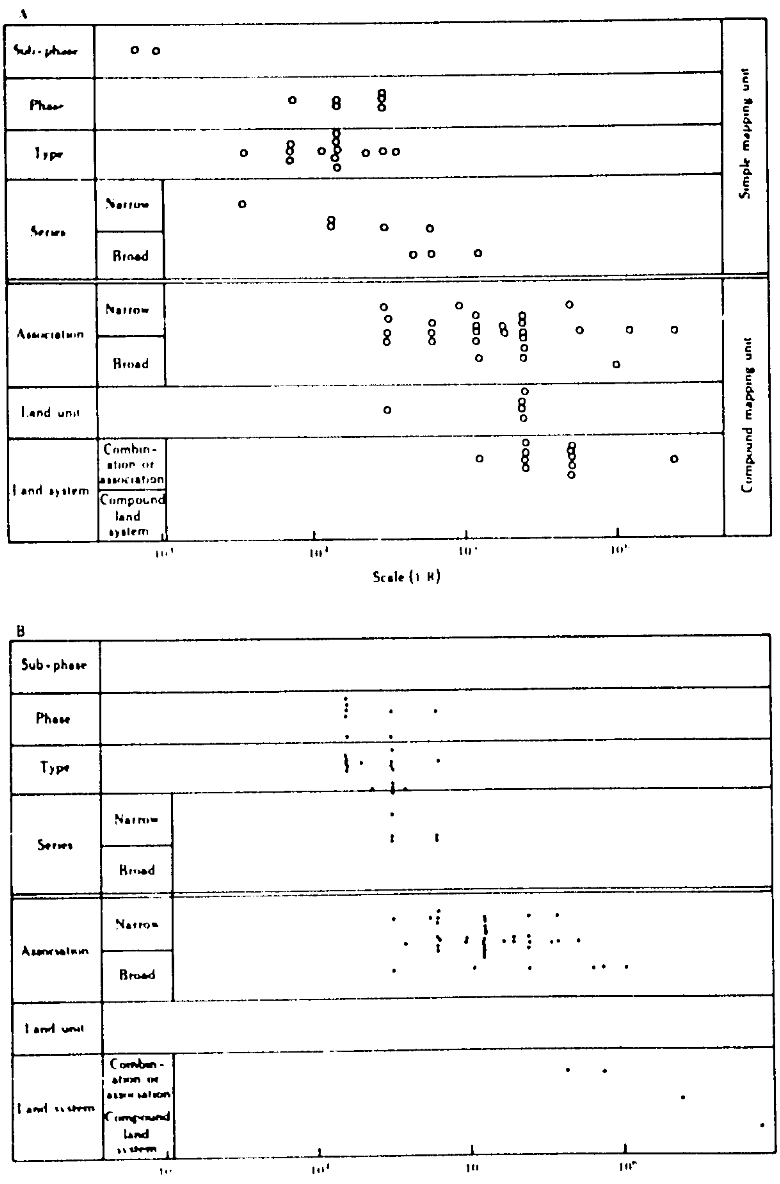


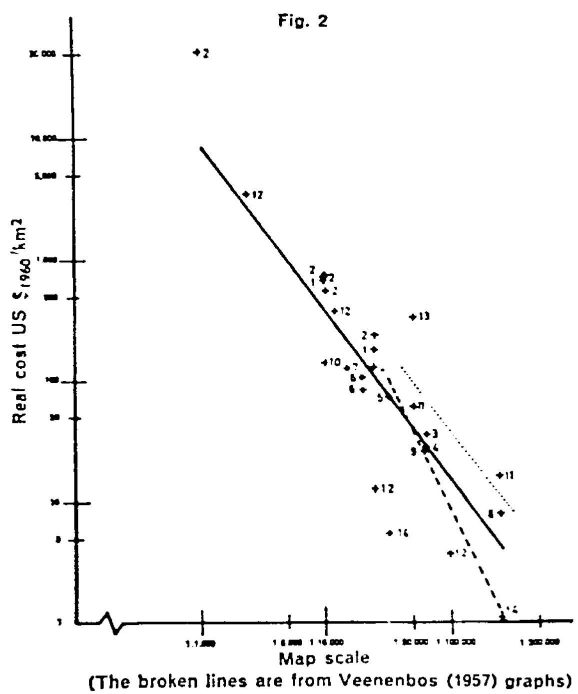
Fig. 5. Map scale and the complexity of the soil mapping units are interrelated (as Fig. 4). Reprinted by permission of CSIRO.

Table 2. Rate of survey in hot climates.

Aim	auger-hole depth (cm)	Intensity: distance between (m)	No. of sites/man-day[1]
Irrigation, Drainage, general engineering	500	100	6
		200	5.5
		500	4.5
		1000	4
		5000	3.5
	300	100	10
		200	9
		500	7
		1000	6
		5000	4.5
Forestry and tree crops	200	100	14.5
		200	12
		500	9
		1000	7
		5000	5.5
Field crops and Pastures	150	100	18
		200	14.5
		500	10
		1000	8
Exploratory survey	150	5000	5.5
General purpose survey	100	100	18
		200	14.5
		500	10
		1000	8
		5000	6

(after S. Western, 1979)

[1]Assuming one field-day comprises 7 hours, of which 1 hour is spent in travelling to and from the area of survey, leaving 6 hours for actual survey.



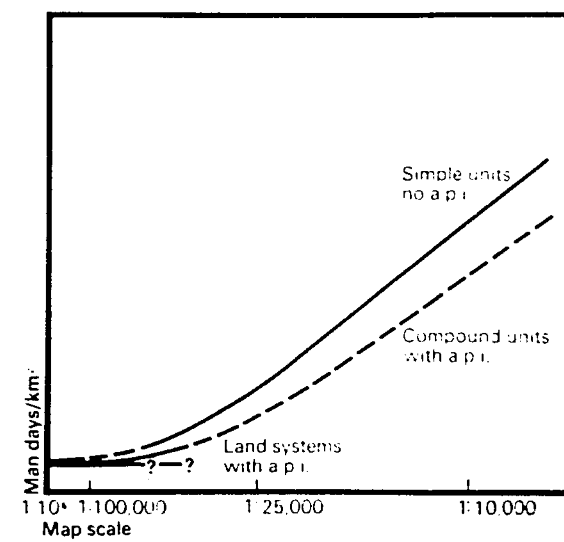


Fig. 6. The cost of soil survey increases with map scale: 1-2 Netherlands, 3-4 U.K., 5-6 U.S.A., 7 Australia, 8 New Guinea, 9 Eire, 10 Rhodesia, 11 Rwanda, 12 Sarawak, 13 Iraq, 14 New Zealand. (Bie and Beckett, 1970); reprinted by permission of the Commonwealth Agricultural Bureaux, Farnham House, Farnham Royal, Slough SL2 3BN, England.)

Fig. 7. The total professional field effort on 66 soil and land system surveys in Australia with and without air photo interpretation. (Beckett, 1971; reprinted by permission.)

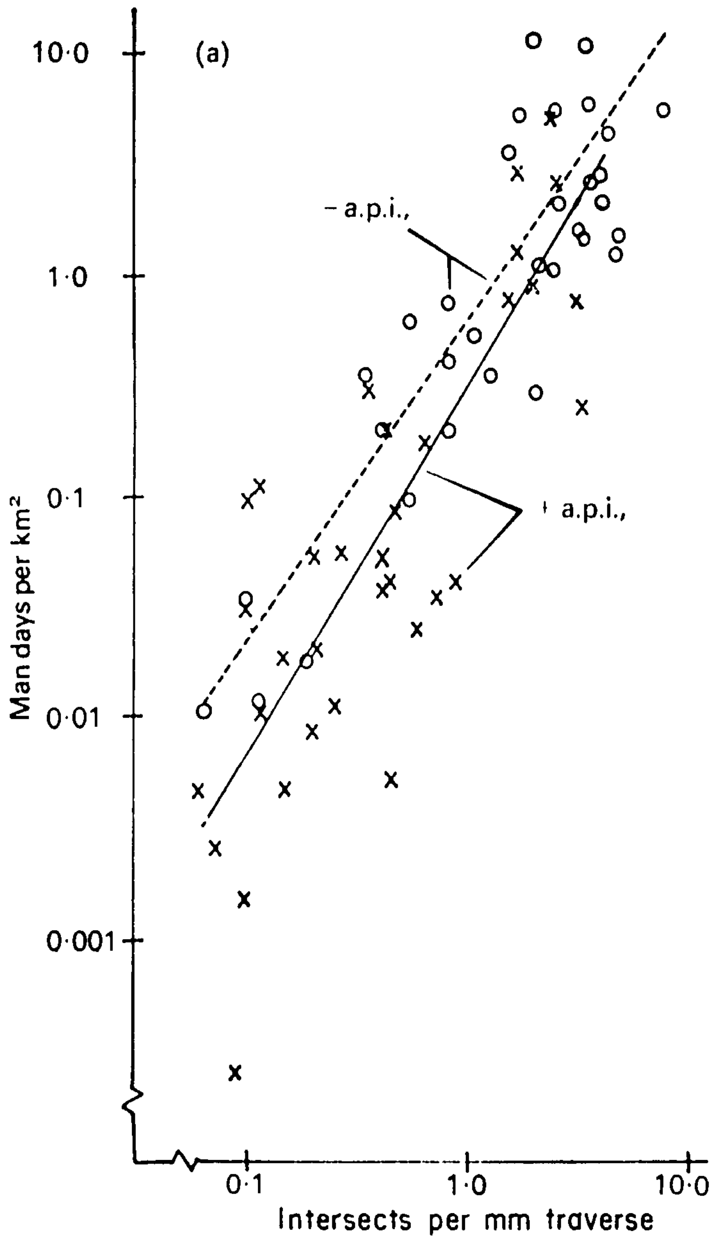


Fig. 8. Survey effort increases with the density of boundaries to be mapped, and may be reduced with air photographs, but the contribution of air photography decreases as map scale increases. (Bie and Beckett, 1971 a).

Table 3. Density of ground observations in relation to map scale.

Scale of published map	No. obs/ha	No. obs/cm^2 of map	Country
1:1000 to 1:5000	5	.05-1.3	W. Germany
1:2500	1.2	.08	Thailand
1:5000	16		Netherlands
1:10,000	1-8	1-8	Netherlands
	0.2-4	.2-4	Hungary
	0.05	.05	Iraq
	0.06	.06	Lesotho
1:20,000	0.07	.3	Tanzania
	0.04	.2	Fiji
	0.07	.3	Lesotho
	2	8	Belgium
1:25,000	0.1	.6	Thailand
	0.7-1	4.4-6.3	Netherlands
1:37,500	0.01	.15	Thailand
1:50,000	0.01	.3	Thailand
	0.03	.8	Nigeria
	0.20	5	Netherlands
1:100,000	0.003	.3	Brunei

(adapted from Western, 1979)

Table 4. Cost of consultant survey proposals.

Publication scale		Country	Year	Cost (£/ha)	Extent (ha)
	Exploratory	Yemen (P)	1976	0.002	19.6×10^6
		Thailand (I)	1973	0.002	5×10^6
1:250,000		Brazil (U)	1973	0.001	24.3×10^6
	Low intensity	Indonesia (I)	1973	> 0.13	25 000
1:100,000		Zambia (U)	1967	0.53	240 000
	Medium "	Thailand (I)	1971	0.37	133 000
		Ivory Coast (I)	1970	0.41	109 000
		Fiji (I)	1968	> 0.41	20 000
		Ethiopia (I)	1973	> 0.89	27 000
1:25,000		Nigeria (I)	1972	0.93	37 000
	High "	Somalia (P)	1975	5.23	15 000
1:10,000		Greece (I)	1972	6.64	1000
	Very high "	Brunei (P)	1975	91.46	12 000

(I) proposal implemented; (P) proposal pending; (U) proposal unsuccessful.
(Modified from S. Western, 1979)

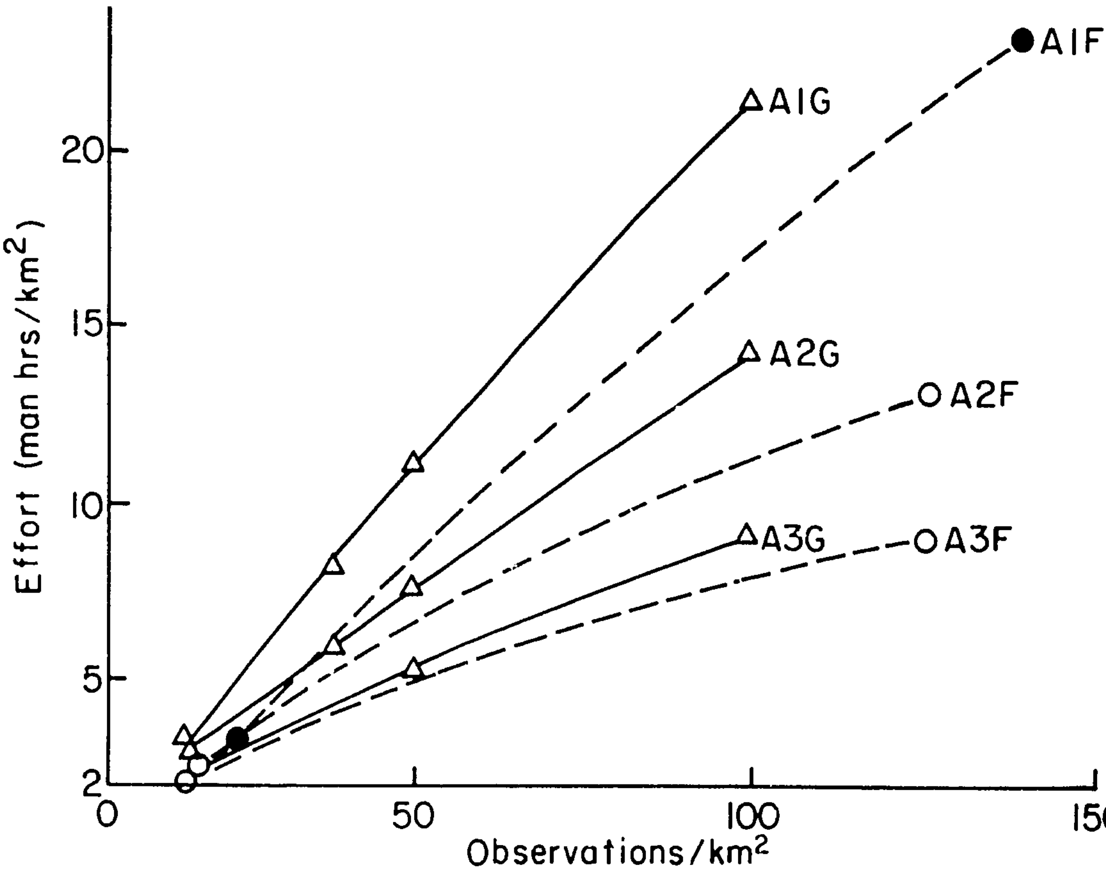


Fig. 9. The total effort required to map soil series in three areas A_1, A_2, A_3) by free survey (F) and grid survey (G) increases with observation density (after Burrough et al., 1971; reprinted by permission of Oxford Univ. Press.)

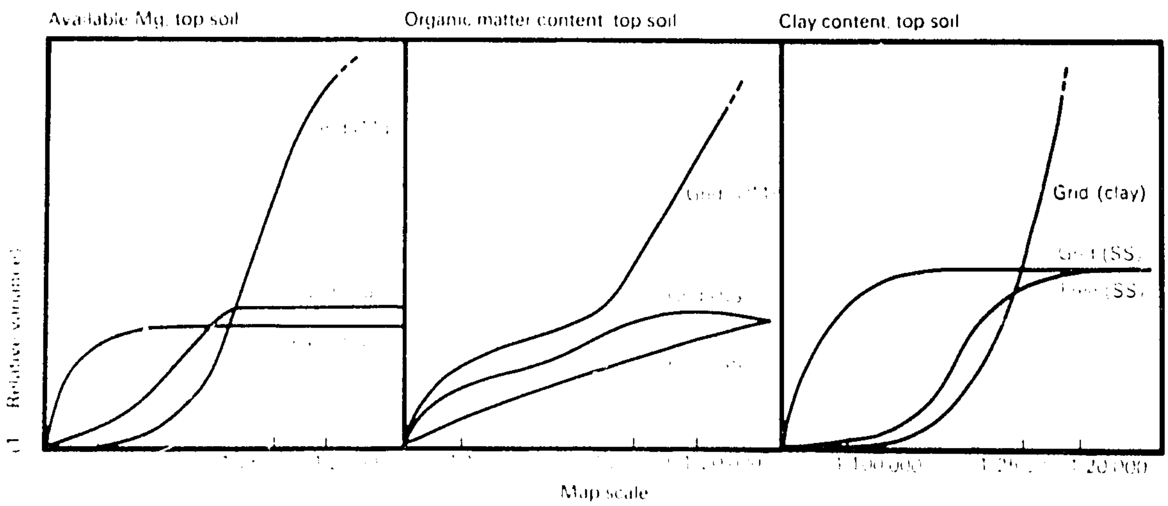


Fig. 10. Increasing the density of soil observations (for free or grid survey) and thereby increasing map scale, increases the uniformity of topsoil, Clay, Magnesium and Organic matter, within the series (SS) or between isolines on single property maps: uniformity is expressed as

$$1 - \underset{(RV)}{\text{Relative Variance}} = 1 - \frac{\text{variance of property within mapping units}}{\text{total variance of property within survey area}}$$

We may assume that the useful life of a soil survey is 25 years. On the one hand most contracted single-purpose soil surveys are part of projects which economic analysts usually assume to have a life of 40 years - which is in fact the average man's concept of eternity. On the other hand economic changes and technological advances may require other soil differentiations than those offered by the survey - it is more usual that the land capability classification becomes obsolete than the soil classification or map legend. Vink (1963) suggested that where land use and soil survey are intensive a survey may be useful for only 5-10 years, but for up to 20 years in areas of more extensive land use. Bie (1972) noted that intensive surveys of some Australian irrigation areas were still in demand after 35 years. Klingebiel's (1966) 25 years seems to be a sound average. The following discussion on benefit analysis assumes a useful life of one year only, because this makes it easier to present. The form of the analysis is not affected, and its results may be scaled up by a factor of 25-fold, with whatever sophistications of compound interest or discounted cash flow the reader likes to apply.

Before proceeding to examine the soil survey itself we must ascertain what the farmer (or the land user) is trying to do - which of the economic parameters of his situation is he trying to optimize? Figure 11 illustrates diagrammatically how the value of the yield or output per unit area from one land use (one crop, a defined rotation of crops, a housing development, etc.) in two fields depends on the values of all variable inputs per unit area (seed, fertilizer, hire of plant, managerial skill). It is not necessary to subsume all inputs into one, as here. A computer can perfectly well visualize and handle an n-dimensional response surface - of one yield and (n - 1) inputs. I have simplified this only to be able to represent it in two dimensions. In n dimensions the land user can choose for example between more managerial skill (i.e. thinking harder) or more fertilizer, and between more water (i.e. irrigation) or lower seed rate and higher phosphates, within each value of total input, but the basic manipu-

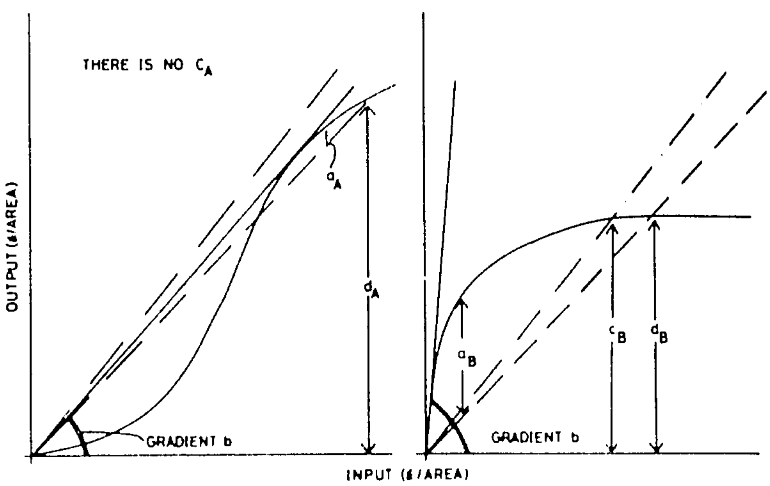
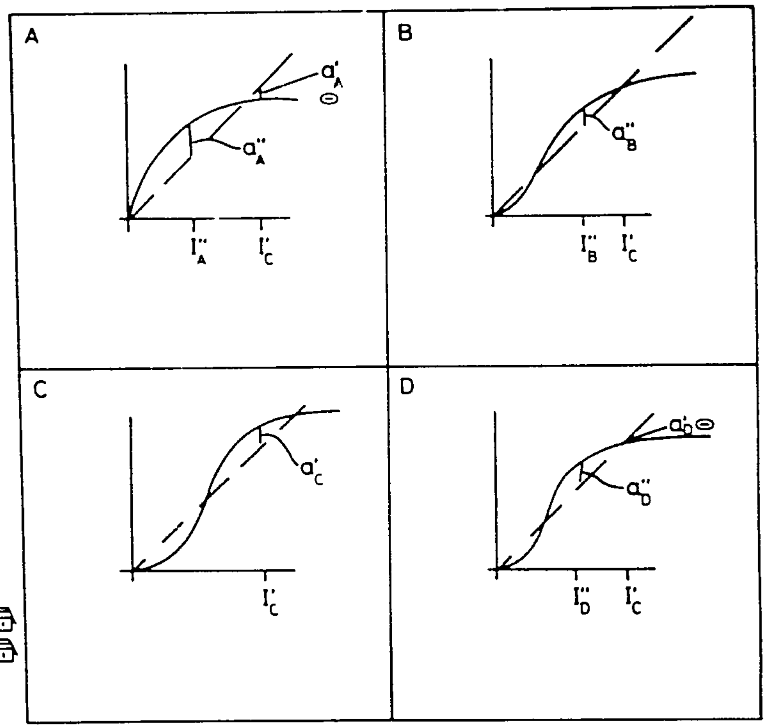


Fig. 11. Yield or output (——) from poorly developed (A) and a highly developed (B) area increases with total variable input: - - - - - = line of Output = Input; -.-.-.-.-.-.- = line of Output = Input + 5%; ___________ = tangent of steepest gradient: a = maximum profit; b = greatest return; c = maximum yield for a 5% return; d = maximum yield to break even.

lations of a complete response surface are the same as the following manipulations of a response curve. The solid lines are basic response curves typical of a poorly developed area (A) and a highly developed area (B). In effect the farmer, etc. in area B already starts some way up curve A because of the residual effects of earlier inputs. The line (--------) at gradient 45^{o} comprises all situations where the land user breaks even (output = input), and line (-.-.-.-.) represents the situation where input = output $(1 + \alpha)$, where α is a predetermined profit level. The landowner chooses his level of input to maximize profit (a), or the percentage return on his variable input (gradient b), or yield for predetermined profit (c), or yield without loss (d - this is more appropriate to governments than individuals). These four criteria are not equally wise, nor are they equally applicable to all situations. Social factors may limit the available quantities of one or more important inputs, and the traditional human factors of sloth or envy may limit an individual's input or the output he dares to be seen achieving. Also the response curves can be modified to include the effects of subsidies on a per area or per unit yield basis. There are various other criteria of success. In the following discussion it is assumed that the farmer wishes to optimize his profit (a on Figure 11). Whether he knows them explicitly as a result of research and extension work, or learns them implicitly from local tradition based on the operation of natural selection against those farmers who consistently choose non-viable options, he is aware of a set of such curves, one for each potential land use.

Now consider the simplest case in which a land user wishes to use all his land for one crop or purpose. In fact (Figure 12) there are four soils on his property, of equal area and each offering a different response survey for that crop, but their differences are subtle. So he thinks that all his property is on soil C, that one that immediately surrounds his house and barns. He applies the input appropriate to soil C (I'_C) to his whole property and his total profit is $\Sigma a' = (a'_C - a'_A - a'_D + 0)$. He is not doing very well. A soil map would have shown him the limits of the four soils A-D, and experience or an extension officer could have given the response curves for A, B and D, to enable him to optimize his inputs separately ($I''_A + I''_B$, I'_C, I''_C) to produce a greater total profit of $\Sigma a'' = (a''_A + a''_B + a'_C + a''_D)$. Clearly $(\Sigma a'' - \Sigma a')$ is the benefit attributable jointly to the soil map and to whatever research or experience produced the three new response curves, provided it could not reasonably be assumed that the farmer did not (as here), or could not have perceived the soil differences himself. There are for example considerable areas round Oxford where gravel terrace and clay loam, or sandy loam and clay loam, or calcareous shallow rendzina and acid sol lessivé, are juxtaposed. When assessing what benefit local farmers have received from the local soil map it will be reasonable to assume that they will not have overlooked such large differences.

Not only will there be different response curves for every land use on one soil, but the differences between crops will be different on different soils (Figure 13). The land user has to choose. He may still do well with a single land use, but in this case better with crop C2 than C1 (as in Figure 12). But he may do better by mixing crops, for example C2 on soil A, C3 on soils B and C, C4 on soil D. Again, the value of the soil map is estimated from the maximum profit the land user can make when he uses it as a framework to optimize such choices compared with his maximum profit without it. There may of course be other constraints: soil erosion control may require



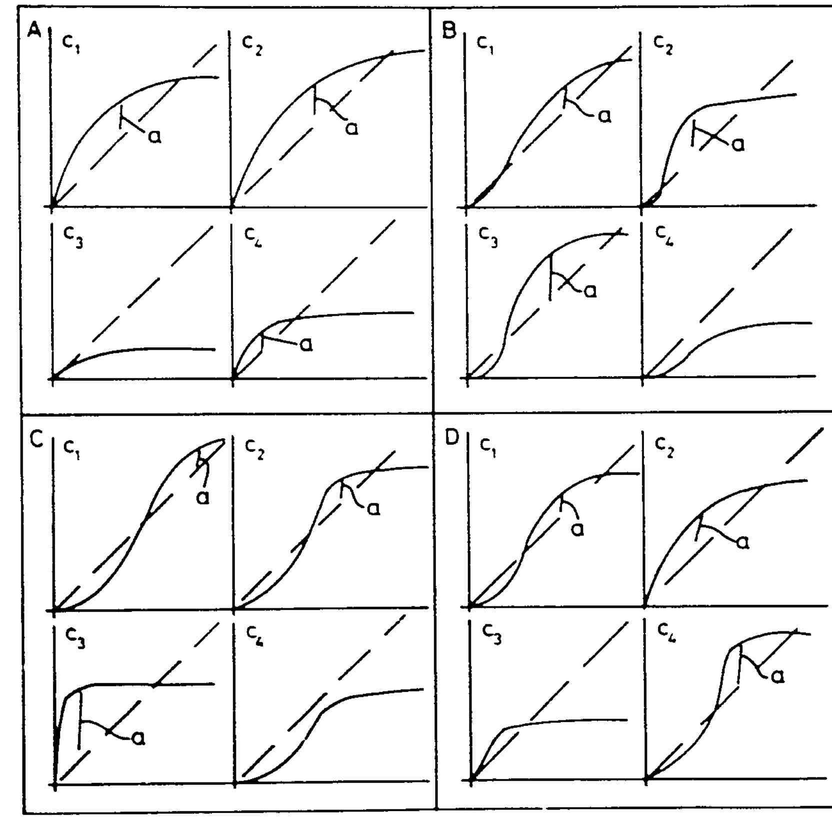


Fig. 12. A farm on four soils A–D of equal area, with substantially different response curves for crop 1. In the first case the farmer assumed all his farm lies on soil C and applied to all soils the optimum input (I'_C) for soil C. In the second case he recognized the existence of four soils and applied to each soil the input that would maximize his profit (I''_A, I''_B, I'_C, I''_D). - - - - - - are lines of output = input.

Fig. 13. Four crops (c1 is the crop in Fig. 12) show very different response curves on the four soils on the farm of Fig. 12; the farmer will achieve maximum profit for very different inputs.

that C1 not be grown except in rotation with C2 or C3, or C3 may occupy the land for 18 months, while only C4 occupies it for as little as six, so that C3 and C4 have to alternate, and so on. Nevertheless, my point stands - the benefit from a soil map is the extent to which the land user can increase his profit (or any of the other criteria of success mentioned above) by including in his decision-making the information that only the soil map and its supporting memoir can provide, either directly as in these examples, or indirectly by enabling extension officers to increase the precision and relevance of their research and advice.

This leads us to a further point. In practice the form of the response curve (or of the response surface it attempts to represent in two dimensions) for each land use on each soil depends on the values of a number of soil properties (the "relevant" properties above), none of which are wholly uniform over any of soils A-D. If the response curve of crop C1 on soil A were determined at 100 locations chosen to typify all delineations of soil A, the trials would produce a bundle of curves within an envelope (Figure 14), of which the breadth increases with the range of the values of the relevant soil properties within soil A, and hence with the breadth of the soil class and probably with the percentage of impurities in its mapping unit. The land user has to base his decisions on an assumed mean or median line (-------- in Figure 14), which leads him to input I. If the distribution of response curves about any point on the median is normal, then the outputs from input I on soil A will show the range described by the histogram; outputs above the "break-even line" represent profits and those below it represent losses. The total profit from input I to all delineations of soil A is then (≡) - (||||||||). Had the land user used a single response curve, but based on trials on an untypical site (e.g. -.-.-.-. or .... on Figure 14) the same train of deduction would demonstrate negative or much smaller profits. Not only then is there a benefit from separating dissimilar soils, but the benefit will usually increase in proportion as the soil classes created show narrower ranges in their relevant properties.

Assume that the farmer chooses the combination of crop and management for each mapping unit that will give maximum profit on its dominant soil class. This management is likely to be suboptimal for any 'impurities,' or inliers of minority soil classes. Thus the total profit for the whole survey area will be less than optimal to the extent that simple mapping units contain impurities. Bie and Ulph (1972) explored the effect of mapping soils to greater purity on the cost-benefits of the survey.

Consider a landscape that contains five sub-areas (I-V), each occupied by two soil classes (S_1; S_2: S_3; S_4: etc.). There are twelve possible land use options (A-M). Their profits on the ten soils (Table 5) are plotted in Figure 15.

It seems unlikely that soil survey will be of much benefit in any landscape for which the land use options are represented by o on Figure 15, since these combinations show nearly the same profit on all the soils that a soil survey might separate. Even if he knew the limits of each soil the farmer would not be able to increase his return.

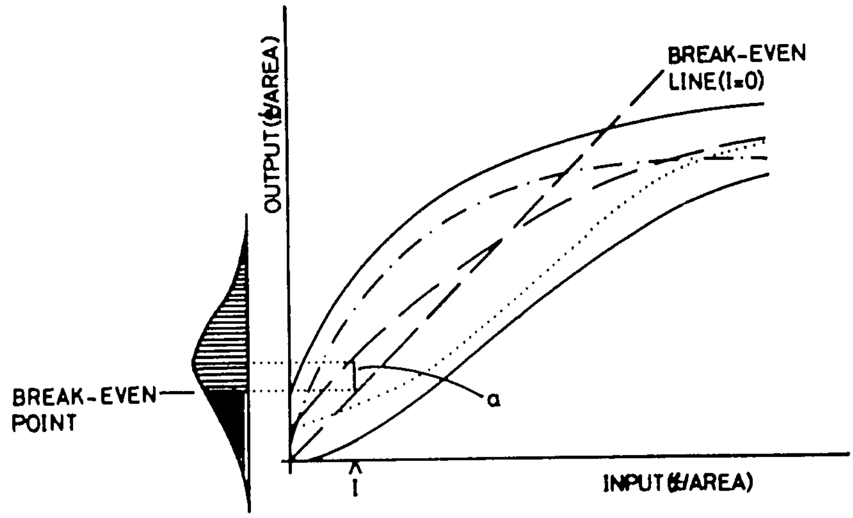


Fig. 14. The response curve of one crop has been determined at 100 different sites on one soil class. The two outermost lines enclose all the results, and - - - - - is the medium response curve. On this basis the maximum profit (a) would be achieved with input I. The histogram illustrates the proportions of different outputs from the different delineations of the soil from a uniform input I; the area of it below the break-even point represents profit. Had the histogram been unsymmetrical, or had the farmer based his decision on a non-typical curve, his profit might well have been less.

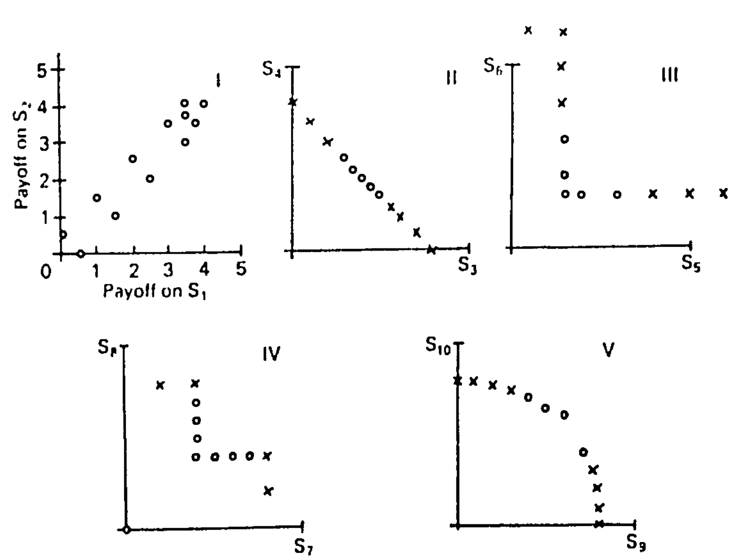


Fig. 15. The payoffs (arbitrary units) from 12 land use options on the two soils present in each of five sub-areas in one landscape (see Table 5). (Bie, Ulph and Beckett, 1973; reprinted by permission of Oxford Univ. Press.)

Table 5. The profits for twelve combinations of land use and management (A-M) on the two profile classes in each of five sub-areas.

		I		*II*		*III*		*IV*		*V*	
		S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}
Area		0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·5	0·5
Purity of soils as mapped so far		0·7	0·5	0·7	0·5	0·7	0·5	0·7	0·5	0·7	0·5
Payoff under managements A–M (arbitrary units)	A	0	0·5	0	4	1·5	1·5	2	2	3·95	0·5
	B	1	1·5	0·5	3·5	2	1·5	2·5	2	3·9	1
	C	2	2·5	1	3	3	1·5	3	2	1·5	3·75
	D	3	3·5	1·5	2·5	4	1·5	3·5	2	0	4
	E	0·5	0	2	2	5	1·5	4	2	2	3·5
	F	1·5	1	2·5	1·5	6	1·5	2	2·5	3	3
	G	2·5	2	3	1	1·5	2	2	3	3·5	2
	H	3·5	3	3·5	0·5	1·5	3	2	3·5	4	0
	J	4	4	4	0	1·5	4	2	4	2·5	3·25
	K	3·5	3·75	1·75	2·25	1·5	5	1	4	3·75	1·5
	L	3·75	3·5	2·25	1·75	1·5	6	4	1	1	3·9
	M	3·5	4	2·75	1·25	0·5	6	0	0	0·5	3·95

(Total area = 5)
(Weighted mean = 0·6)

Table 6. Gross return (in A$ per acre) for three varieties of peaches.

Soil type	*Proportion of area*	*Golden Queen Cling*	*Phillip Cling*	*Pullar Cling*
1	0·028	1367	1293	1237
2	0·004	1128	958	1543
3	0·038	1427	1293	1696
4	0·056	1207	498	919
5	0·046	1082	1073	824
6	0·009	820	843	306
7	0·069	923	862	848
8	0·046	900	690	848
9	0·028	661	709	542
10	0·017	1036	891	1154
11	0·048	66[illegible]	354	236
12	0·186	7[illegible]9	498	589
13	0·103	7[illegible]8	661	954
14	0·099	5[illegible]	584	565
15	0·038	615	335	94
16	0·105	410	402	283
17	0·027	433	364	0
18	0·055	353	421	59

From Bie and Ulph, 1972.

Conversely he may derive considerable benefit from soil maps of any landscape where the land use options are represented by x. In these landscapes the farmer will achieve less than optimal return by using any part of either of his soils for the group of uses which give small returns, and will therefore benefit from information which indicates more exactly the limits of each soil.

An existing soil map of the area shows that each sub-area contains two simple mapping units of equal area but of purities 70 and 50 percent respectively (Table 5). The procedure of Bie and Ulph (1972) was used to calculate the maximum farmer's profit if the whole area, or each sub-area separately, were re-surveyed:

(a) to raise the minimum purity for each mapping unit in steps from 50 to 90 percent;

(b) to raise the weighted average purity of the mapping units in each sub-area in steps from 60 to 90 percent.

As shown in Figure 15, the economic impact of suboptimal management practices are greatest in sub-areas II and III, so that detailed soil surveys of these sub-areas will be the most profitable. All land uses yield similar profits in sub-area I, so there will be insignificant benefits. According to how the purity to be achieved depends on the cost of the survey, it might be profitable to survey sub-areas II and III to higher purity than areas IV and V.

The procedure has been applied (Bie, Ulph and Beckett, 1973) to peach-growing in the Uanco (NSW) area in Australia, for which economic data (Table 6) is available for the three main varieties of Cling peaches on each of 18 soils. The analysis assumes that the impurities in each mapping unit were in proportion to their occurrence in the landscape as a whole. It also assumes that optimum input is independent of variety of soil, so that gross return is proportional to profit.

Figure 17 indicates how the gross returns would increase (over and above the $757/acre achieved if Golden Queen Cling was grown on every soil) as the purity of each mapping unit is raised from 20 to 90 percent. In this case the graph is nearly linear for purities between 50 and 90 percent. There must be a ceiling imposed by the farmers' inability or unwillingness to plant single trees on small inliers of different soils.

Similar calculations can be performed on the yield data in many survey reports, provided only that the relevant unit costs for input and output can be obtained. Approximate estimates of the benefits from soil survey to various purities may be based on soil data obtained during the presurvey reconnaissance and on agronomic data obtained from economic surveys and extension officers' local knowledge.

COST-BENEFIT RATIOS

The general form of the relationship between the cost of a soil survey and its precision or the uniformity of relevant soil properties within its mapping units is known (Figure 18): it represents the Law of Diminishing

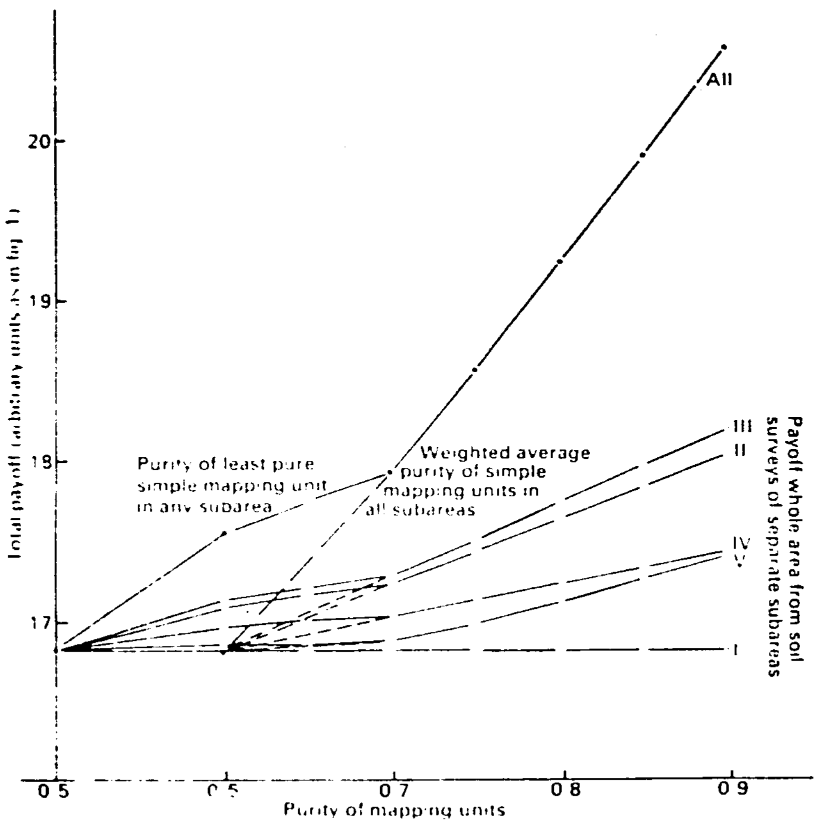


Fig. 16. The increased payoff (arbitrary units) results from the more exact matching of land uses A-M (Table 5) to soil class that may be attained as the "purity" of soil mapping units is increased by more detailed survey. There are two soils in each area, of which one was already mapped to 70% purity and the other to 50% purity: the areas may be resurveyed to bring the purity of the latter up to the level of the former, or to increase the average purity from its initial value of 60% (Bie, Ulph and Beckett, 1973; reprinted by permission of Oxford Univ. Press).

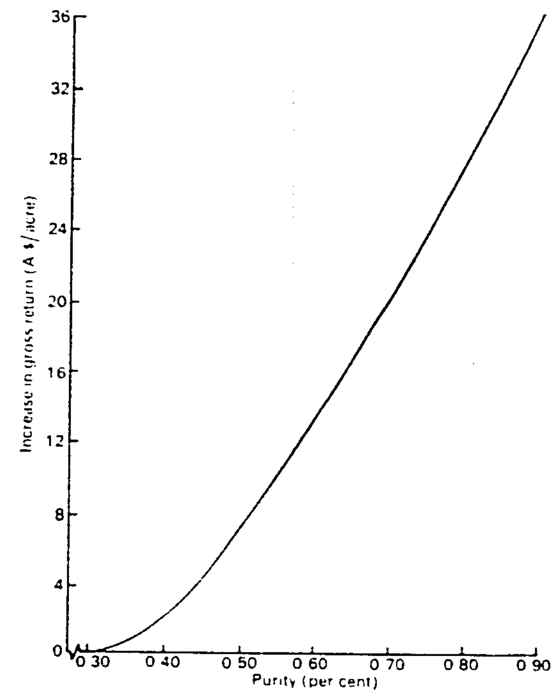


Fig. 17. The calculated increase in gross returns (A$ per acre) as increasingly detailed soil survey enables farmers to adjust peach variety to soil type more precisely (Bie, Ulph and Beckett, 1973; reprinted by permission of Oxford Univ. Press).

Returns. Clearly the cost-benefit ratio (Figure 18) is very sensitive to the form of the profit-precision relationship and the general form of this relationship is less well known. Figure 18 assumes that it is of the same form as Figure 17. The relative magnitude of the units on the cost and payoff aces are not certain, and the land user will not take notice of discrepant areas of less than some critical size, but none of these uncertainties present inseparable problems.

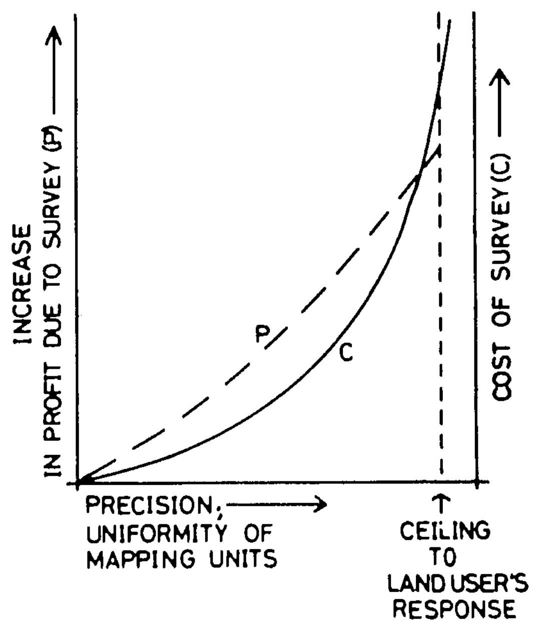


Fig. 18. The uniformity of "relevant" soil properties within mapping units increases with survey cost: the benefit from the survey increases with the uniformity of its units. Unfortunately the forms of the two curves are not known for the same survey.

ACKNOWLEDGEMENTS

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QUESTIONS/COMMENTS (by H. Eswaran):

1. In the graph on effort vs cost, I expected a greater divergence.

2. If we go to scales smaller than 1:100,000 will the two lines intersect?

ANSWERS:

(1) There just is not enough data to know what is normal. It would be interesting and useful to persuade a few surveyors making a contrast in landscapes to record their votes of working in terms of e.g. travel to and from home, mapping, interruptions (lunch, weather, talking to bystanders)

(2) Could be - not sure.

QUESTIONS/COMMENTS (by T. R. Forbes):

Do you have any ideas on how limits of properties etc. for taxonomic classes such as series should be defined?

ANSWERS:

In most taxonomic systems the classes are defined, and identified, on permitted ranges of some soil properties, so these present no problem. However, many such properties are of limited practical value and some of them (e.g. number of months saturation) are the sort of information that it was hoped the soil map would provide. The problem arises when we consider those properties that earlier speakers have shown to be important to various crops. These properties often show poor correlation to the definitive properties of conventional soil data.

I am not sure how to proceed. At the phase level it is possible to subdivide series to produce taxa with limited ranges of useful soil properties. It will be better to match local series to local management problems, and not worry too much about high level correlation. B. E. Butler has proposed the "taxonomic hiatus" as an essential part of any practical system of soil classification!

QUESTIONS/COMMENTS (by A. Van Wambeke):

Is there any definition of Soil Series in the UK? Is it a taxonomic unit?

ANSWERS:

The series is a taxonomic unit; also a simple mapping unit dominated by one series taxon is named for that unit, so the series name becomes attached to a map unit.

I am not aware of any studies, except a few sets of measurements made after surveys were completed, to establish the range of useful soil properties within series data or series map units.

QUESTIONS/COMMENTS (by R. L. Tinsley):

The paper implies that the production functions are static when in reality they are dynamic depending on climatic variability and to a lesser degree changes in cost of inputs and outputs. How is this taken into account? Is it reasonable to work on a level smaller than soil series? I would think normal climatic variability between years would be of a magnitude that would make production functions of units less than a series level unreliable.

ANSWERS:

Surely the problems of climatic variability, like changes in unit input and output costs, are already taken care of by economists making similar calculations.

I assume that it will not be necessary or reasonable to consider very narrow taxonomic units. However, the purpose of the model was to demonstrate how to decide at what level to map and classify soils. If it is not possible to demonstrate meaningfully different production problems for two definable combinations of soil and climates, are they really sufficiently different to be worth separating at all?

QUESTIONS/COMMENTS (by Gordon C. Thomasson):

I question the assumption that "farmers seek to maximize profits" as stated. Many LDC's reported per capita incomes appear to be low and are in fact skewed by the fact that most small farmers/rural dwellers exist outside a cash economy. Money is only one possible measure of benefit. Preserving the "health" of their land, subsistence/security, minimization of risk, religious opportunities, free time may all be more important.

If alternatives are fully presented (vagaries of international markets, etc.) few traditional farmers are willing to cash crop unless and until their own food supply is insured. Countries would do well to follow their example.

Neo-classical framework of paper's economic analysis ignores problems raised and in large part answered by dependency theory.

Others in workshop noted problems in cost-benefit analysis due to dynamic nature of market inputs (especially petrochemicals). This problem highlights how soil survey benefits should be assessed and represented to planners in terms that take into account the "social costs," etc.

Few traditional or small farmers are incapable of distinguishing their soils and potentials.

Most soil survey information is useful only if a change in crop, technology, etc. obsoletes their traditional methods.

Simple cost-benefit analysis is a questionable measure. If, instead, local farmers are involved as informed participants in the planning/ development process more valid measures of the value of soil survey efforts for the individual case will become apparent. Perhaps the problem is precisely trying to create a single calculus to apply to what are not really comparable phenomena. Do these measures, in other words, fit every case, or are they instead a procrust bed, doing violence to those agricultural systems that do not fit precisely?

ANSWERS:

Clearly there are many soil survey projects which are not part of a project that is likely to alter the way of life of the peasant attitudes. In such cases it may not be appropriate to perform a strictly economic cost-benefit analysis. However there are many unit surv... that form part of major projects from which many different kinds of returns are expected. In such cases it may be unsuited to try to identify all benefits in the same units. The dangers of such procedures, the possibility that the result may be misused, are well known.

Finally, there is some benefit to the survey organizer if he is at least aware of the form of the calculations by which the nature of his work would be utilized. Whether or not the education is done, it sharpens his perceptions of what is involved.

QUESTIONS/COMMENTS (by W. Fuglie):

How do we get response curves (agro-economic information) for LDC situations?

ANSWERS:

There has been some very interesting work recently in Latin America and at Rothamsted (UK), on the extent to which the curvilinear production function may be approximated by 3 straight lines. The determination of this requires only limited experimentation, to estimate: a) minimum input to produce appreciable yield; b) minimum input to produce output that is not significantly less than the maximum attainable.

QUESTIONS/COMMENTS (by Gordon C. Thomasson):

I feel your paper would be much stronger if you distinguish the types of analysis you are doing. The one type, cost effectiveness of soil surveys, compares cost to data-output (i.e. Figs 2, 10, etc). This information is highly useful and virtually indisputable. The demonstration of points of diminishing return to research/survey inputs is relevant to every soil survey. The other type of analysis, "cost-benefit," is much less reliable because the number of variables (socio/cultural, political, etc.) that are excluded in this type of calculation makes the results achieved questionable at best. I hope much more effort can be put into recognizing the effective minimum research inputs that are needed, based on cost effectiveness. The other predictors of benefit will, I suspect, have no more effect than the constant output of national economic predictions that are often mutually contradictory.

ANSWERS:

Agreed.

EVALUATION OF RICE LANDS IN MID-COUNTRY KANDY DISTRICT, SRI LANKA

A Case Study of SRI in a Complex Region, with Limited Resources

S. Somasiri, R. L. Tinsley, C. R. Panabokke and F. R. Moorman[1]

Rice is the preferred staple food for all ethnic and cultural groups constituting the people of Sri Lanka. Providing sufficient rice for the population is a national concern. During the British colonial period Sri Lanka's economy was regulated to produce the export plantation crops of tea, rubber, coconuts and spices while the staple foods were imported. After independence the Department of Agriculture began a long-term effort to produce a self-sufficient amount of rice, while maintaining the export-oriented plantation sector of the economy. This effort continues to be the major concern of the Department of Agriculture, aimed at assisting the multitude of small farmers to obtain a better way of life while fulfilling the national production needs. An essential part of the effort is understanding the diverse physical conditions under which rice is produced so that proper technology can be applied for each individual environment.

For a small country, rice is produced under an exceptionally wide range of physical conditions. The country comprises one main pear-shaped island with a mountain hub in the broad southern part and is divided into three geographic elevation regions (Figure 1) that largely correspond to the three peneplains formed by telescopic block uplift during the geological history of the island. The upper two peneplains have since become strongly dissected. These geographic regions are:

- Low-country : below 300 meters
- Mid-country : between 300 and 1000 meters
- Up-country : above 1000 meters

The mountain hub interacts with the Northeast and Southwest monsoon air mass circulation to give the island a basic bi-modal rainfall distribution. This divides the year into two rainy seasons, Maha from October to January corresponding to the Northeast monsoon and Yala from April to August corresponding to the Southwest monsoons. The variation in the amount of these rains partition the country into three broad zones of wetness, referred to as Dry Zone, Intermediate Zone and Wet Zone.

Each rainfall zone is again subdivided into additional units. The various rainfall distribution sub-zones permutated across the appropriate geographic elevation regions have been demarcated on the national map to provide 24 agro-ecological regions (Land and Water Use Division, Department of Agriculture, 1979) in which the physical environment is sufficiently

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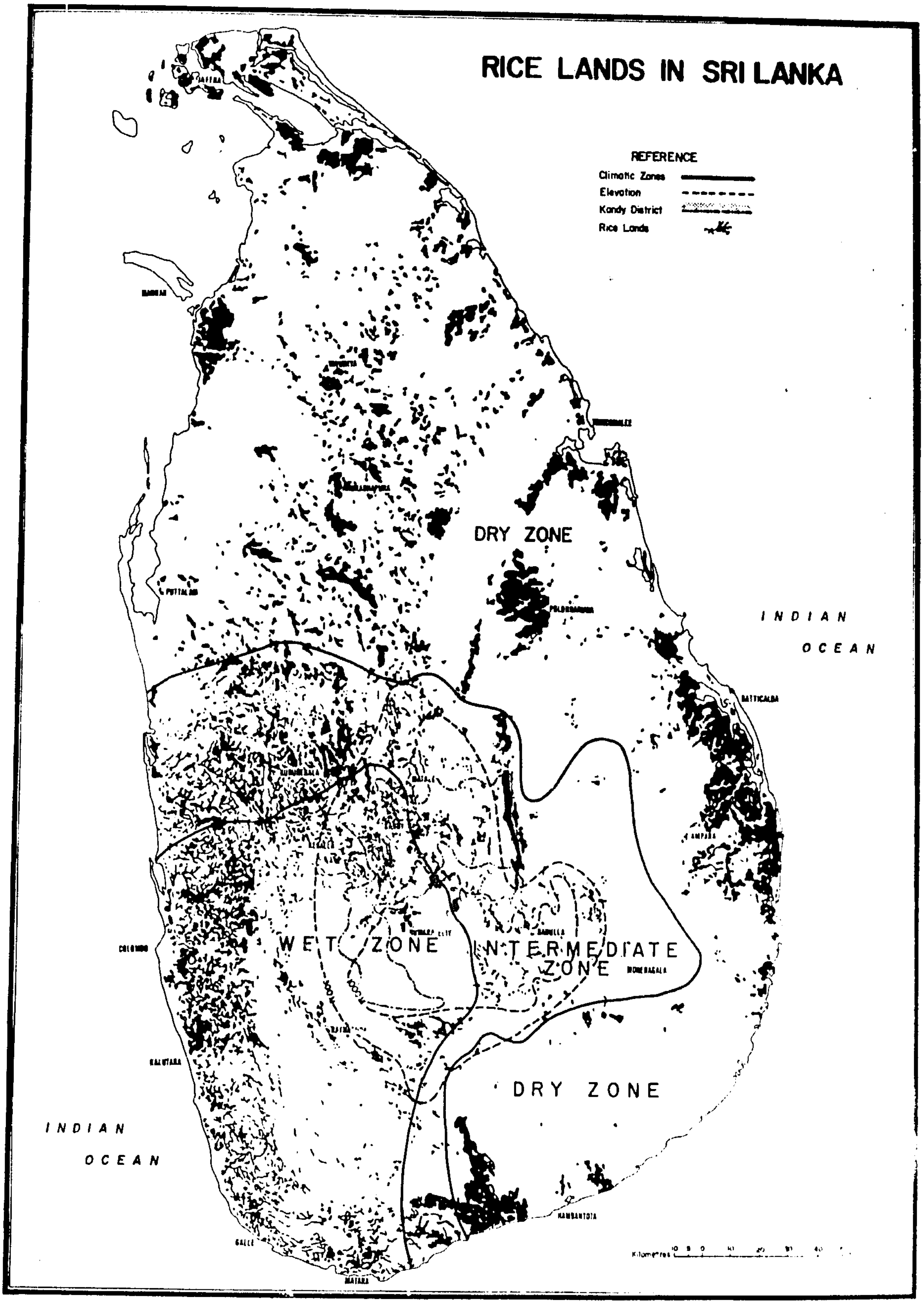

Fig. 1. Rice Lands in Sri Lanka - Distribution in relation to climatic zones.

different to have a major impact on both annual and perennial cropping. Most of these agro-ecological regions are clustered around the mountain hub.

Except for the very high elevations where temperatures are too cool, rice is grown in virtually all these agro-ecological regions. Most of the rice lands are in the low-country dry zone, where they are supported by tank irrigation schemes of various sizes. The rice lands are almost always relatively narrow tracts in the lowest portions of the landscape (Figure 1), and not the extensive alluvial plains generally used for rice through most of Asia, the exception being the few large irrigation schemes which provide sufficient water to blanket the area under command.

PREVIOUS SOIL RESOURCE STUDIES

Soil studies in Sri Lanka including rice land soils have been conducted and published over the last thirty years. Most of the early work was confined to the mineral soils in the low-country wet zone. Ponnamperuma (1959) applied the Kanno classification system with certain modifications in a survey of mineral soils in the low-country wet zone. Panabokke and Nagarajah (1964) reported on the fertility characteristics of rice soils throughout the country. Kawaguchi and Kyuma (1977) conducted a detailed study of 35 soils representing the more important rice-growing conditions in Sri Lanka.

Systematic soils survey work was initiated in 1960. Subsequently a soil map of Sri Lanka was compiled showing the aerial distribution of the great soil groups and associations. This was printed by the Survey Department for which a supporting text was prepared by de Alwis and Panabokke (1972). This concentrated largely on the upland soils considering the rice land soils as the hydromorphic variant of the more well-drained soils. In the more level low country this was expressed as the poorly drained members of general soil catenas, while in the more rugged mid-country and up-country the rice lands were generalized as homogeneous local alluvium or colluvium. Desaunttes et al. (1974) applied the land system approach to study the wet zone for diversification of uneconomic tea and rubber lands. Again the rice lands were dismissed as simply "mini-plains." The development of major irrigation schemes for large sections of the dry zone required high and medium surveys of the irrigated areas. This provided a basic knowledge of soils and landscape relationships in the dry zone and thus the couuntry's most important rice lands.

Panabokke (1978) presented a general description and categorization of all rice lands in Sri Lanka including both low-country and mid-country. Besides indicating the need to understand how the systematic variation in the "mini-plains" and "local alluvium" of the mid-country rice lands was affecting rice production, this also broadly discussed the general relationship between the landscape and the hydrology of the narrow valleys of the mid-country in as far as this influenced the land qualities. The program was started in the mid-country portion of Kandy district where the general rugged terrain creates a highly complex physical situation and curtails the possibility of major capital development projects for the rice lands. This in turn restricts the cost/benefit ratio for a land evaluation study. The budget was therefore limited and forced some basic modification from typical Soil Resources Inventory (SRI) studies.

RICE LANDS IN KANDY DISTRICTS

Most of Kandy district (Figure 1) is in the mid-country surrounding the last pre-colonial capital of Kandy. This is approximately 110 km east of Colombo, at an elevation of 500 meters. The Kandy-Peradeniya area is the headquarters for the most technical agricultural services of the country. This includes the Faculty of Agriculture, Headquarters of the Department of Agriculture, Central Agricultural Research Institute and Botanical Gardens. There are approximately 20,000 ha of rice lands in Kandy district. These lands are largely found in small inland valleys nestled into the general mountainous area or on terraced mountain slopes. These two general types of rice lands correspond closely to the two geomorphic subdivisions of the middle peneplain. The inland valleys occur on the Kandy plateau portions and the terraced mountain slopes on the transition regions from the low-country to the mid-country, and from the mid-country to the up-country. A high percentage of the rice grown remains the indigenous varieties. When improved varieties were introduced in the district they grew poorly and in a patchy manner over large portions of the rice lands, indicating severe stress symptoms of various kinds. This focussed attention on the natural variability that was occurring in what was previously thought to be homogeneous lands and the need to determine the cause and predictability of problem areas in the landscape.

METHODOLOGY

The effort was essentially a single-purpose study focussed on wet rice culture. The determinants evaluated were those specific for paddy rice and concentrated on understanding the hydrological conditions of the different land units. However, hydrological conditions strongly interact with the entire landscape so that evaluating the rice lands requires understanding the adjacent uplands as well.

The method used for the study was a modification of Christian and Stewart's (1953) Australian "land system" approach, a land system being a physical area of uniform climate over which soils hydrology and land use occur in a predictable pattern. In this case the basic land units were identified on 1:63,360 (1 inch per mile) topographic maps in which the rice lands had been distinctly printed in green (Figure 2). The recurring patterns of rice lands are clearly apparent and readily allowed demarcation of basic land systems. The pattern of paddies on the topographic maps were then related to the five agro-ecological regions found in Kandy district (Figures 2 and 3). More detail on individual tracts was obtained from aerial photographs of 1:5000 enlargement from contact prints of 1:40,000 or 1:20,000. Subsequently field visits to several tracts in each system were made for final evaluation and determining subdivisions of tracts and how these subdivisions fitted into the general landscape. The end result of the study was a four-tiered scheme of rice land classification with increasing specificity for successive categories (Table 1).

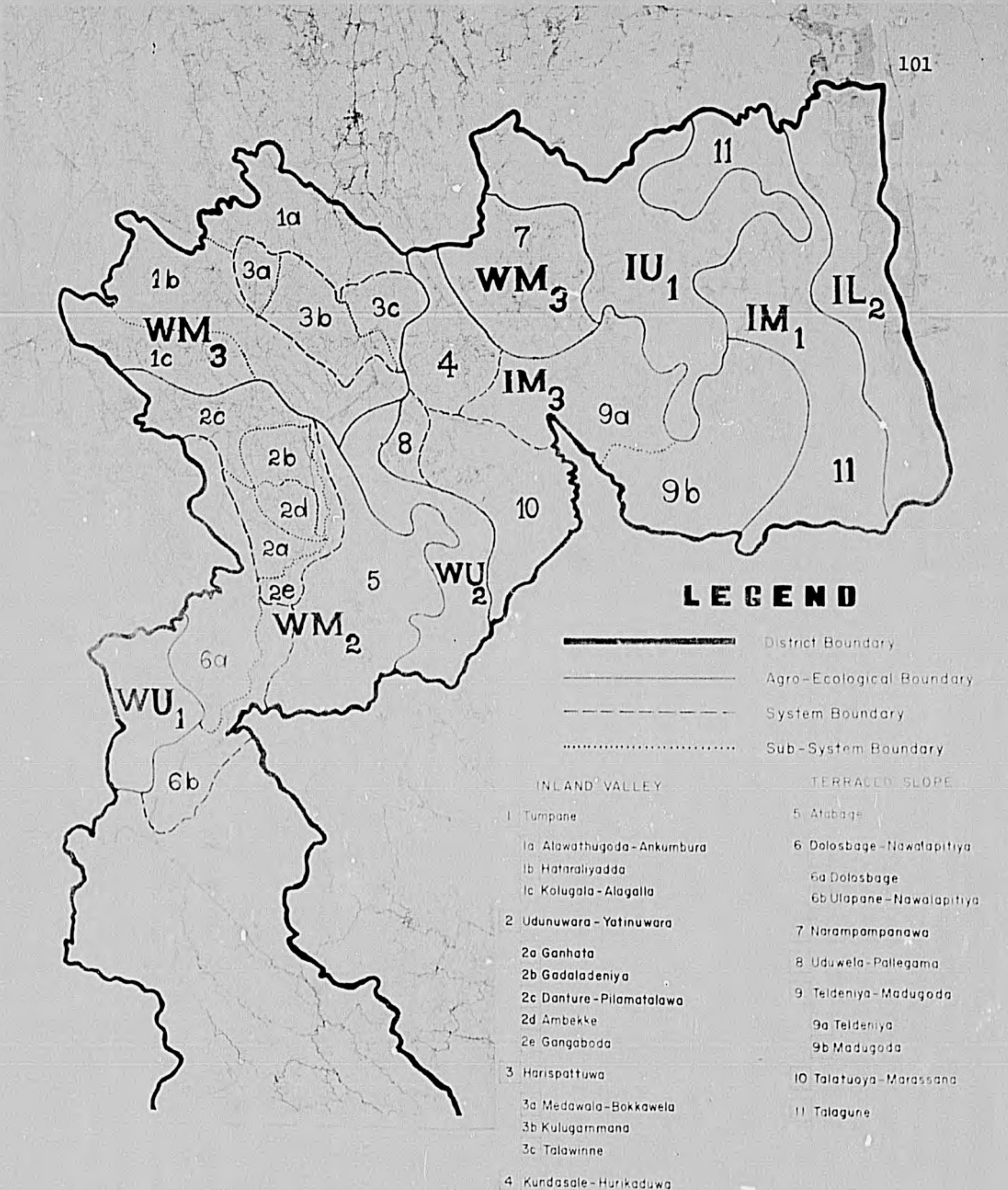

Fig. 2. Land Systems and Sub-systems in different agro-ecological regions of Kandy district as seen against the topographic map with original scale at 1:63,360 and rice land printed in green.

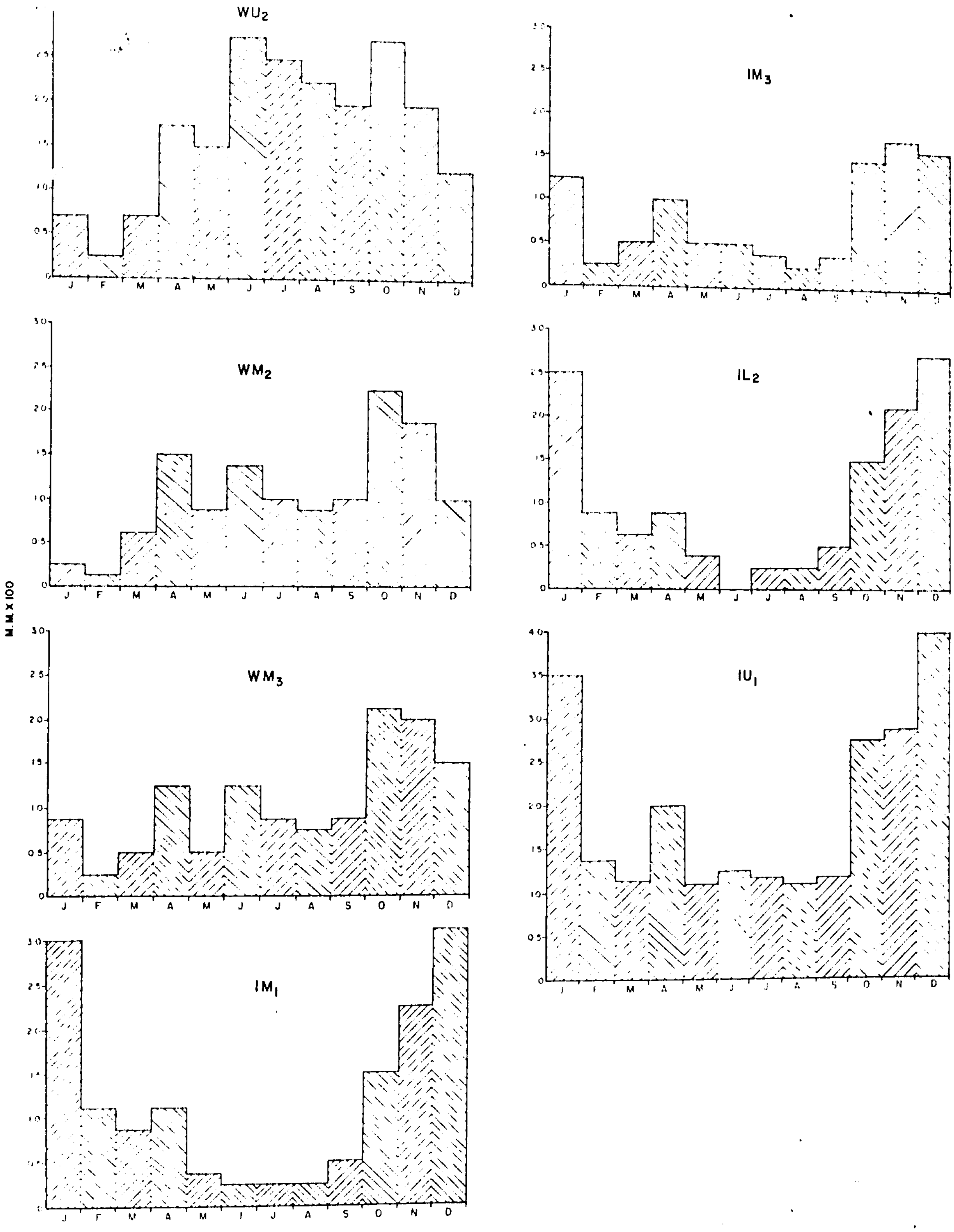

Fig. 3. Rainfall distribution patterns at 75% expectancy for agro-ecological regions in Kandy district.

Table 1. Rice land classification scheme.

Land Category			Determinants/Components
I.	SYSTEMS	...	Relief, Agro-Climate
II.	SUB-SYSTEMS	...	Hydrology, Micro-relief Paddy/Upland Ratio Upland Soils Parent Material
III.	RICE LAND COMPLEX		Individual Tracts - Inland Valleys - Terraced Slopes
IV.	RICE LAND ELEMENTS		Inland Valleys - Valley Head - Valley Sides - Valley Bottom with Incised Drain - Valley Bottom without Incised Drain - Confluence Terraced Slopes - Concave Slope - Concave Contour - Straight Slope - Convex Slope - Convex Contour - Ridge Crest

As the study progressed it became rapidly apparent that the depth of detail required to accurately delineate the subdivisions needed for adjusting production management in a normal SRI mapping would require a scale of 1:2,000 or 1:5,000. The cost of this would be prohibitive on a developing country's operational budget. At the same time it was noticed that many sub-units were recurring in an orderly manner within the general landscape of the individual tracts within the different systems. This allowed the study to avoid the costly, and what would have been a highly repetitive, effort of mapping each and every tract and concentrate on the economically easier approach of developing modal tracts for the different land systems. The various modal tracts were drawn illustrating how the various subdivisions' "land elements" systematically fit the landscape and how they would be easily identified by various simple techniques such as changes in size and shape of individual paddies, various degrees of wetness, physical strength of the soil, condition of the rice, etc. The modal tract illustrations were then used in field day presentations to agricultural specialists from both research and extension divisions. From this it was hoped that extension personnel could review similar tracts within the system, recognize the different land elements and assist the farmers in adjusting their management practices. Likewise it was hoped that research personnel would get a sufficient understanding of the problems to develop technology suitable for individual land elements in which adversities occur.

KANDY DISTRICT RICE LAND CLASSIFICATION SCHEME

The four categories in the rice land classification scheme are the "land system," "land sub-system," "rice land complex" and "rice land element" (Table 1).

Land System

This is the highest category. The land systems are first demarcated on the basis of agro-ecological regions. Rice lands in the mid-country part of Kandy district are found in five of the 24 agro-ecological regions of the country. These include WM_1, and WM_2 and WM_3 of wet zone, and IM_1 and IM_3 of the intermediate zone (Figure 3). Within the agro-ecological regions the land systems were demarcated according to recurring relief patterns in terms of height and width from crest to trough in the landscape. Eleven land systems were identified in this manner. Five of the eleven land systems are subdivided at the next lower category.

Land Sub-system

This is the second category. The land sub-systems are demarcated by the determinants of the micro-environment. This includes (1) upland soils and their parent material, (2) ratio of rice to non-rice lands, (3) surface drainage patterns, (4) hydrology, (5) soil drainage, and (6) natural nutrient status. The six land systems that were not divided into sub-systems were uniform in these micro-environment determinants.

The characterization at the sub-systems level resulted in 21 land units. These were the limit of what could reasonably be mapped as distinct units. All the land systems and sub-systems were named after places, villages or regions well-known locally.

Rice Land Complex

This third category simply recognizes a contiguous tract of rice lands within a sub-system. They are generally lower order valleys or tracts of terraced slopes.

Rice Land Elements

This lowest category of the classification scheme recognizes sub-division of rice land complexes with sufficiently constant land qualities for uniform management over the entire element. For the most part, the different land elements define areas of different hydrological conditions within the complex. This separates areas of relative natural moisture enrichment from areas of relative moisture depletion, the extreme case of moisture enrichment being the artesian upwelling condition that is usually accompanied by severe stress problems in the rice.

In the inland valley complexes (Figure 4) rice land elements correspond to:

Valley heads
Valley sides
Valley floor with incised drainage
Valley floor without incised drainage
Confluences of valleys, etc.

In the hill and mountain terrace complexes (Figure 5) the rice land elements correspond to:

Concave contours
Convex contours
Straight slopes
Concave slopes
Convex slopes
Ridge crest, etc.

Generally in any given complex the number of land elements is limited to four or five. The same type of land element will reappear in similar complexes of different systems or sub-systems but assumes different agronomic values reflecting the changes in land qualities between different sub-systems and agro-ecological regions. For example, a valley side in a wet sub-system will be best suited for double cropping rice while the same element in a dryer sub-system will be suited for an upland rice cropping pattern.

LAND SYSTEMS AND LAND SUB-SYSTEMS IN KANDY DISTRICT

The individual land systems and land sub-systems in Kandy district are reviewed taking the systems with rice lands predominantly in inland valleys first, followed by those systems where rice lands are predominantly in

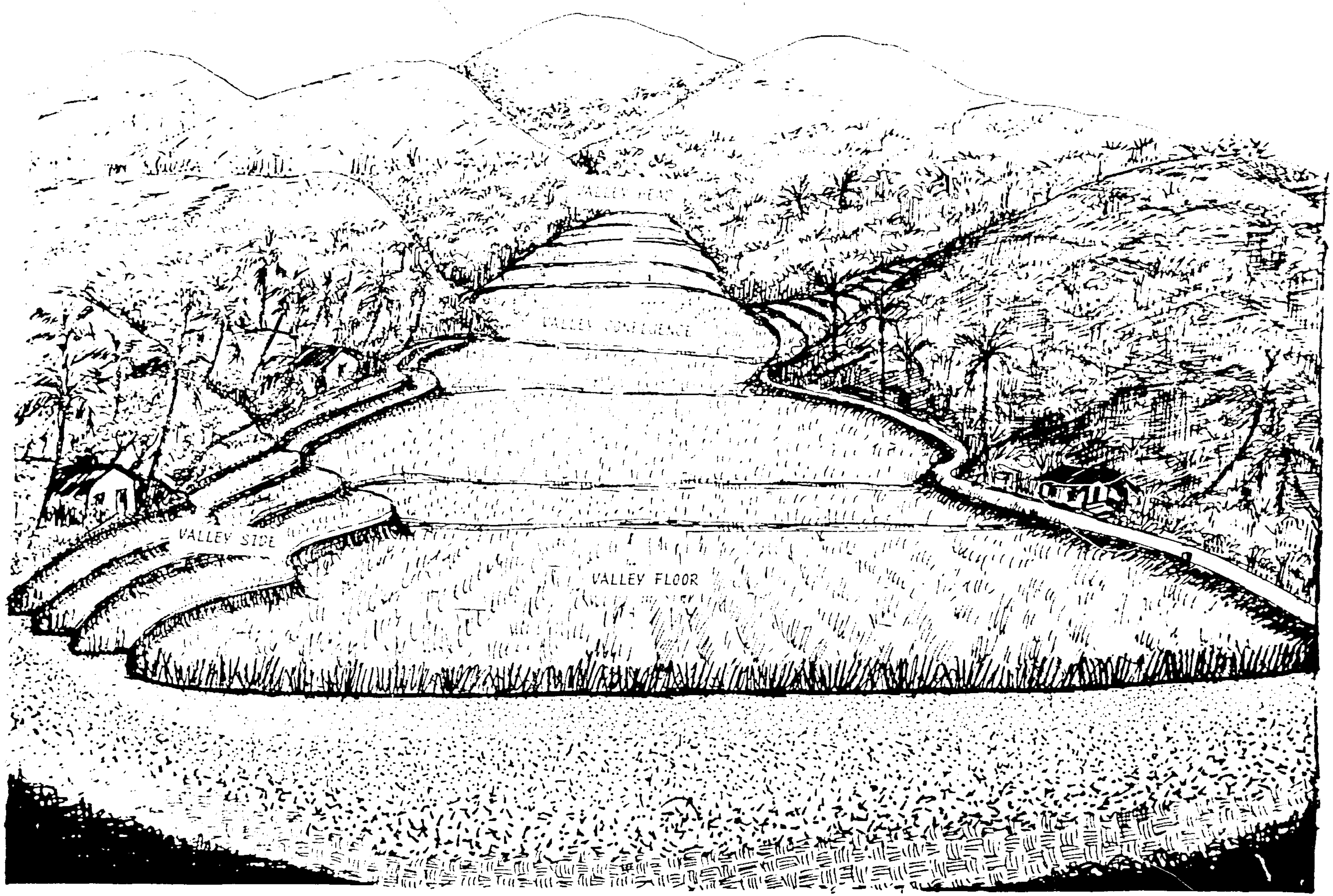

Fig. 4. Land elements found in inland valley complexes.

Fig. 5. Land Elements found in terraced slope complexes.

terraced slopes. Land systems and sub-systems within each of the two groups are reviewed in the order of decreasing total wetness.

The four land systems in which the rice lands occur predominantly as inland valleys are:

(1) Tumpane
(2) Udunuwara-Yatinuwara
(3) Harispathuwa, and
(4) Hurikaduwa-Kundasale.

Expect for the Hurikaduwa-Kundasale system all others have been subdivided into two to five sub-systems.

Tumpane Land System (1)[3]

The Tumpane land system consists of moderate to high relief ridge or hill and valley landform patterns in the agroecological region WM_3. The valleys are commonly narrow and "V"-shaped. This particular land system has features common to both those of the plateau region and the transition region. The sub-systems are:

(1a) Alawatugoda-Ankumbura,
(1b) Hataraliyadda, and
(1c) Kolugala-Alagalla, respectively.

Alawatugoda-Ankumbura sub-system (1a). This sub-system consists of ridge or hill and valley landforms with moderate relief in the range 100 to 200 meters between trough and crest. Highlands consist of Reddish-Brown Latosolic soils (Rhodudults) with average slopes of 40-60 percent. Highlands are in tea and Kandyan mixed forest home gardens.[4] In this sub-system rice lands occupy approximately 15 percent of the total land area. The rice lands occur as long smooth central valleys with weak gradient (1-2%) along the axis, and variable width across, with smooth moderate gradient (2-10%) narrow side valleys. Both flat bottomed "U"-shaped valleys, and sharper bottomed "V"-shaped valleys occur. Some of the foothill slopes are terraced for rice. Soils on the terraced slopes are moderately well drained whereas those soils in valley side elements or sloping elements are imperfectly drained and in valley floor elements the soils are gleyed and poorly drained. The drainage pattern is dendritic. This sub-system is the wettest of this land system. Annual rainfall is sufficiently high (>1250 mm at 75% expectancy) and the upland soil is deep enough to store sufficient water in highlands to maintain a high degree of wetness in the rice lands of the valleys and water flow in all streams during the limited dry periods.

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[3]Numbers in parenthesis correspond to land system and sub-system numbers on Figure 2.

[4]Kandyan mixed forest home garden is an assortment of high value trees, shrubs and vines grown in and around homesteads. They are in reality a recreation of a multiple canopy rain forest with economically valuable plants. This would include cloves, nutmeg, coffee, cocoa, tropical fruits, pepper, jak etc.

In most complexes this water has been diverted to provide local irrigation to side slope elements as well as across the valley bottom elements. The double cropping of rice is assured but flash flooding is a serious hazard in valley bottom elements.

Hataraliyadda sub-system (1b). This sub-system consists of ridge and/or hill and valley landforms with moderate relief, in the range of 100 to 200 meters between trough and nearest crest. Highlands consist of Reddish-brown Latosolic soils with average slopes of 40-80 percent. The highlands are in rubber, or Kandyan mixed forest home gardens. The rice lands occupy 15 to 20 percent of the land area. The rice lands are in stepped moderate gradient (2-3%) central valleys with smooth moderate to steep gradient (2-17%), narrow side valleys. Valley side elements and foothill slope elements have slopes up to 17%. Moderately well drained soils occur in foothill slope and valley side elements and poorly drained soils are in the valley floor, in steps and in very narrow valley elements. The drainage pattern is dendritic and streams are incised. The annual rainfall is high (>1250 mm at 75% expectancy) and the upland soils are deep enough to store a greater part of the rainfall which keeps the valleys well supplied with water and the streams flowing continuously. Double cropping of rice is assured but flash flood hazards occur in central valleys.

Kolugala-Alagalla sub-system (1c). This sub-system consists of ridge and/or hill and narrow valley landforms of high relief in the range of 200 to 400 meters from trough to crest. The highlands consist of Reddish-Brown Latosolic soils with average slopes of 40-60%. Highlands are in tea, rubber and Kandyan mixed forest home gardens. The rice lands occupy approximately 5 percent of the land surface. The rice lands occur as terraced hill slopes because the valleys are too narrow and "V"-shaped to asweddumize[5]. The drainage pattern is dendritic. The annual rainfall is high (>1250 mm at 75% expectancy). The dry weather flow in 2nd order streams is moderate but sufficient to provide the terraced slopes with supplementary irrigation from diversions. Double cropping of rice is assured without serious problems. New high-yielding varieties are adopted throughout this sub-system.

Udunuwara-Yatinuwara Land System (2)

The Udunuwara-Yatinuwara Land System consists of low relief ridge and/or hill and valley, plus isolated hillock landforms in the agro-ecological region WM_2. This land system is completely within the Kandy plateau region. On the south and east boundaries are mountainous land masses and on the north and west boundaries are steeply dissected mountainous slopes. The physical environment has a high degree of variability within the system. Therefore, the land system is divided into five sub-systems (Figure 6).

Ganhata Sub-system (2a). This sub-system consists of hill and/or ridge and valley land forms with moderate relief, in the range 100-200 meters. The soils of the highlands are Reddish-Brown Latosolic and the

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[5]Asweddumization is the process of land development and land formation with perimeter bunds, etc. to suit wetland rice cultivation.

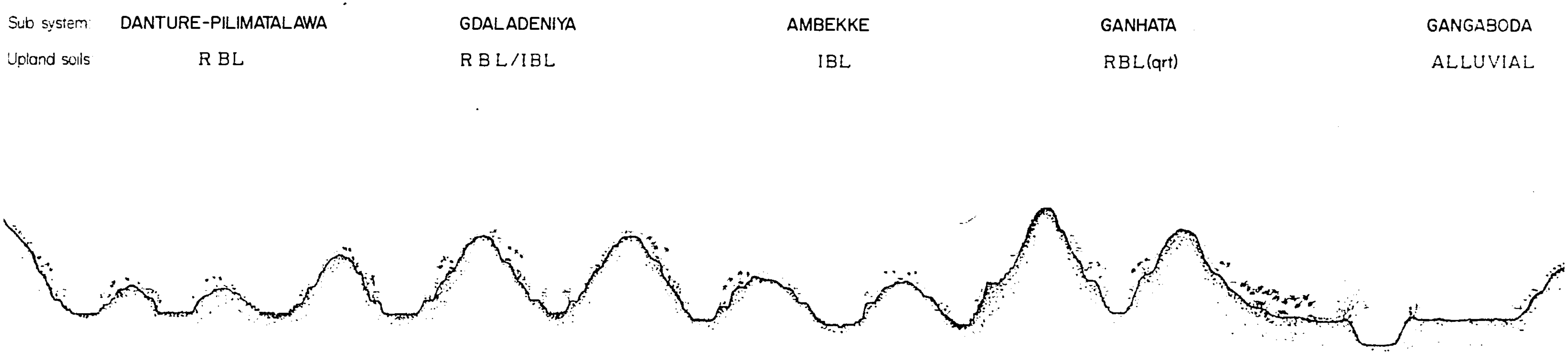

Fig. 6. Transect of Sub-systems of the Udunuwara-Yatinuwara land system.

average highland slopes range from 30 to 65 percent. The highlands are in tea and Kandyan mixed forest home gardens. The rice lands occupy approximately 20% of the land area. They are in smooth, weak gradient (1-3%) long narrow central valleys with narrow side valleys of moderate gradient (4-5%); in isolated suspended valleys resembling amphitheatre-like structures towards valley heads; and in terraced slopes of 2-30% on both valley sides and foothill slopes. Moderately well drained, strongly mottled soils occur on terraced slope elements; imperfectly drained soils occur on mid-slope and valley head elements and the poorly drained gleyed soils occur on bottom land elements of basin type valleys and narrow valleys in the absence of incised streams. The annual rainfall is high (>1375 mm at 75% expectancy). The proportion of highland and the soil depth in the highlands is high enough to store enough rainfall to keep valleys well supplied with water. Double cropping of rice is assured. Interflow and upwelling conditions appear to cause nutrient imbalances in the confluence of valleys and bottom of suspended valleys. The flash floods in central valleys are an additional hazard.

Gadaladeniya sub-system (2b). This sub-system consists of ridge and/or hill and valley, and hillock landforms with low to moderate relief (30-200 meters). The highlands consist of Reddish-Brown Latosolic soils or Immature Brown Loams (Inceptisols). The average highland slopes range from 20 to 40%. They are in tea or Kandyan mixed forest home gardens. The rice lands are mainly in stepped weak gradient (1-2%) long narrow or long irregular width, central valleys with narrow side valleys of moderate gradient (2-7%). The valleys are flat bottomed or "V"-shaped. Some foothill slopes and valley sides are terraced for rice. Moderately well drained soils occur on valley side and foothill slope elements, whereas imperfectly drained soils are in midslopes, valleys of moderate gradient or in valleys with incised drainage. The poorly drained soils are gleyed from the surface, and occur in valley step elements and narrow valley elements in sections of moderate relief. The drainage pattern is trellis with prominant bedrock control. The annual rainfall is high (>1375 mm at 75% expectancy). Both the low relief and the shallow soil depth cause lower moisture storage in the highlands than in the Ganhata sub-systems and the dry weather flow is very low. The hydrological conditions are good enough for double cropping rice with slight drought risk. In late Maha season flash floods in higher order valleys and interflow in steps are additional hazards to rice production.

Gangaboda sub-system (2c). This sub-system is a narrow alluvial terrace of the Mahaweli Ganga probably formed in a much earlier time in the history of the landscape. Along the boundaries of the alluvial terrace are mountainous land masses at the foot of which are alluvial cones and fans. The entire sub-system is in rice. The soils are moderately well drained alluvial with some slope colluvium. The streams that originate in the wetter highland cut through the sub-system. Diverting of these streams provide a plentiful water supply for the whole sub-system to be cropped with rice or upland crops. Occasionally (1 year in 15-20) high floods are a major hazard. High-yielding varieties are adaptable throughout the sub-system.

Danture-Pilimatalawa sub-system (2d). This sub-system consists of hill and valley, and rounded hillock landforms of low relief in the range of 30 to 100 meters. On the highlands are Reddish-Brown Latosolic soils with average slopes ranging from 6 to 30%. The highlands are in tea or Kandyan mixed forest home gardens. The rice lands occupy nearly 50% of the land area. The rice lands are in smooth weak gradient (1-2%) central valleys with side valleys of moderate gradient (4-7%). These side valleys are either narrow and smooth or stepped. There is a very limited extent of hill slope terracing towards some of the valley heads. Moderately well drained soils occur in terraced slope or in valley side elements. The imperfectly drained soils are in gently sloping valley or in valley bottom elements with incised drainage. The soils are gleyed and poorly drained in steps of valleys, narrow valleys and flat valley bottom elements in the absence of incised drainage. The drainage pattern is dendritic. The annual rainfall is high (>1475 mm at 75% expectancy). The first order valleys and steps of valleys are well supplied with water. The valley bottom tends to dry up in late February-March. During the limited dry periods supplementary irrigation is made available through stream diversions. A very high percent of the rice lands are double cropped. However, late sown rice in Maha season may suffer from water shortage in valley bottom elements at the lower ends, the valley side elements and hill slope elements. Interflow and upwelling in valley step elements appears to cause nutrient imbalance of deficiencies in Maha season. Flash floods are a hazard in valley bottoms.

Ambekka sub-system (2e). This sub-system consists of hill and valley, and hillock landforms of low relief in the range of 30-100 meters. The soils in highlands are Immature Brown Loams. The average land slopes are in the range 10-30%. These lands are in Kandyan mixed forest home gardens. The rice lands occupy about 40% of the land area. The rice lands are in smooth weak gradient (1-2%) long central valleys with moderate gradient (3-5%) narrow side valleys. There are some bedrock control features; the first order valleys towards the valley head are stepped. The moderately well drained soils occur in valley side elements, whereas imperfectly drained soils occur in midslopes of valleys with moderate gradients. The soils in valley bottoms, steps of valleys, and narrow valleys are gleyed and poorly drained. The drainage pattern is dendritic with incised streams in the higher order valleys. The annual rainfall is high (>1375 mm at 75% expectancy). The moisture storage in the highlands is low as a result of low relief, large percentage of rice land and shallowness of highland soils. There is very little dry weather flow in streams. The well drained and imperfectly drained soils require supplementary irrigation in late Maha season. Yala season is good only for upland crops. Flash floods are a hazard in the sub-system.

Harispattuwa Land System (3)

The Harispattuwa land system consists of hill and valley, and hillock landforms of low relief, in the agroecological region WM_3. The land system is entirely within the Kandy plateau. It is bounded by ridges of moderate relief on the north and south, moderate to high relief ridges on the south-west, and by a steeply dissected slope on the west. The land system is divided into three sub-systems:

(3a) Medawala-Bokkawala
(3b) Kulugammana, and
(3c) Talawinna.

Medawala-Bokkawala sub-system (3a). This sub-system consists of hill and valley, and hillock landforms of low relief in the range of 30 to 100 meters from trough to the nearest crest. The soils on the highlands are Immature Brown Loams with the average slopes ranging from 20 to 40%. The highlands are in tea and Kandyan mixed forest home gardens. The rice lands occupy about 40% of the land area. The rice lands occur in weak gradient (1-2%) long smooth central valleys with stepped moderate gradient (2-7%) narrow side valleys. Some valley sides up to 10% slopes and foothill slopes up to 10% gradient are terraced for rice. The valleys are "U"-shaped. Moderately well drained soils occur on valley side elements, hill slope elements and along incised streams, the imperfectly drained soils occur on valley head elements, moderately sloping valleys closer to streams. The poorly drained soils, gleyed from surface, occur in steps of valleys. The drainage pattern is dendritic. The annual rainfall is moderately high (>1250-1375 at 75% expectancy). A low but steady dry weather flow is maintained in streams. Rice is double cropped but the drought risk is high. Interflow in valley heads and steps appears to cause nutrient imbalance of deficiencies. Flash floods are a common hazard.

Kulugammana sub-system (3b). This sub-system consists of hill and valley, and hillock landforms with low relief, in the range of 30 to 100 meters from the trough to the nearest crest. The soils on highlands are Immature Brown Loams and the average highland slopes range from 20 to 55%. The highlands are in Kandyan mixed forest home gardens or in tea with some spice crops. The rice lands occupy approximately 30% of the land area. These rice lands occur in stepped weak gradient (1-2%) narrow central valleys with stepped moderate gradient (2-5%) narrow side valleys. Some of the rice lands are located in terraced foothill slopes up to 12% gradient with limited extent in valley side slopes. Moderately well drained soils occur on foothill slope elements and valley side elements, whereas imperfectly drained soils are confined to valley head elements, mid-slope elements or stepped valleys and valley floor elements with incised drainage. The poorly drained soils occur on valley step elements and narrow valleys. The drainage pattern is dendritic but with some bedrock control of the valleys. The annual rainfall is moderately high (>1250-1375 mm at 75% expectancy). The storage in the highlands is low because of low relief and shallowness of soils. Dry weather flow in the streams is very low and the water supply to valleys is limited. Rice is double cropped to a limited extent with vegetables during Yala season in valley side elements and foothill slope elements. The drought risk is high throughout the sub-system.

Talawinna sub-system (3c). This sub-system consists of hill and valley, and hillock landforms with low relief in the range of 30 to 100 meters between the trough and nearest crest. The soils on highlands are Immature Brown Loams. The average highland slopes are in the range of 20-30%. The highlands are in Kandyan mixed forest home gardens. The rice lands occupy about 20% of the land area. The rice lands occur in stepped weak gradient (1-2%) narrow central valleys with stepped, moderate gradient (2-5%) narrow side valleys. A limited extent of valley sides are terraced for rice but foothill slopes up to 10% gradient are terraced. Moderately well drained soils are in valley side elements and foothill slope elements whereas the imperfectly drained soils are in mid-slope and valley head elements. The poorly drained soils occur in steps. The drainage pattern is dendritic. Strong bedrock control, though not expressed in the drainage, is evident in the valley form. The annual rainfall is >1250-1375 mm at 5% expectancy. The moisture storage in the highlands is limited because of the shallowness of soils and low relief. Dry weather flow is very low in the streams. Double cropping of rice in this sub-system is the common practice, but the drought risk is high.

Kundasale-Hurikaduwa Land Systems (4)

This land system consists of hill and valley, and hillock landforms in the agro-ecological region IM_3 within the Kandy plateau region. The relief is low in the range of 30 to 100 meters from trough to crest in the landscape. On the northern, eastern and western boundaries of the land system are ridges of moderate relief with an elevation difference in the range of 100-200 meters. This land system is not subdivided at the next lower category. The soils of the highlands consist of Immature Brown Loams. The average highland slopes are in the range of 15-30%. The highlands are mainly in cocoa, coffee, coconuts, and pepper. The rice lands occupy about 20% of the land area. They occur in stepped weak gradient (1-2%) long central valleys with moderate gradient (2-5%) side valleys. A limited extent of valley sides and foothill slopes are in rice. Moderately well drained soils occur on valley side, foothill slope, sloping valley elements and weak gradient valley elements. A limited extent of poorly drained soils are in valley step and slope elements with continuously flowing irrigation channels on upper contours. The drainage pattern is dendritic. The rainfall is between 875-1250 mm. The storage in the highlands is low because of the shallowness of soils and low relief. Dry weather flow in streams is low and frequently ceases during Yala season months of May to September. Rice is double cropped in land elements with poorly drained soils and the valley side elements and foothill slope elements with irrigation. Most commonly, rice is grown in Maha season in all rice lands and other crops in Yala season in the land elements with moderately imperfectly drained soils. The drought risk is high in this land system.

The seven land systems in which rice lands occur predominantly on terraced mountain or hill slopes are:

(5) Atabage
(6) Dolosbage-Nawalapitiya
(7) Naranpanawa
(8) Uduwela-Pallegama
(9) Teldeniya-Madugoda
(10) Talatuoya-Marassana, and
(11) Talagune.

Of these the Dolosbage-Nawalapitiya and Teldeniya-Madugoda systems are subdivided into two sub-systems each. These systems and sub-systems are spread over both the wet and intermediate zone parts of the district. As mentioned previously the terraced systems are in transitional regions between the Kandy plateau and the upper and lower peneplains, the wet zone systems are transitional to the upper areas, while the intermediate zone systems are transitional to lower areas.

In evaluating rice lands on terraced slope systems the determinants of the percentage of rice lands in the system (Figure 7) and the extent of terraces on a given slope have not been fully examined. However, it is observed that the physical determinants of rock structure stability, soil depth, and percent of slope influence the ability to form stable terraces of workable size on a given slope. Also the availability of water in the upper catchment above the terraces for diversion as a local irrigation system influences the extent of terracing on a slope. In some cases the priority of land use for large tea estates constricts some potentially terraceable lands. All this generally makes the terraced land systems less extensive than the corresponding inland valley systems.

Atabage (5)

Atabage is a highly dissected, very steep hill and valley landform of high relief (200-400 mm) in the agro-ecological region WM_2. The highlands consist of Reddish-Brown Latosolic and Red Yellow Podzolic (Ultisols) soils with average slopes of 40-70%. The highlands are planted in tea, patna grasslands, and Kandyan mixed forest gardens. The rice lands constitute only 5% of the total land area. They are found on the less sloping (<25%) lower slopes of narrow valleys. A small extent of the rice lands in the system are in moderately broad valleys and alluvial terraces. The well drained rice land soils are found in the more steeply sloping convex slopes while the imperfectly drained soils occur in valleys and terraced slope elements below the irrigation channels. The overall drainage is dendritic and rice lands are generally very wet. Double cropping of rice is assured, but generally because of excessive wetness and upwelling conditions on lower parts of the complex, only low-yielding indigenous varieties are used. Improved varieties are restricted to well drained areas, but their yield potential is frequently reduced by heavy cloud cover. Also harvesting of rice is frequently affected by nearly continuous light rains.

Dolosbage-Nawalapitiya (6)

This land system consists of an elevated but steeply dissected secondary plateau, and the escarpment leading from the main Kandy plateau up to the secondary plateau. It is also in agro-ecological region WM_2. The land system is divided into the two sub-systems Dolosbage and Ulapane-Nawalapitiya, representing the plateau and escarpment parts respectively.

Dolosbage (6a). This is the plateau portion of the system. It represents the highest rice lands in the district and the upper limit of the middle peneplain. The original plateau has been dissected until it is now a landform consisting of high relief (200-400 m) hill and/or ridge and valleys. Highland soils, slopes and land use are similar to the Atabage system. The rice lands occupy about only 10% of the total land surface, with the remaining almost exclusively in tea. The rice lands are essentially the lands too wet for tea and are composed of isolated suspended basin type valleys, smooth narrow valleys of strong gradient, and terraced hill and mountain slopes. Well drained rice land soils are

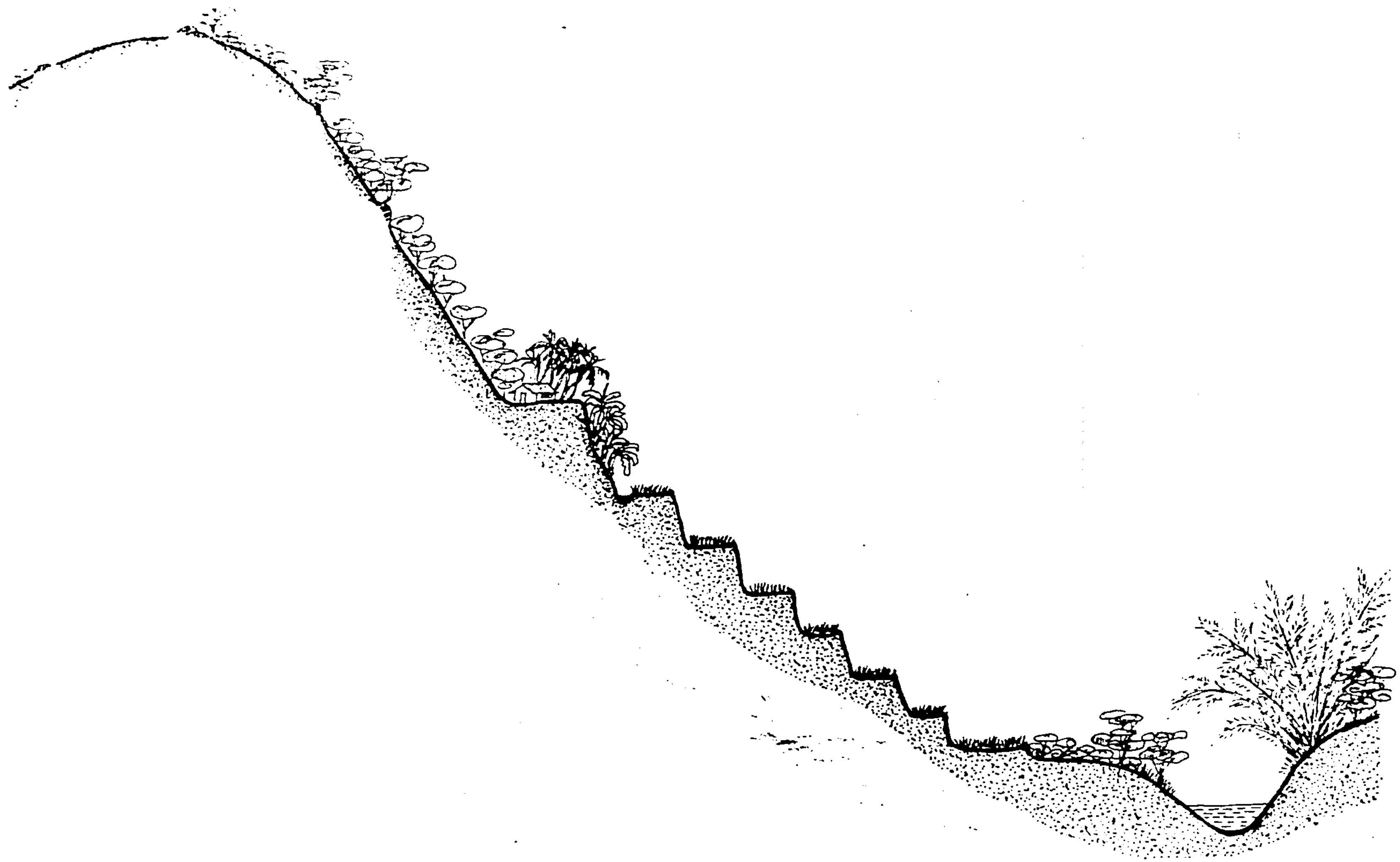

Fig. 7. Schematic Illustration of a terraced slope rice land complex.

limited to the upper terrace slopes, while imperfectly drained soils occur on the bottom lands of the basin valleys. Both the surface and sub-surface inflow of water into the basin valleys remain high even during limited dry periods. This results in a large percentage of the bottom lands having upwelling conditions and low support strength. Most terraced areas are supplied with irrigation water from stream diversion. The bottom lands are double cropped generally with old improved varieties, while the hill slopes without irrigation are mostly single cropped with indigenous long age varieties. When irrigation is available double cropping occurs with old improved varieties. Few areas are suitable for new improved varieties. As in the Atabage system continuous rains frequently hinder harvesting activities.

Ulapane-Nawalapitiya (6b). This is a small sub-system comprising the escarpment portion of the land system. The rice lands cover about 20% of the area. They consist of a line of alluvial fans and cones at the root of the escarpment plus the alluvial terraces on both sides of the stream at the bottom of the escarpment. Sub-surface water flow through the alluvial fans, cones and inner alluvial terrace cause almost all these soils to be poorly drained with only isolated patches of imperfectly drained soils. Moderately well drained soils occur only on the other alluvial terrace. Upwelling problems occur throughout much of the fan and cone portion of the sub-system. A continuously flowing irrigation canal is found along the top of the alluvial cones and fans that provides irrigation so that the entire sub-system is double cropped. New improved varieties are used on the outer terrace while old improved varieties on the poorly drained remainder.

Narampanawa (7)

This system consists of a hill and valley landform of high relief (200-400 m) in the slightly drier agro-ecological region WM_3. On the north and east is a mountainous landscape while on the south and west is a lower relief range. The highland soils are Reddish-Brown Latosolic derived from quartzitic parent materials. The highly quartzitic parent material has resulted in soils of generally low fertility throughout the land system, and are responsible for the abandonment of several terraced rice land complexes. The highlands have an average slope of 35-60% and are used mainly for poor quality tea, with some Kandyan mixed forest gardens. Coconut in many of the gardens show yellowing typical of Mg deficiency. Rice lands occupy about 5% of the land surface. They occur mainly on steep mountainous slopes and foothill slopes with a small component in narrow sloping inter-hill valleys. The soils would be similar to the upland soils except for the artificial hydromorphism induced by local diversion irrigation schemes. The well drained rice land soils occur on convex contour elements with the imperfectly drained soils on straight slope and mid-slope elements; poorly drained soils are on concave slope elements and in the inner hill valleys. The overall drainage pattern is dendritic. All rice lands are supplied with ample irrigation so double cropping is assured with high-yielding varieties adaptable to most areas. However, the low inherent fertility limits their full yield potential from being obtained. Slumping can be a major hazard.

Uduwela-Pallegama (8)

This system is a landform of warped basins enclosed by moderate to high relief ridges; narrow "V"-shaped, downcutting valleys in the agro-ecological region WM_3. Highland soils are Reddish-Brown Latosolic. The average highland slopes are 30-80%. The highland land uses are tea, Kandyan mixed forest gardens, patnas[6] and conservation forest. The rice lands occupy about five percent of the land surface, and occur on lower terraced hill and mountain slopes. Moderately well drained rice land soils occur on convex slope elements, while the imperfectly drained soils are on straight slope, mid-slope elements, etc. The poorly drained soils are in concave contour and concave slope elements. An exception is the convex contour slope elements with perennial irrigation channels on upper contours. The rainfall is similar to the Narampanawa system, but the dry weather flow is somewhat less. The double cropping of rice is assured for most elements with a slight drought risk on strongly sloping elements in Yala. Upland crops are grown on less than 10% of the rice lands in Yala season. These are concentrated on the drier convex contours or convex slope elements.

Teldeniya-Madugoda (9)

This land system is a landscape of parallel and sub-parallel ridges and narrow valleys and hills, with the relief of 200-400 m. The system is in the agro-ecological region IM_3, with a 75% expectant rainfall of 875 mm per annum. This system has been divided into the two sub-systems:

(1) Teldeniya
(2) Madugoda

Teldeniya (9a). This sub-system consists mostly of a ridge and/or hill and narrow valley landforms. The highland soils consist of Reddish-Brown Latosolic and Immature Brown Loams and the highland slopes average 30-60%. The highland land use is tea, Kandyan mixed forest gardens, and tobacco. The rice lands occupy about 5% of the land surface. These lands are in terraced steep mountain slopes and hill slopes. The strongly sloping convex contour and convex slope elements contain the well drained soils, while the concave contour and concave slope elements contain the poorly drained, and the straight mid-slope elements consist of imperfectly drained soils. The flow in streams is seasonal and the drainage pattern is dendritic. Local irrigation systems are developed by diverting the creeks formed in the concave contours along the upper contour to supply water for most of the complex during Maha season, but only to a limited amount during Yala season. Thus double cropping rice is restricted to the concave contour areas near irrigation sources while remaining lands are cropped to vegetables.

Madugoda (9b). This sub-system consists of a primary ridge with parallel secondary ridge and/or narrow valley landform. The highland soils are Red Yellow Podzolic and Mountain Regosols with average slopes of 25-65%. Highland use is confined to a few home gardens, with most of the land in conservation forest. The rice lands occupy about 5% of the total land

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[6] Patnas: Natural low productive grasslands, the origin of which is not definite.

surface. They occur either as suspended gently sloping secondary ridge crests irrigated with water collected from the primary ridge, or gently sloping inter-ridge foot slopes irrigated by stream diversion. Remaining lands appear too steeply sloping for terrace development. The pattern of soil drainage classes is similar to the Teldeniya sub-system. Stream flow remains seasonal except for third order streams which have a low continuous flow during extended dry periods. Except in poorly drained land elements near irrigation sources, rice is grown only in Maha season. Unlike the Teldeniya sub-system, heavy winds in Yala season drastically limit the Yala cropping potential to the limited extent of vegetables.

Talatuoya-Marassana (10)

This land system consists of secondary ridges and valleys of moderate relief bound by the high relief primary ridge on the south and southeast in the agro-ecological region IM_1. The highland soils are Reddish-Brown Latosolic and Rendzina (Udoll). The average highland slopes range from 10-50 percent. Highlands are in tea, tobacco, mixed home gardens, and vegetables. The rice lands occupy about 15 percent of the land area. They occur in highly dissected ridge slopes and foot slopes, and smooth moderate gradient (2-5%) central valleys with side valleys of moderate gradient (5-8%). Moderately well drained soils occur on convex contour slope elements and concave contour slope elements. The annual rainfall is moderately high. The drainage pattern is dendritic to sub-parallel and streams are incised. The dry weather flow is moderate and steady. Most commonly Maha season rice is followed by vegetable crops. The drought risks in Yala season are high. Rice is double cropped only in situations where the soils are unsuitable for other crops and supplementary irrigation is available.

Talagune (11)

This land system consists of parallel or sub-parallel ridges and narrow valleys in the agro-ecological region IM_1. The relief in the region is high. The highland soils consist of Red Yellow Podzolic and Mountain Regosols. Average highland slopes are 25-55%. The highland is restricted to a few home gardens in which tobacco is a major component. Most of the region remains in some form of forest cover or patna grasslands. The rice lands occupy about 10% of the land area. These lands occur on terraced mountain and foothill slopes or rounded convex crest of ridges whose sides are too steeply sloped for terracing. The soil pattern is very much similar to that of the Madugoda subsystem. The rainfall is moderately high; the drainage pattern is subparallel to rectangular. Dry weather flow is low but steady only in major streams. Double cropping of rice is possible on poorly drained land elements, while rice is grown on all land elements during Maha season. Heavy Yala season winds are a hazard in this system as in the Madugoda sub-system. Short-term drought risks are high in both Maha and Yala seasons. The cropping calendar is delayed compared to the other land systems.

SUMMARY AND CONCLUSION

This paper illustrates an SRI effort to evaluate the systematic variation in the rice land sub-portion of a rugged mountain district. The rice lands are scattered across most of the numerous landforms in the district but comprise less than 25% of the total surface area. Using extensive field observations of physical determinants for rice culture, topographic maps, and aerial photographs a four-tiered rice land classification scheme was developed based on the land systems approach. This scheme made it possible to focus on the rice lands and the variability in them. In the final analysis it was possible to recognize why advanced varieties could only be used in limited areas and why preference had been given to indigenous or old improved varieties. It was also possible to predict where in a given complex of a system various problems would most likely occur.

The land qualities of the lowest category in the classification, 'the land elements,' is highly specific. In any land system or sub-system the evaluation of this basic unit would be in terms of biological responses and specific management requirements. This would provide sufficient guidance to research indepth studies on specific problems, particularly those problems associated with widely varying hydrological conditions. Further, the knowledge of individual land elements and their relationships to the modal land complexes of a given land system provide guidance to the extension services to improve their understanding of the system in terms of the potentials, limitations, and variable management needs. The flow of information from the SRI stage to the utilization stage is very rapid at minimum cost.

ACKNOWLEDGEMENTS

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QUESTIONS/COMMENTS (by P.H.T. Beckett):

It is of very great interest to see the Land System concept extended to such humid areas.

The basic assumption of such an approach is that it is possible to map a landscape into compound land systems each containing several kinds of soil or terrain provided that their pattern is simple and capable of simple description.

This assumption applies in e.g. Uganda, Kenya, C. Australia, lowland Britain and parts of N. America. It does not apply in e.g. Arctic Sweden, sub-Arctic Canada, and the mountains of N. Britain, where the patterns of soils and terrain cannot be simply described. It would be of very great interest to know how widely the land system concept can be used in Sri Lanka.

ANSWERS:

The land system concept is readily applicable to the wet upcountry region of SRI Lanka. This region is highly complex in terms of physiography and landforms, etc. We are in the process of studying the wet low country and it appears to be reasonably good. In the study of soils of the dry zone we have used the normal soil survey procedures.

QUESTIONS/COMMENTS (by A. Van Wambeke):

What would be the useful scale of mapping to get soil information to farmers (in Sri Lanka)?

ANSWERS:

A map scale larger than 1:5000 would be most useful.

QUESTIONS/COMMENTS (by A. Van Wambeke):

Is soil taxonomy useful in rice land? What is the basis for agro-climatic subdivisions?

ANSWERS:

Soil taxonomy should be useful in rice lands. Much more work is required in this direction.

The agro-climatic regions are demarcated on the basis of rainfall expectancy at 75% probability, elevation, and soils. There are three major devisions of elevation-low country 0-1200 ft., mid-country 1000-3000 ft. and upcountry over 3,000 ft. There are three major climatic zones, wet zone, intermediate zone, and dry zone. Each of the zones are subdivided, except dry zone, into low, mid and up on the elevation criteria. Finally, on the basis of monthly rainfall expectance and soil distribution, the agro-ecological regions are demarcated thus:

Wet, low country into four regions;
Wet, mid country into three regions;
Wet, up country into three regions;
Intermediate, low country into three regions;
" mid country into three regions;
" up country into three regions; and
Dry zone low country into five regions, making a total of 24 regions.

SESSION IV

NATURE OF SOIL RESOURCE INFORMATION NEEDED BY PLANNERS

Chairman: J. Schelling

Speakers

R. Fauck - Evaluation of Soil Resources by ORSTOM

W. B. Peters - The Role of Water and Land Resource Information in World Bank Programs for Agricultural Development

J. W. Putman - The Comprehensive Resource Inventory and Evaluation System: A Caribbean Experience

EVALUATION OF SOIL RESOURCES BY ORSTOM

R. Fauck[1]

Since 1946, Office de la Recherche Scientifique et Technique Outre-Mer scientific workers have drawn up more than a thousand soil maps, from moist tropical forest to Sahelian regions, from Black Africa to the Mediterranean areas, the West Indies and French Guiana, and the Pacific islands. The primary aim between 1946 and 1956 was to catalogue types of soils, often unknown to begin with, and map them on a medium scale (1:200,000). Subsequently, four other types of maps were prepared: two large-scale types for development schemes (1:50,000 and 1:20,000); and two small-scale types for regional planning purposes (1:500,000 and 1:1,000,000). For various reasons, government departments in the countries involved differed considerably in the use they made of these maps. Certain technical services had considerable difficulty interpreting, in development terms, maps and reports written by soil scientists. Aware of this difficulty, ORSTOM prepared new documents to supplement soil maps to provide a clearer definition of soil capabilities. As time has gone by, various methods of presentation have been used. It is the experience of ORSTOM in this area that is described in the following report.

USERS' NEEDS AND DIFFICULTIES IN RESOURCE EVALUATION

The land user's ideal would be to have documents giving, for each soil type, all possible forms of crops and optimum conditions of usage to ensure maximum yield, while preserving natural fertility. For many reasons it is extremely difficult to achieve this objective in most tropical regions.

To begin with, the state of soils knowledge varies widely depending on world regions; but in general, agricultural research does not yet provide all the factors needed to define all the opportunities of use for each type of soil.

Next, assuming that this objective can be achieved, another very important problem involves the wide range of possible farming methods, from the most intensive to the most extensive. Between drip irrigation, drought-animal tilling and the extensive stockbreeding of the Sahelian nomads, there exists a whole series of possible farming methods, which depend mainly on local social and economic factors as time passes. This is impractical, at any rate for soil scientists.

Finally, there is the problem of map scale. There are three scales to be considered: for soil distribution on the ground, for land use by man, and for soil maps. Soil distribution on the land is closely related to topography and parent material variations. Soil types succeed one another in a toposequence over variable distances: some tens-of-meters in some cases; a few hundreds in others; and thousands of meters are occasionally found. In these circumstances, maps show pure soil units only when they

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[1]Dr. R. Fauck is Inspecteur Général de Recherches of the Office de la Recherche Scientifique et Technique Outre-Mer in Paris, France.

are large-scale or very large-scale. When medium or small-scale, soil units become complex, regardless of the method of classification or taxonomy.

By soil-utilization scale is meant the size of farming units. This factor can vary considerably, from a few acres for the family holding for market gardening, to several thousand hectares for the stock ranch. The method of utilization of soil maps will differ considerably depending on such factors.

Finally, the soil map scale is rarely determined by ground truth, in other words, by the soil-distribution scale. It is sometimes determined by the objective, for example an irrigation scheme or regional planning. But it is usually governed by financial requirements, and in most cases the map scale is much smaller than the soil distribution scale. Consequently, most maps represent complex units, usually soil associations.

An association is a combination of soil types consisting of one dominant soil and its associated soils, which when grouped together often corresponds to a geomorphological unit. An association may comprise soils with very different capabilities, sometimes incompatible with one another. And that is what frequently makes soil maps difficult to use. The concept of capabilities is a complex one: the capabilities of the various soils in an association differ from one another increasingly as agriculture intensifies. On the other hand, for unmechanized agriculture in Sudan regions, involving very little or no fertilizer use, many types of soils could be grouped together. This can be done even if they are labelled differently by soil scientists in order to conform to classification or taxonomic rules, provided that they allow the same range of crops. Differences among these soils will involve the level of yield of the various plants grown, in relation to inputs or farming techniques.

These remarks suggest the separation of two types of factors affecting capability: one factor concerns the suitability or unsuitability of soils for a specific use; and the other factor concerns soil fertility levels in relation to different cultivation methods, and depends on intensiveness and on complexity. The case of suitability or unsuitability involves the concept of limiting factors or utilization constraints. The second case must take into account, for each particular use, soil capabilities in relation to likely inputs and social and economic conditions.

This analysis of users' needs and the difficulties of meeting them in tropical regions explains the decision by French scientists to use different methods of cartographical representation.

SOLUTIONS ADOPTED

Various technical solutions have been adopted; they vary depending on the climatic environment, as well as on map scale. In most cases, however, maps have been drawn on the basis of a conventional soil map. A few examples may be given to illustrate this. A very great number of large-scale soil suitability maps (1:10,000 or 1:20,000) have been produced, for Cameroon, Madagascar, the West Indies, etc. This is the most straightforward case, in which soil units represent a single type, and in which the caption indicates possible uses. Two categories of maps have been established in Tunisia, one showing suitability for dry farming, and the other suitability for irrigated farming. Together with the soil map, users accordingly have three maps with different legends.

Another method is at present being tried in French Guiana, where soil variability is very high. Soil cover is not characterized by specific contours but by isodifferentiation curves. Toposequences are represented in cross sections or diagram blocks. Agricultural engineering units categorize all soils with the same type of drainage. In view of the major effect of lateral circulation of water in upper horizons, for example on plant rooting and on soil erodibility, this is the characteristic method to categorize soils with a morphology that changes quickly on slopes.

Not many examples exist of medium-scale soil suitability maps based on conventional soil maps. There is, however, the case of a soil-resource map taken from a 1:200,000 soil map, with an agricultural engineering unit key. The method, performed on a small scale (1:500,000), will be described later. On the other hand, maps exist combining geomorphological and soil data and defining wide farming suitability groups. Two systems are being worked out. One of these, produced by Institut Recherches Agronomie Tropicale (Paris), first defines morpho-soil units on the basis of an interpretation of links between morphogenesis and pedogenesis. It then assesses the capabilities of the physical environment, allowing constraint maps and land-allocation recommendation maps to be drawn. The second system, at present being developed by ORSTOM in the Ivory Coast, concerns morphological and soil landscapes to the scale of 1:200,000. Internal drainage, water-holding capacity, percentage of coarse components, and rock depth are given for each unit. Information on agricultural suitabilities is supplied in the text accompanying each map.

For small-scale maps (1:500,000 and 1:1,000,000), it is difficult to define soil-utilization possibilities in a key, because the map includes complex soil units or soil associations. However, planners are interested in such soil maps insofar as they make a useful contribution to the choice if not of crops, at least to possible systems of exploitation. This is why authors of the various maps that have been drawn confine themselves to showing either a wide classification of agricultural qualities (rich, fair, poor), or very general farming possibilities, such as dry farming, irrigated farming, or grazing. A typical example is the 1:1,000,000 map of New Caledonia.

Another method has been tested in Sahelian regions, notably in Upper Volta: the "soil resource map." It is based on dividing soil cover into units suitable for the same type of traditional or extensive farming. Anything is possible in intensive farming, where the soil may be no more than a physical support. For example, let us consider the sand dunes, found over wide areas of the Sahel. It is not recommended that the dunes should be used to grow millet, since this traditional crop results in movement of the dunes by wind erosion. But it would be possible to recommend drip irrigation with the use of fertilizer and manure to grow strawberries, as is done near Dakar. Given the social and economic situation in the Sahel, a 1:500,000-scale map provides only for low-intensive or medium-intensive cultivation, with an emphasis on utilization constraints. These constraints comprise those which cannot be altered by human intervention, and those which can be changed more or less easily. The former constraints include soil depths and textural classes, which govern suitability or unsuitability for a given purpose. The latter include chemical richness, which can be altered by the use of fertilizers; soil water resources, which can be improved by irrigation; and the upper horizon structure, which can be altered by working the soil.

From a practical viewpoint, the method is based on prior establishment of a fertility factor table. Eight soil characteristics have been selected as governing farming capabilities. The order in which they are given is based mainly on the degree of constraint: the first two, depth and texture, are immutable, as mentioned above; the others can be altered by human intervention. Fertility factors are as follows:

1) Available depth: this is not the depth of the soil but the depth that can be reached easily by roots (cf. presence of gravel in many tropical soils).

2) Textural type: this is represented by two textures: the upper horizon and the B horizon (importance of textural variation is for rooting and water dynamics).

3) Existing water economy: this is the available water and its variation in relation to climatic season, namely soil moisture characteristics.

4) Chemical features: these consist of the sum of cation exchanges and base saturation.

5) Deficiencies (e.g. phosphate).

6) Presence of adverse chemical elements (e.g. free aluminum, sulphides).

7) Organic matter: quantity and quality.

8) Adverse physical properties (e.g. sealing).

The fertility factor table was composed by analyzing the references on 1:500,000 soil maps. Next, units were categorized on the basis of soil types ("dominant" types) in the same class for soil depth and textural type (in other words the two inalterable units) on the basis that they represent fairly homogeneous groups for agricultural purposes. It is understood, of course, that the types of "associated" soils that they contain may vary, with different capabilities or at least fertility levels.

This initial soil classification for defining agronomic units is inadequate for planning purposes, since small-scale maps are involved. Soil classified within the same unit - regardless of the method of classification used- may be distributed widely over different climatic zones from an agricultural viewpoint. This is why comparable agronomic units (according to average depth and textural type) have been subdivided on the basis of a third criterion, climatic zonality. The different zones take into account the length of rainy season or seasons, and also average rainfalls. Because of the insufficiency of such data in many regions and the year-to-year variability in Sahelian regions, zone boundaries are somewhat vague.

Ultimately, one obtains a key of agronomic units. Opposite each of the units of this key, there are details of constraints (erodability) and recommendations for land use (fertilizer requirements, working of soil, etc.). In practice, land use planners find out quickly from the map about comparable agronomic units. They then examine the table, which details the eight essential characteristics for each of them, representing fertility factors on the basis of which choice of specific uses may be made. Finally, land users refer to another table, which shows correspondence with soil map units. The reader should consult this soil map and the report accompanying it, first to find out about soil distribution in the landscape (toposequences, associations), and partly to discover the morphological and physico-chemical properties of each of the soils in the association.

Initial reactions from government departments are encouraging. Technicians seem to be less discouraged than in the past by the complexity of soil maps and soil scientist's jargon because of the preliminary reading of soil resource maps. They have therefore been found to meet a need.

CONCLUSIONS

Beek (1978) emphasized the high number of map systems aimed at evaluating soil utilization possibilities. The ORSTOM experiment does not allow any conclusions to be drawn about the advantage of one system over another. The choice must depend first on the scale adopted, second on the accuracy of available data, and finally on the local social and economic framework. Maps are easier to produce on a large scale. But planners often call for small-scale maps, wanting all farming possibilities to be defined for each type of soil, with an indication of the potential fertility level for various hypotheses of extensive or intensive cultivation. This objective cannot be achieved by soil scientists alone; but it would be reached if soil scientists, agricultural experts and economists combined their resources. Unfortunately, the state of agronomic knowledge of the average depth of profiles could involve the elimination of certain crops or their acceptance; the recommendation that mechanized methods should not be used; or accepting the methods with the risk of insufficient yields on a local and economic level - this last factor can vary in time. In addition, the idea of depth is sometimes counterbalanced by the concept of chemical richness, and advances in the development of new varieties further complicate the situation.

The state of affairs and regional planning needs in new African states have led ORSTOM to produce small-scale "soil resource" maps. These supplemental soil maps still have to be drawn. It is not their purpose to propose precise forms of soil utilization, but to stipulate constraints on use. In other words they list limiting or favorable soil factors, with quantitative details of soil erodability and the level of chemical fertility. Definitions of farming methods, which involve technical, social and economic factors, is at a later stage, which for the moment lies in the field of agricultural experts, planners and decision-makers.

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Van Wambeke, A. 1978. Problèmes relatifs au maintien de la productivité des sols. Colloque sur l'amélioration des systèmes de production agricole. Bamako, Mali.

QUESTIONS/COMMENTS (by T. R. Forbes):

Is the model of Y. Chatelin's "volumes pedologiques" used extensively in ORSTOM soil surveys?

ANSWERS:

Presently it is an experimental model, only used in Ivory Coast, in humid climates. The first results are interesting, but it's necessary to wait for judgment.

QUESTIONS/COMMENTS (by A. Van Wambeke):

Are ORSTOM people sometimes using Soil Taxonomy in their surveys?

ANSWERS:

ORSTOM people know soil taxonomy well-moreover, in some cases, for instance in Latin America, soil scientists utilize soil taxonomy. In other cases, Ivory Coast in particular, they have given correlations between French classification and Soil Taxonomy.

THE ROLE OF WATER AND LAND RESOURCE INFORMATION IN WORLD BANK PROGRAMS FOR AGRICULTURAL DEVELOPMENT[1]

William B. Peters[2]

Water and land resource development and maintenance are of paramount importance in meeting the food, fiber, and energy crises and helping man. This paper summarizes the role of water and land resource information in meeting this challenge by World Bank programs for agricultural development. The paper briefly describes the purpose and activities of the Bank alone with the nature, diversity, and scope of financed projects; requirements with respect to basic data, evaluation, and product from the standpoint of an international financing agency; factors in addition to soil that need to be taken into account, kept in perspective, and integrated; preferred approaches to land selection; the need for streamlining investigations; and principal deficiencies in surveys as commonly made in meeting needs. The paper emphasizes that data collection and land selection need to be approached as an interdisciplinary exercise wherein contributions are made by economists, hydrologists, drainage engineers, agronomists and others. The importance and usefulness of screenable soil characterization as a tool for support of studies is also stressed. Ways and means are suggested whereby soil surveyors may produce a better product by becoming more involved and taking an expanded role in the planning process.

THE WORLD BANK -- BACKGROUND[3]

Along with the International Monetary Fund (IMF), the International Bank for Reconstruction and Development (IBRD or World Bank) was founded in 1944 at the United Monetary and Financial Conference of 44 governments at Bretton Woods, New Hampshire, USA. These were established as complementary, international finance institutions to meet needs of international cooperative agreements to deal with monetary and financial problems by providing the machinery that would enable nations to work together toward world prosperity, thereby aiding political stability and fostering peace among nations.

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[1] The views expressed in this paper are those of the author and not necessarily those of the World Bank.

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[3] Based on World Bank Reports and Publications namely: World Bank/ Annual Report 1978; The World Bank, December 1977; The World Bank - Questions and Answers, March 1976; World Bank - International Development Association, April 1978; The International Finance Corporation/Annual Report 1978; and The paper by Mr. Frederick L. Hotes, World Bank Irrigation Adviser entitled: "World Bank Activities in Financing International Water Resources Efforts" presented at the 1977 Annual Meeting of the University Council on Water Resources, Brookings, South Dakota, USA, July 26, 1977.

Although their joint objective as stated above is the same, their roles differed. As indicated by the formal titles, the Fund's main concern is with monetary affairs, and the IBRD's with economic development. The main objectives of the Fund -- the promotion of international monetary cooperation, the encouragement of expansion and balanced growth in international trade, the promotion of exchange stability, the elimination of exchange restrictions, and the correction of balance of payments disequilibria -- complement the IBRD's efforts to promote economic growth in member countries through its loans for productive development projects. The two institutions cooperate closely on operational and analytical matters, hold joint annual meetings, and are housed in neighboring buildings in Washington, D.C.

Membership in IBRD is open to all members of the IMF, and by June 30, 1978, 132 countries had joined. IBRD is owned and controlled by its member governments. By a formal agreement in accordance with the United Nations (UN) Charter, it is recognized as a special Agency of the UN. It began operations in June 1946.

The World Bank is now a group of three institutions, the International Bank for Reconstruction and Development (IBRD), the International Development Association (IDA), and the International Finance Corporation (IFC). The common objectives of these institutions is to help raise standards of living in developing countries by channeling financial resources from developed countries to the developing world.

Sources of Funds

IBRD makes or guarantees loans for productive reconstruction and development projects, both from its own capital, which is provided by its member governments, and through the mobilization of private capital. IBRD's share capital is so structured that any risk involved in its operations is shared by all member governments, roughly in proportion to their economic strength. Capital subscription on June 30, 1978 aggregated the equivalent of about 41,016 million in current U.S. dollars. Only ten percent of the capital has been called and paid in; the remaining ninety percent is subject to call by IBRD only if and when required to meet the obligations of IBRD created by borrowing or guaranteeing loans. Thus, investors, i.e. member countries who might otherwise never become involved in the financing of projects directly are contributing to the economic growth of developing countries.

Lending operations are financed in the world capital markets including private investors, governments, and central banks. Aside from borrowings, paid-in capital subscription, and charges on its loans, IBRD has two other principal sources it can lend. Most important is the flow of repayments on previous loans. In addition it often sells portions of its loans to other investors, chiefly commercial banks. Profit or net earnings are also used to help developing countries by placing these in reserves which strengthen ability to borrow and making reserves available for lending.

To maintain the confidence of both member governments and the international finance community and thereby enable a continued source of funds for development, IBRD carefully appraises all aspects of projects submitted to it for financing. Thus, the planning of projects and analyses must be technically and economically sound. Studies, particularly water and land resources investigations, must be relevant and of the highest quality commensurate with objectives. IBRD also periodically reviews the execution and operation of those projects which it helps finance, and provides advice and assistance to the borrower in the attainment of project objectives.

IBRD's role as a prudent lender is directed to be in the best interests of all concerned: member governments, lenders to IBRD, and borrowers. The performance of IBRD and its borrowers in the use and repayment of the invested and borrowed capital so far continued to find general approval of the world financial community, as demonstrated by their continued willingness to provide needed resources to IBRD.

IBRD Loans

IBRD's charter spells out certain basic rules that govern its operations. It must lend only for productive purposes and must stimulate economic growth in the developing countries where it lends. It must pay due regard to the prospects of repayment. Each loan is made to a government or must be guaranteed by the government concerned. The use of loans cannot be restricted to purchases in any particular member country. And IBRD's decisions to lend must be based only on economic considerations.

IBRD loans generally have a grace period of five years and are repayable over 20 years or less. They are directed toward developing countries at more advanced stages of economic and social growth. The interest rate the Bank charges on its loans is calculated in accordance with a formula related to its cost of borrowing.

While IBRD has traditionally financed all kinds of capital infrastructure, such as roads and railways, telecommunications and ports and power facilities, its present development strategy places a greatly increased emphasis on investments that can directly affect the well-being of the masses of poor people of developing countries by making them more productive and by integrating them as active partners in the development process. This strategy is increasingly evident in the agricultural and rural development projects that IBRD and IDA help finance. It is also evident in projects for education, family planning, and nutrition, and in the Bank's concern for the urban poor who benefit from projects designed to develop water and sewerage facilities as well as "core" low-cost housing, and to increase the productivity of small industries.

At the same time, lending for traditional projects continued, and is being redirected to be more responsive to the new strategy of deliberately focusing on the poorest segments of society in the developing countries.

IDA

The International Development Association was established in 1960 to provide assistance for the same purposes as IBRD, but primarily in the poorer developing countries on terms that would bear less heavily on their balance of payments than IBRD loans. IDA's assistance is, therefore, concentrated on the very poor countries--mainly those with an annual per capita gross national product of less than $520 (in 1975 dollars). More than 50 countries are eligible under this criterion.

Membership in IDA is open to all members of IBRD and 120 of them have joined as of June 30, 1978. The funds used by IDA, called credits to distinguish them from IBRD loans, come mostly in the form of subscriptions, general replenishments from its more industrialized and developed members, special contributions by its richer members, and transfers from the net earnings of IBRD. The terms of IDA credits, which are made to governments only, are 10-year grace periods, 50-year maturities, and no interest, but an annual service charge of 0.75% on the disbursed portion of each credit. Although legally and financially distinct from IBRD, IDA is administered by the same staff.

Its standards for reviewing projects are IBRD's standards, its purpose is the same as the IBRD's and it lends to the same economic sectors for the same purpose as IBRD. Yet the sectorial composition of IBRD loans and IDA credits shows noteworthy differences. These differences result from the varying economic priorities of IBRD borrowers and IDA borrowers.

IFC

The International Finance Corporation was established in 1956. Its special purpose is to promote the growth of the private sector and to assist productive private enterprises in its less developed member countries where such enterprises can advance economic development. IFC is an affiliate of IBRD and, as such, shares with it common objectives and policies for improving the well-being of the peoples of less developed member countries.

Membership in IBRD is a prerequisite for membership in the IFC, which totals 108 countries as of June 30, 1978. Legally and financially, the IFC and IBRD are separate entities; the Corporation has its own operating and legal staff, but draws upon IBRD for administration and other services. It has the same President and many of the same Executive Directors.

IFC is not limited as to the form in which it may provide financing and its terms are flexible. Such financing normally consists of subscriptions to share capital or long-term loans without guarantee of repayment by governments, or both. It helps mobilize other capital and technical expertise for productive ventures that contribute to economic development and meet sound investment criteria. IFC also has a responsiblity to promote such ventures by identifying and bringing together investment opportunities and qualified investors.

In addition, IFC seeks to encourage the flow of private capital in the countries it assists. To this end, it supports the establishment or expansion of local capital markets and financial institutions. It also offers technical assistance to member governments in support of their efforts to create an investment climate which will encourage productive and beneficial domestic and foreign investment.

IBRD/IDA/IFC Lending

In Fiscal Year 1978 (ending June 30, 1978), IBRD together with its affiliates, IDA and IFC, made lending and investment commitments totaling US $8,749.1 million. One hundred and thirty-seven IBRD loans to 46 countries totaled US $6,097.7 million. Ninety-nine IDA credits to 42 countries amounted to US $2,313.0 million. The IFC made 41 investments amounting to US $338.4 million in 31 countries.

The combined IBRD and IDA lending amounted to US $8,410.7 million and was distributed by sectors as follows:

Sector	US $ Million	% of Total
Agricultural and rural development	3,269.7	38.9
Education	351.9	4.1
Energy	--	
Industrial development and finance	909.9	10.8
Industry	391.8	4.7
Nonproject	155.0	1.8
Population and nutrition	58.1	0.7
Power	1,146.2	13.6
Technical assistance	20.3	0.2
Telecommunications	221.1	2.6
Tourism	50.0	0.6
Transportation	1,092.9	13.0
Urban development	368.6	4.4
Water supply and sewage	375.2	4.5
	8,410.7	100.0

The Bank does not fix rigid sectorial priorties; it lends on the basis of the needs of a particular country or a particular region at a particular time. The relatively large amount lent for agriculture reflects the Bank's emphasis in recent years on agricultural development resulting in: (a) a larger proportion of total lending being donated to agriculture; (b) an increased share of agricultural lending going to the poorest countries; (c) a larger number of people benefitting from Bank-supported projects; and (d) projected increases in output by those farmers being assisted.

Assistance to small farmers to become more productive accounts for the major share of lending in this sector. The Bank considers that the small farmer is a critical element as a producer of foodgrains and other food products in many major food-deficit countries. Also, improved economic and social conditions are factors of prime importance in the effort to reduce population growth rates through lower birth rates. Massive rural poverty, sustained and spurred on by an increasing rural population, limited land resources, and inadequate supporting systems, is a continuing feature in most of the Bank's member countries. Bank programs aimed at the poverty problem include land and tenancy reform, credit, water supply systems, extension, training, and research.

Approximately 1/3 of the agricultural lending was for irrigation and drainage projects. The Bank normally finances from 30 to 50 percent of total project costs. Hence the loans represent a share of total project costs of more than double the figures shown. Other multi-lateral and bilateral sources contributed about US $3,000 million to total project costs, with the remainder being contributed by the borrowing countries. The typical Bank-financed irrigation or drainage project can include, in addition to the irrigation supply and distribution system, land preparation, extension and research services, rural water supply, electrification, schools, roads and health facilities, storage and marketing facilities, technical assistance, and training. Some of the other agricultural projects, such as agricultural credit, include substantial amounts for irrigation facilities such as tubewells, minor irrigation systems, and improved on-farm irrigation schemes.

Operating Methods

Every project, irrespective of scope and size, financed by the Bank is considered in the light of a country's total needs, capabilities, and policies. Therefore, comprehensive studies are made of the economy of the country requesting assistance. The studies include detailed analyses of individual sectors and relationships between them, which throw light on the relative importance of alternative projects in achieving the country's development goals. Chiefly, on the basis of these studies, and after consultation with the government, a program of Bank operations in the country is drawn up for a five-year period with an updating annually. This program provides a framework for concrete proposals for action to help the country implement agreed strategy of development. Each individual project is considered within this framework. Equally, project proposals arise out of the joint efforts of government and Bank staff in their search for solutions to common problems. The project is subjected to careful analyses, and a detailed agreement is worked out with the borrower before a loan or credit is approved.

Often, the Bank will recommend that consultants be hired to prepare detailed plans. Upon completion of the preparatory work, the Bank sends a staff mission to make a thorough appraisal of all aspects of the project. When agreement is reached on details of the proposed project and on financial requirements, a formal loan or credit agreement is negotiated. If this is satisfactory, the President presents the proposal to the Executive Directors, who represent all member countries, for their approval.

The approval of a loan does not end the Bank's involvement. In most cases, the borrower seeks bids, on the basis of international competition, for the goods and services required. The Bank releases money only as needed to meet verified expenditures on the project. Goods and services paid for by Bank loans or IDA credits may be obtained from any member country or Switzerland. The Bank pays in whatever currency is required, and the borrower repays in the currency used by the Bank.

Bank involvement continues throughout the life of the project. The borrower provides periodic progress reports, and Bank staff members visit the site from time to time, helping to anticipate and overcome difficulties and ensure that the project's intended benefits to the country are realized. This close supervision is facilitated by the fact that the borrowing country is a part owner of the Bank and shares in the control of its policies and operations. As a cooperative multinational institution, the object of the Bank is to see that each project is carried out at the least possible cost and that it makes its full contribution to the country's development.

Technical Assistance

The provision of technical assistance, an integral part of the Bank's services to its developing member countries, has been expanding vigorously. Consultations take place between Bank staff and borrowers during project preparation and appraisal, and during country or sector reviews. Aside from this steady flow of technical information, the Bank assists its borrowers with the financing of feasibility studies, engineering, and resource surveys, and in helping build up institutions, in training, and the like.

Technical assistance was the exclusive purpose of one loan and two credits, for a total of US $20.3 million during fiscal year 1978. In addition, technical assistance components were included in 151 lending operations, for a total of US $230 million. Also, US $6.4 million of financing was provided by the Bank's Project Preparation Facility. The Facility makes temporary advances for studies and other forms of technical support; the borrower repays the advances by refinancing them through a Bank loan or an IDA credit for the project concerned as soon as it becomes effective. Other forms of assistance are provided on a reimbursable basis, or under equivalent compensatory arrangements, to oil-exporting countries that do not borrow from the Bank. In fiscal 1978, this kind of assistance in the amount of $33 million was directed to four countries.

For many years, the Bank has served as executing agency for preinvestment and technical assistance projects financed by the United Nations Development Programme (UNDP). A number of UNDP-financed, Bank-executed projects provide economic planning assistance. Typically, they call for small teams of planning advisers, supporting consultant services, and training programs for local counterpart staff. Of great significance to the developing countries is the fact that Bank-executed, UNDP-financed projects have an operation focus that very often leads to projects suitable for Bank financing, producing substantial investment follow-up.

The Bank maintains a staff college, the Economic Development Institute (EDI), to train officials of developing countries in the techniques of development. About 5,000 have attended EDI courses in Washington and overseas.

In addition, the Bank conducts a large, continuing program of research -- both basic and applied -- in virtually every aspect of development with which its members are concerned. At present, this program consists of more than 100 studies. Subjects include economic planning, agriculture and rural development, income distribution, international trade and finance, industry, labor-capital substitution, unemployment, urbanization, regional development, public utilities, transportation, financial institutions, and population and human resources.

International Cooperation

While the Bank is large in relative terms, it is only one of many institutions -- national and international, public and private -- that provide financial and technical assistance to developing countries. In the public sphere alone, a dozen or more international institutions and 25 or 30 national agencies are involved in one way or another. With such a multiplicity of donors, lenders, and providers of technical assistance, close cooperation and some degree of coordination are essential. Methods employed by the Bank to achieve this vary widely, depending, among other factors, on the nature and scope of each institution's program.

The largest and oldest of the Cooperative Programs concerning agriculture is that between the Bank and the Food and Agriculture Organization of the United Nations. During fiscal year 1978 it staffed and carried out 177 missions in 55 countries. Loans for projects prepared by the Program represented about one-third of the year's lending for agriculture. Emphasis was on projects to benefit the rural poor and to promote close involvement of member countries in the formulation of projects.

Types of Missions

There are usually four types of Bank missions involved in generating, financing, and implementing agricultural projects. The mission names are derived from the specific functions, i.e. identification, preparation, appraisal, and supervision.

Identification missions go to the field to make a preliminary determination of the nature and size of potential projects and the establishment of their prima-facie priority. Preparation missions provide advice to governments on project formulation and on the planning and execution of feasibility studies. Occasionally consultants may assist these types of missions. The feasibility study may be performed by the government or by consultants from external government or international agencies or by private consultants.

Appraisal missions evaluate projects on the basis of feasibility or equivalent studies and prepare a report that provides technical, economical, and financial justification of the proposed project for review by Bank management and for loan negotiations with the borrower. The appraisal report also serves as technical background and guide for project implementation. Typical types of consultants or Bank personnel used in irrigation project appraisals are: irrigation and drainage engineers, agriculturalists, agricultural economists, soil scientists, dam designers, hydrologists, and financial analysts.

Supervision missions are sent during project execution, usually twice a year, to review progress in the field. Normally such missions are small and exclusively comprised of Bank staff, but occasionally a need develops for augmenting regular staff or for special expertise to review an unusual field problem. The principal role of the supervision mission is to ascertain that the project is being executed and operated as set forth in the loan documents, but borrowers frequently seek Bank advice during these phases.

The Bank has spent about US $7 to US $8 million annually in recent years to engage the services of the individual consultants that provide special expertise on Bank missions. In some cases the Bank contracts with a company or an institution for the services of a specific individual expert, if this is the best way to obtain the services of the specialist. The consultant joins other mission members to review in the field the project under consideration, and upon return to headquarters is expected to prepare a complete report for his area of responsibility which can be incorporated into the mission report.

Examples of Agricultural Projects

Four examples of agricultual projects approved for IBRD and IDA assistance in Fiscal Year 1978 that involved water and land resource studies with participation of soil scientists are as follows:

Afghanistan. IDA - US $22 million. Some 12,000 farm families stand to benefit from a second Khanabad irrigation project which aims to develop agriculture by rehabilitating and extending existing irrigation and drainage schemes, extending agricultural credit to farmers, and by providing an efficient extension service. A malaria control program is included; so, too, is a feasibility study for a dam about 90 kilometers above the project area. Total cost: US $28.7 million.

Indonesia. IBRD - US $140 million. Some 189,000 farm families will benefit from a tenth irrigation project designed to rehabilitate, upgrade, and expand existing irrigation systems. Three construction components are included in the project, as are feasibility studies and detailed design work for a number of dams. Total cost: US $216 million.

Pakistan. IDA - US $70 million. Soil salinization will be halted and surface water deliveries increased by a project that includes canal remodeling, tubewell and drainage system construction, and credit and technical assistance to farmers living east of the Indus River in the Rahimyar Khan district of Punjab province. Agricultural production (mainly foodgrains, seed cotton, and oilseeds), employment, and incomes should all increase substantially. The United Kingdom is extending a US $16 million grant and the Kreditanstalt fur Wiederaufbau (KfW) a US $9.5 million credit to help meet project costs. Total cost: US $170 million.

Philippines. IBRD - US $150 million. To help finance the second stage development of a multi-purpose project on the Magat River, a loan will be made available to support a project consisting of all civil works for the main dam and appurtenant structures, reservoir area population resettlement, installed mechanical equipment, and the services of consultants. Total cost: US $346 million.

WATER AND LAND RESOURCE INVESTIGATIONS

The studies made in generating, appraising, and implementing agricultural projects usually address the present social, agronomic, and economic situation with respect to food and fiber production, marketing, consumption, and means and feasibility for modification. This includes water, land, human resources, and institutional development. Also changes in land use for increasing production and marketing to benefit farmers and other people are considered commensurate with promoting social well-being and improving or maintaining a favorable environment. For these studies, agriculture encompasses land resources, farm enterprises, and socioeconomic surveys. The agriculture study might cover a diversity of needs and conditions including both rainfed and irrigated lowland or upland agriculture under either private or government ownership and management.

Water and land resource studies serve an important role in the Bank's programs for agricultural and economic development. The investigations must integrate the activities of the several disciplines including water quality, plant science, hydrology, drainage, environmental science, engineering, sociology, geology, soil science, economics, and land and water use and management. Important in these studies is coordination of their independent activities into a meaningful framework of analyses. From the evaluations, alternative plans are developed to indicate required programming, operation, and development procedures conforming to area needs and controlling policies. Analysis is made of land use problems and opportunities associated with alternative plans, recognizing the natural and modified resource base; existing and potential land use patterns; zoning regulations; and general relationship to environmental, social, and economic aspects of the setting. All plans developed for achieving goals involve costs and benefits. In this regard, land use suitability classification, if properly structured and implemented, is a useful tool for identifying needs, establishing opportunities, and selecting lands for development.

The process is somewhat analogous to arranging for transportation at a travel office, eating at a large cafeteria or shopping at a large supermarket. The choices of items and combinations are numerous but somewhere along the line, someone has to pick up the tab and digest the bill. The final cost of investigations for planning is also very important. The borrower has to also bear these costs.

Land Selection

Land use suitability classification is a key element in identifying, appraising, implementing, and maintaining agricultural developments. The Bank is in the process of establishing general requirements and guidelines for scope, kind, and amount of work for the various types of planning investigations and conditions encountered. The Bank is giving consideration to all known systems of soil survey and land classification, particularly those used by member governments. Further, the Bank is open to and solicits suggestions from any group or persons wishing to contribute ideas and recommendations. The Bank staff participates in the many consultations held for improving and advancing land selection criteria and procedures.

In many of the developing countries, the land resource studies, particularly those of feasibility grade, are made by consulting firms. The borrower, on its own or with the assistance of advisors or consultants, is expected to propose and undertake suitable soil survey and land classification procedures. They are encouraged to prepare techniques drawn from their experience or that of others applicable to the particular conditions of the project under investigation. In exceptional cases at the request of the government, the Bank may propose to the consultant standards, methods, procedures and specifications for the conduct of a specific survey.

The system of land classification should be unifying and universally applicable to either diversified cropping or wetland rice production for all situations and ranges in water supply and control including rainfed agriculture, irrigated agriculture, water regulation in food plains, and reclamation of marshlands and tidelands (Peters, 1975). Accordingly, the surveys must cope with differences in the source, quality, and control of water. The economics with respect to productivity, land development, flooding, and drainage are highly relevant.

A feasibility grade land resource survey for irrigation development should establish the extent and degree of suitability of lands for sustained profitable irrigated agriculture. It should deal with the question of whether or not the project is worthy of construction. It should be supported with special studies in the fields of water quality, soils, topography, drainage, economics, and land use in selecting lands for irrigation. The compilation of findings and presentation of results should be accomplished by narrative reports and land classification maps and pertinent field and laboratory data. The report should cover basic data, premises, description of methods of study, discussion of results, and pertinent conclusions and recommendations relating to investment feasibility.

Bank experience in working on many projects in many countries having diverse policies, goals, and conditions have brought out some definite requirements. A major requirement is the necessity to fully explore and consider the controlling policies in structuring and implementing a land classification for local application. To be useful and effective a survey must avoid a rigid or fixed procedure. A survey should be structured to effectively serve the purpose of the investigation at hand and be site-specific in scope and application, i.e. it must be fitted to the specific environmental setting including economic, social, physical, and legal patterns existing in the area. It is extremely important that a survey be accomplished at a cost that the borrower can afford to pay and be acceptable in relation to the investment foreseen for ensuring development activities. It is also important that the survey be completed within a time frame that will facilitate planning.

So often, it is not understood that requirements of a land classification set up primarily to guide on-farm land development and settlement following initial project construction can be expected to differ from one aimed at determining engineering, economic, and agronomic feasibility in planning for a project. Both the scope and degree of detail can differ markedly.

Methodology between countries may vary according to whether the government expects the farmer or landowner to pay for all development costs or if the government does all of the on-farm development with no direct cost to the farmer. The matter of handling land development costs should be resolved prior to initiating a survey.

Land classification surveys or interpretations of soil surveys should express the land-water-crop and economic interactions expected to prevail after resource and management modification (Maletic and Hutchings, 1967). This involves identifying and evaluating changes anticipated to result from development or reclamation and management. The interactions should be expressed in terms of a suitable economic parameter reflecting productivity, preferably net farm income.

Most land factors, including soil depth, are changeable at a cost. Typical changeable factors include salinity, sodicity, titratable acidity and exchangeable aluminum, depths to water table, relief, brush and tree cover, rock cover, drainage, and flood hazard. Particle-size distribution or texture of subsoils and substrata occurring at depths not disturbed by tillage and landforming is about the only factor that may not be altered.

Some of the changes can be brought about by modifying water control measures and management. These include variation in depths to water tables and associated soil moisture, salinity, and aeration conditions affecting tillage and crop growth. Other examples are modification of slope and microrelief by landforming; and alteration of soil profile characteristics by deep plowing, chiseling, or addition of amendments. Soil texture may be modified by sediment in water entering the soil.

The manner and magnitude of water control can effectively serve to regulate salt effect on lands, crops, social and economic conditions, and the environment. The concentration and composition of salts in the soil solution and associated exchangeable ion status on soils can be influenced by numerous factors including the composition of water applied, the rate of water application and leaching, dissolution and precipitation of soil solution constituents, and the rate and amount of drainage. Flooding of soil, as practiced under rice cultivation, sets into motion a series of physical, microbiological, and chemical processes which influence crop growth (Ponnamperuma, 1965). Soil acidity usually decreases upon flooding.

Whether given characteristics will be changed usually depends upon economic considerations. The survey must deal with two aspects of this principle. Can the change be accomplished, and what degree of change is economically feasible? This is largely dependent on the climatic and economic setting of the project. For example, a large investment may be made to reclaim a saline, sodic or acid soil which after improvement will yield a new farm income of US $500 per hectare. In another setting, where net income after improvement would only be US $75 per hectare, the soil having similar conditions might be regarded as non-reclaimable. In the latter case, it may be infeasible to make the change.

The establishment of the minimum land quality of maximum development cost that should comprise arable land or the service area is requisite in implementing the basic and most important decision in land selection, which is the separation of lands which are suitable for development from those which are not. In doing this, recognition should be given to the fact that in fitting economics into a land selection there is a limit on the attainable precision. Thus, management levels, yield estimates, and related factors can be expected to vary in a particular area and with time. The imprecision involved needs to be accepted; otherwise, the economic principles guiding choice of land can be rather useless and the alternative would be to use arbitrary physical limits for land class determination. This usually results in poor planning for the development of a resource. When confronted with decisions to build or not build, to serve this area and not the other, and to properly size facilities, someone needs to make a firm interpretation. Much of the data can be collected when surveys are approached as interdisciplinary exercises.

In investigating lands consisting of highly leached and weathered soils, a strong soil characterization program should be conducted. The chemical status of such soils needs to be carefully evaluated along with observable characteristics in making sound selections of arable land. The problems confronted with these soils are usually fertility-related chemical characteristics requiring special appraisal. These include degree of weathering of the clay minerals; soil acidity; charge status both negative and positive and associated ion population; soluble and exchangeable iron, aluminum, and manganese; base saturation of cation exchange capacity at relevant pH values; and nutrient status of the soils. Such characterizations identify infertile soils having limited suitability for continuous crop production because of the need for high inputs of both money and management. On the other soils they indicate the type and level of production inputs required to attain specified yield levels of particular crops. Of course, other soil characteristics such as texture, structure, depth, water-holding capacity, infiltration rate, permeability, and claypans are evaluated as are water quality, climate, topography, and drainage conditions. Salinity reclamation and control can be a factor in high rainfall areas including the tropics.

It is imperative that irrigation suitability surveys be supported by laboratory and field testing and evaluation that will assure a definitive diagnosis of soil salinity and sodicity under present (without project) conditions and prognosis of these soil properties associated with agronomic response and economic significance under future (with project) conditions. This necessitates adapting and implementing meaningful procedures and studying the irrigation experience on similar lands. It is essential that land classification surveys and the drainage investigations be fully integrated and coordinated.

Drainage Investigations

Both land drainability and drainage requirements are needed in water and land projects. Kinds of information needed include: the capacity of the soils, subsoils, and substrata to transmit water; amount, source, movement and chemical characteristics of the water that must be transmitted; and available hydraulic gradients, both natural and those that can be induced by engineering works (USDI Bureau of Reclamation, 1978). The studies usually should include evaluation of hydrology, geology, meteorology, particularly effective precipitation, topography, soils, and present and anticipated irrigation practices and cropping patterns; conduct of field measurements for hydraulic conductivity, and design of any required drainage.

Water Suitability

The suitability of a water for irrigation should be determined by integrating the land and water factors and identifying those lands that will respond feasibly to a water supply of a given quality. Water quality standards or ratings per se may not be appropriate in appraising the usability of water for irrigation. Criteria of water suitability vary with the intended use of the water (Bower, 1974). As has been stated by Fireman (1960): "Its usability depends on what can be done with the water if applied to a given soil under a particular set of circumstances. The successful long-term use of any irrigation water depends more on rainfall leaching, irrigation water management, salt tolerance of crops, and soil management practices than upon water quality itself." Thus, the suitability of an irrigation water must be evaluated based on the specific conditions under which it will be used, including crops to be grown, soil properties, irrigation management, cultural practices, climatic conditions, and especially leaching fraction (Rhoades and Merrill, 1976).

Present Land Use

Information is usually needed on present land use in a proposed project and within impacted areas associated with the project. The land use categories to be mapped and who does the mapping need to be established in consultation with planners.

Laboratory Support

In addition to field measurements for water and salt movement and retention in soils, a certain amount of characterization by laboratory methods is required in support of land selection for water and land resource development. The objective of characterizing soil is to support judgment in estimating land development reclamation potential. The laboratory analyses should be performed on an action program basis and serve a practical purpose.

A system of screenable soil characterization that is sequential in analytical approach should be implemented. This involves applying logical deductive reasoning in providing for specific useful data. These data are generated and evaluated sequentially as required to support decisions to soil-specific problems directly and to determine additional properties. This maximizes use of data for problem quantification and degree of remedial measures necessary. It should be used to study problems and derive solutions rather than using standardized routine tests. It follows that application of this technique optimizes effort and reduces expenses (personal communication, L.L. Resler, USDI Bureau of Reclamation, Denver, CO).

There is a tendency among many laboratory activities to "over test"; i.e. perform too many or unnecessary tests on certain soils at the expense of not performing essential or critical testing on particular samples. Also, some laboratory activities tend to emphasize comprehensive analyses of samples from master sites and neglect selection, sequence, and quality control in mass testing performed on a screenable basis. The latter-type testing is frequently handled as routine work utilizing the least dependable personnel and considered not worthy of competent and close supervision.

Thus, too often the screenable laboratory testing becomes a liability rather than an asset in supporting surveys. Because the screenable testing represents coverage of areas involving a high sampling density, it serves as an extremely important input into land categorization. Therefore, it should be administered for performance with respect to both quality and quantity commensurate with the goals and objectives of the investigations.

To effectively support field appraisals, all laboratory work should be closely coordinated with field work. Laboratory studies should be preceded by or made concurrently with field studies. The number and type of studies should be determined by area conditions -- particularly variability, the controlling survey specifications, and needs. There should be a joint plan between field and laboratory investigations prior to taking of samples (Kellogg, 1962).

In implementing screenable testing, relevant evaluation parameters need to be established and measured and their interrelationships understood. In all investigational programs, care should be taken to not create a false impression of technical excellence by generating superfluous analytical data. Screenable testing tends to avoid this, provided it is properly set up, implemented, and results interpreted. Of course this type of characterization program should not preclude testing on the conventional "complete analysis" basis of samples from master sites.

Usefulness of Soil Surveys

Soil surveys, particularly genetic and morphological classifications (taxonomic soil surveys) are useful in planning for water and land resource development. Invariably, there have been limitations involved with such surveys and interpretations that could be made in selecting lands for irrigation development for diversified cropping. The limitations along with mutual support possible in substituting soil surveys for land classifications become understandable through recognizing the unique differences in relation to specific needs for varied applications. That soil surveys may not fully satisfy requirements should not be taken as a case for indictment, drastic change, or abandonment. On the contrary, soil surveys should be used to the fullest extent possible.

In addressing the subject and trying to develop understanding of the subject over a period of many years in several countries, it is helpful to recognize the numerous types of soil surveys conducted in the world and reasons for different approaches along with the many specific requirements for varied applications involving a wide range in climatic and economic settings. Often, it is not possible when making a soil survey to foresee all future applications. Further, the demands of a soil survey even though anticipated in advance usually preclude structuring a system that will serve all purposes. It is frequently difficult to obtain participation of the requisite disciplines especially when planning for a specific use which may not materialize immediately or for several years. The cost of investigations can be a constraint on the amount of data collection. Thus, limitations in using soil surveys are inevitable.

Soil characteristics which are important in a genetic or morphological classification are normally by no means the only factors that are of primary importance in land classification for certain uses, particularly irrigation. Soils are an important aspect of lands but may be overshadowed by many factors including economic circumstances, agricultural technology, resourcefulness of people, climate, topography, and drainage. It follows that the factors other than soil have to also be taken into account, kept in perspective, and integrated. Data collection and land classification for irrigation planning need to be approached as an interdisciplinary exercise, wherein contributions to the land classification are made by drainage engineers, economists, and hydrologists. Unsatisfactory land classification surveys can arise if a soil scientist works alone and concentrates almost solely on the soil mantle. Most soil survey organizations even in the developed countries, being vertical rather than horizontal with respect to management, do not accommodate participation of other specialists.

There can also be other problems in implementing soil surveys and making interpretations for uses such as irrigated agriculture. Many workers trained in mapping natural bodies have great difficulty in initial attempts to adopt and adapt to economic land classification. The difficulty seems to be in conceptualizing the landscape under the conditions expected to prevail under the new land use regime through economic reasoning and installation of control structures. Another difficulty concerns notions that boundaries of natural bodies will coincide with class boundaries, ranking land for use suitability. This rarely occurs because kinds of soil having natural boundaries are commonly found in contrasting economic environment or vice versa. The location, size of tract, and other economic characteristics of land are highly significant in land classification.

It can be very difficult to rely upon natural body mapping, as commonly made, for classifying a given area, particularly on complex and problem lands consisting of soils and substrata requiring extensive and intensive field and laboratory characterization. Although logical procedures can be advanced for accomplishing the required integration, experience has shown that the procedures necessary for a land classifier to establish class boundaries related to natural body mapping units can be nearly as time-consuming as the conduct of a basic land classification without benefit of a soil survey. This is not to imply that soil surveys are not useful. Natural soil bodies, because of their information content, can provide much essential information, including bases for deriving predictions.

Principal deficiencies of most soil surveys in planning for irrigation development are insufficient depth of soil characterization, simulation of soil moisture retention and movement in the laboratory without field confirmation, inadequate soil drainability and land drainage appraisals, and lack of definitive laboratory characterizations for soil sodicity (alkali), beneficial gypsum, and effective soil acidity. Soil profile examination to the depth of 1-2 meters usually will not suffice in appraising economics of drainage. Soil profile examination should include depths to 3 meters and some of these need to be extended to greater depths.

There is no theoretical reason why soil surveys, if properly structured and adequately supplemented, will not meet needs in planning for water and land resource development for alternative uses. Many workers have given thought to this and some have advanced suitable procedures (largely unpublished) for accomplishing this. Often, it is not practical nor technically and economically expedient to go this route. Also, in areas having no previous soil survey and where a decision has been made to embark upon detailed investigations involving extensive coverage and intensive study, the soil survey can be the product of the land classification rather than vice versa.

Increasing and Expanding the Role of Soil Surveyors

Soil survey organizations and soil surveyors worldwide are dedicated to having a specialized and professional product in soil inventory information and interpretive evaluations and classifications that will be extremely valuable and relevant to needs in water and resource development. Many workers, primarily in the more developed countries, are generally contending that their product is neither adequately understood nor used by planners and decision makers. Some are gravely concerned and express frustration at having an outstandingly useful product but not being able to attract logical customers and selling it to them. They are seeking ways and means by various methods and forums as evidenced by this Workshop to bridge the gap whereby there might be generated an increased awareness for and transfer and use of soil inventory information.

Certainly and unfortunately, there is validity and justification in some of the contentions. However, in certain circles and too many instances, there seems to be too much crying and only posing a dilemma. Although this may serve to get needed attention, it, in being rather negative, is not likely to facilitate changing the situation. A more objective and positive approach along with more consultation and cooperation with users is needed if the problem is to be identified and solved.

It should not be the sole prerogative of the soil surveyor to determine the nature of the product and what should be marketed. The user (including farmers, planners, taxpayers, financing agencies, governments, and others) of soil inventory information and interpretations that can be made also have an interest and stake in applications and have the right to be in on decisions on what can be used and is to be bought for specific needs within institutional, legal, time, and financial constraints. Therefore, the soil surveyor should seek out the users and solicit views on needs and jointly develop the product. It is essential that the process be a two-way street with communications and travel going in both directions.

Soil scientists represent a basic discipline vital to planning but do not possess a monopoly on involvement and knowledge in the collection of land resource information, interpretations, and integration in planning for irrigation. As previously stated, other basic and cooperating groups include agronomy, engineering, hydrology, geomorphology, environmental science, economics, law, and sociology. The decision-making discipline is political science. The soil surveyor or land classifier, after consultation with the other disciplines in developing survey specifications or guidelines for a specific setting, can accomplish most of the mapping, delineation, and classification of areas susceptible to sustained agriculture, i.e. arable lands as guided by farm production economics. This would include evaluation and mapping of land productivity, land development costs, land drainability, and interaction of water quality on soils and crops for ranges of leaching fraction. The selection of those lands classed arable to be actually served by project facilities is guided by economics of plan formulation with the other disciplines, particularly engineering, economics, and law, having major roles but with the decision maker doing the final selection. This selection usually reflects the desire to promote socio-economic development and achieve a more equitable distribution of wealth.

Irrigation engineers, drainage specialists, and water utilization hydrologists are knowledgeable as a result of both training and experience in the importance, methods of measurement, and applications of moisture retention and movement in soils, e.g. infiltration rate, hydraulic conductivity, hydraulic head, hydraulic gradient, water table location and conditions, moisture retention at various tensions, and so-called field capacity. It is usually the soils report rather than the engineering report that fails to provide a satisfactory confirmation of a perched water table and distinguish between q and k in Darcy's law. The dam engineers and drainage specialists are usually most proficient in installing piezometers to establish the occurrence of artesion pressures and characteristics of moisture movement in slowly permeable earth material.

Enlisted personnel of many navies readily adapt to testing the quality of distilled water for usability in boilers to produce steam. This involves appraising the intensity of acidity or alkalinity, i.e. pH, salinity, and total hardness, by rapid but quantitative measurements respectively for electromotive force, electrical conductivity, and calcium plus magnesium by versenate titration. The same type of analysis, using a kit, can be used to rapidly characterize soil in the field with respect to both salinity and sodicity (alkali). In the latter regard, reliable values can be obtained for the estimated sodium adsorption ratio, gypsum requirement, and residual gypsum. These characterizations in combination with other innovations are more useful in the diagnosis and prognosis of soil sodicity than only measuring for exchangeable sodium in milliequivalents per 100 grams and exchangeable sodium percentage by conventional procedures, which are time-consuming, and using sophisticated laboratory equipment by flame photometry and atomic adsorption spectrophometry. The procedures for rapid field testing were developed by the USDA Salinity Laboratory about 25 years ago and kits have been on the market as long. Yet, few laboratory and field soil scientists have availed themselves of this opportunity to become more effective and efficient.

The requisite level of land productivity or permissible land development cost for a specific project setting as perceived by a soil surveyor or land classifier may differ from that of an economist even if the interrelationship of their work is mutually understood and there has been close cooperation. Just as the pedologist has his tools, diagnostic criteria, and jargon, the economist also has tools and jargon but that of the latter is more standardized and universal and can be translated into and comprehended in most languages including English. Attempts at translating the Greek nomenclature of the American system of soil taxonomy into English have not been too successful.

To serve the user of soil survey information in an increased and expanded role by working more effectively with other disciplines, most soil surveyors need to become more cognizant of the role, tools, and terms of economists. Land selection for development and increasing productivity is influenced by economic evaluation in several ways. Some of the terms that need to be understood are accounting price, adjustment value, benefit-cost ratio, book value, consumptive rate of interest, discount rate, economic rate of return, elasticity of the marginal utility of income, externality, financial rate of return, least cost analysis, opportunity cost of capital, shadow exchange rate, and world market price.

Probably the least understood and most scoffed at is the role of lawyers in land selection for irrigation. The delineation of irrigable areas and water allocations and impacts must conform to the laws of a country and international law. Water lawyers and courts are the final authority on what lands can be legally served under existing laws with irrigation and drainage facilities. Some are even knowledgeable in irrigation suitability land classification.

In the United States, the legal profession in representing the principal user, i.e. the people especially farmers, wrote, through Congress, the paramount legislation comprising the 1924 Fact Finder's Act. This law established the type of land classification required for all Federal Reclamation Projects and defined the land classes in terms of an economic parameter, i.e. net farm income and payment capacity. This led to development by planners, economists, lawyers, engineers, hydrologists and soil scientists of the USDI Bureau of Reclamation system of land classification for systematically obtaining and interpreting resource information. Other countries do not have the specific law but it can be expected that policies and executive orders will be in accordance with legal constraints, particularly in the many countries having Anglo-Saxon law.

The United Nations Food and Agriculture Organization (FAO), Rome has been developing, over a period of about 10 years, A Framework of Land Evaluation. This is being developed through international cooperation and stems from consultations with the World Bank which has always insisted (as recognized by FAO) that soil surveys as traditionally made did not meet needs in assessing agricultural potential of the world's land resources. In this regard, the inadequacy of soil surveys in serving needs of users and some of the reasons why are eloquently presented by Dudal (1978a). In the Framework, land is being defined as the physical environment including soils, climate, relief, hydrology, and vegetation. The evaluations are made for specific uses with respect to specific inputs and with interdisciplinary participation of crop ecologists, agronomists, climatologists, and economists in addition to pedologists. While the evaluations of lands have been initially based on physical attributes, developers of the framework recognize that economic and social factors need to be taken into account (Dudal, 1978b). FAO is presently exploring requirements with respect to both social and economic aspects and giving consideration to evaluation of these factors in the Framework.

In advocating a system of classification for a specific use, the soil surveyor should dig in and think how the use differs from and is better than others, and to what extent the user will benefit by endorsing it.

Soil surveyors can be assured that the users of soil inventory information are hungry for a good product and want to know as much as possible about the product, how it is produced, and the people and organization who produce it. Hopefully, participation by the Bank at this workshop will be construed as confirming this view and as an effort by a major user of soil resource information to seek this type of information and to exchange views.

CONCLUSION

Soil surveyors have made contributions to water and land resource development and will continue to do so in the future. The Bank would like to be kept advised of findings and advances and looks forward to sharing experiences and views on this important work. The opportunity to participate in the workshop is appreciated.

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QUESTIONS/COMMENTS (by H. Eswaran):

Does the Bank have guidelines for making assessment of SRIs before granting a loan or is it made from personal experience and judgment. Are these guidelines available?

ANSWERS:

As indicated in the paper, the borrower, on its own or with the assistance of advisers or consultants, is expected to propose and conduct suitable soil survey and land classification procedures. They are encouraged to prepare techniques drawn from their experience or that of others, applicable to the particular conditions of the project under investigation. These are reviewed by the Bank for relevancy and adequacy. In exceptional cases, at the request of the Government, the Bank may propose standards, methods, procedures and specifications for conduct of a specific survey.

As stated in the paper, the Bank is in the process of establishing general requirements and guidelines for scope, kind, and amount of work for the various types of planning investigations and situations encountered. Major requirements of land classification surveys are given in the paper. When completed these generalized guidelines probably will be available upon request.

QUESTIONS/COMMENTS (by R. Lucey):

Do the farmers you refer to as poor agree that they are poor?

ANSWERS:

The term poor is what the "Bank" uses, i.e. the people in the Bank use. In my opinion some of the farmers are poor and some are not. Perhaps we should use a different term than poor farmer.

THE COMPREHENSIVE RESOURCE INVENTORY AND EVALUATION SYSTEM

A CARIBBEAN EXPERIENCE

by

John W. Putman[1]

The creation of a natural resource base assessment for national planning poses formidable problems. The problems are even more severe in the developing world. The time, budgetary support, and professional expertise necessary to develop these data are extremely scarce. Moreover, developing countries have an immediate need to plan and monitor agricultural resource management and development programs. Hence, soil scientists and planners must draw upon their scientific backgrounds to provide initial resource assessments for national-level planning from data that do exist in developing countries.

CRIES OBJECTIVES

The Comprehensive Resource Inventory and Evaluation System (CRIES) Study was initiated two years ago in the Dominican Republic, Nicaragua, and Costa Rica to explore methods for adapting U.S. procedures to the agricultural resource planning problems of developing countries. The study involves the Agency for International Development (AID), three agencies of the United States Department of Agriculture [Economics, Statistics, and Cooperative Service (ESCS), Soil Conservation Service (SCS), and Science and Education Administration (SEA)], and two Departments of Michigan State University (Agricultural Economics and Resource Development). The overall goals of the study are to transfer to the participating countries the capacity to analyze agricultural resource problems. Specific objectives are:

1) To assist host countries in incorporating the system and developing a data base and analytical capacity to explore the extent, quality, and use options of agricultural resources and estimate the impact of alternative resource policies and procedures.

2) To expand the number and enhance the capability of host country planning personnel to maintain, refine, and use the information base and analytical procedures on a sustained basis.

3) To develop a coordinated resource classification system and analytical framework adaptable to many countries and capable of accumulating, storing, and transferring consistent information among countries.

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[1]Leader, Agricultural Production Potential Studies, NRED; Economics, Statistics, and Cooperative Service; USDA; East Lansing, Michigan.

Objective 3 is the focus of my remarks today. Before getting to the specifics, however, let me elaborate on some longer-range goals that underlie the design of the study.

Long-range planning of U.S. agriculture and forecasting of domestic production needs and prices are heavily dependent upon world markets and the United States' share in those markets. Further export markets will be determined, in part, by the ability of food- and fiber-deficit countries to increase their own production. Hence, the accumulation of consistent estimates of country and multicountry production capability and relative supply costs is of great importance to the USDA in assessing comparative advantage among countries and prospects for world food supplies.

As a consequence, project development has stressed the need for a system which can be universally applied to support long-range departmental objectives of developing information systems with consistent linkages among systems. Moreover, we are concerned with a sound basis for agrotechnology transfer. Beyond the traditional use of technology transfer, we see it as a way to extend information and improve forecasts.

CONCEPTUAL NEEDS

Figure 1 depicts the major components needed for a resource assessment. The system poses a heavy burden on planners in developing countries. Getting empirical data to fill every cell is impossible. Hence, the immediate objective is to conceptualize the needed data in appropriate form and fill the "first generation" data set with the most objective and informed judgments possible. Even judgmental data, when arranged in a logical, systematic system, can improve decisions. More importantly, the system provides the structure and form for future data development efforts. If properly designed and maintained, the system can be very useful while it is being refined and can create great efficiency in prioritizing future data gathering efforts.

As in any resource assessment, the "cornerstone" of the system is the scheme used to identify and stratify land resources into functional planning units. The resource classification scheme provides the means for storing and using all of the many data in the system. The resource units must be sufficiently homogeneous to be characterized by unique estimates of all other variables -- land use, crop adaptability and productivity, management practices, treatment needs, and development potential. The resource units must also be geographically located for computational purposes and analysis with other data sets from other sources and other geographic configurations. Finally, the system must be controlled to manageable data proportions.

CRIES AGRICULTURAL RESOURCE INVENTORY SYSTEM

The basic conceptual units for the CRIES Agricultural Resource Inventory System (ARIS) are the resource planning unit (RPU) and the production potential area (PPA). RPUs and PPAs are defined as follows:

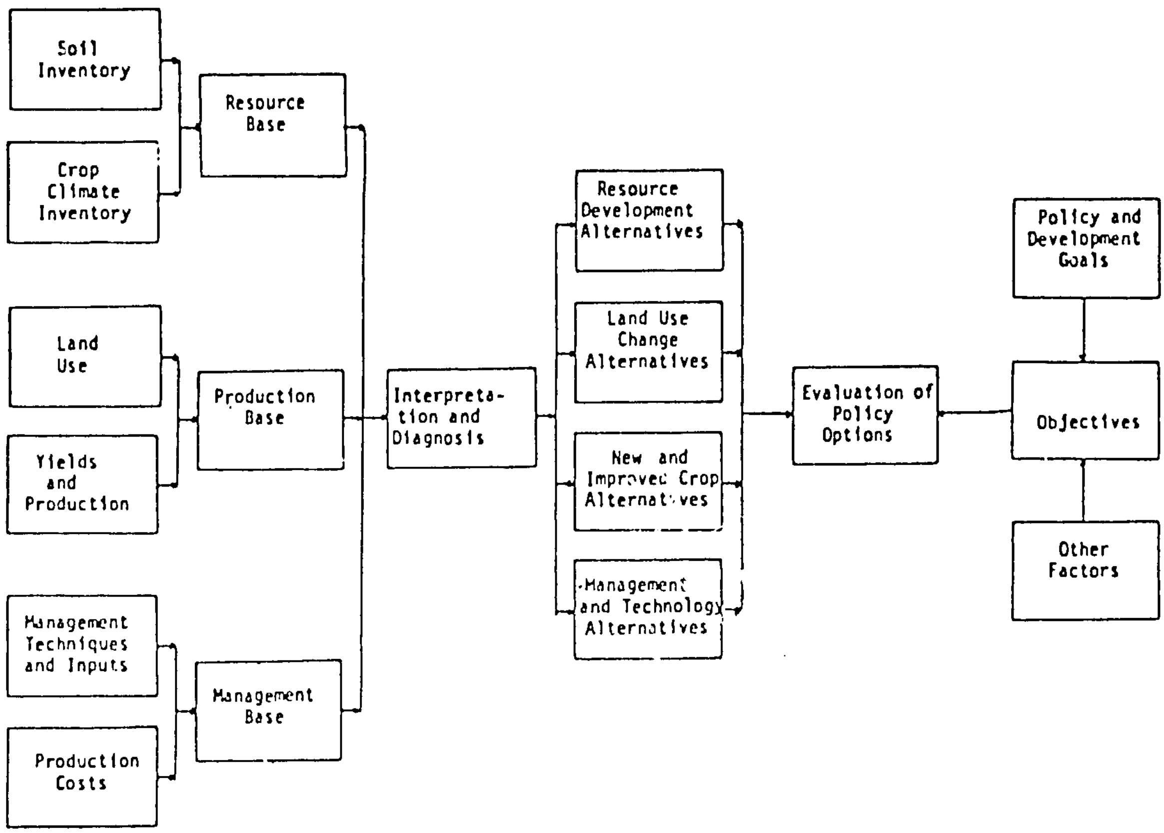

Fig. 1. Flowchart depicting major components and their interrelationship in the CRIES system.

Resource Planning Unit

An RPU is a geographically delineated unit of land (not necessarily contiguous), that is relatively uniform with respect to the land forms, kinds and patterns of soil bodies, climates, water resources, potential vegetation, and general types of agriculture.

Production Potential Areas

A PPA is an aggregate of individual soil bodies and associated micro-climates within an RPU which is sufficiently homogeneous with respect to plant adaptability, potential, productivity, and management requirements to be reliably depicted by unique agronomic and economic estimates for national and regional analysis and planning.

The concepts and definitions of RPUs and PPAs reflect the relationships among soils, climate, and plant growth. They are based upon two underlying taxonomies -- soils and crop climate. The soil resources are stratified according to USDA's Soil Taxonomy (Soil Survey Staff, 1975). I won't attempt any explanation of soil taxonomy to this group. The crop climate taxonomy is a classification system being developed by the Eco-systematics Program, Science and Education Administration [formerly Agricultural Research Service (ARS)], USDA, entitled, "Crop Climate Taxonomy" (Science and Education Administration, USDA, 1978). Intended as a universal system, it can accommodate inputs and interpretations from the many climatic vegetative systems used in the various parts of the world. Three levels of categories are described in this hierarchical system -- primary, secondary, and tertiary. Criteria for the system are based upon annual temperature and rainfall and seasonality of precipitation.

DERIVATION OF RPUs AND PPAs

Since RPUs generally depict physiographic areas, they can be mapped rather quickly and efficiently in areas where soil information is scarce and scattered. They have discernible natural features and, when combined with crop climate zones, are describable with respect to climate. They provide the cartographic reference for analytical purposes and serve as reference points for field technicians.

To interpret an RPU for plant adaptability, productivity, and management choices, the soil bodies and associated microclimates within an RPU must be considered in greater detail. Hence, the major soil bodies and associated microclimates are identified and described as PPAs. They are estimated with respect to their extent and patterns within an RPU. The PPA descriptions provide the basis for determining coefficients used in our system of resource assessment and analysis.

PPAs are taxonomically definable and could be mapped. Mapping them, while very desirable, is unnecessary for national planning and policy analysis. Policy choices and priorities can be based upon the general knowledge of the extent, distribution, and patterns of the PPA within the map units. Scarce manpower and funds to generate the soil detail for implementation can be more efficiently programmed after national policies and priorities are established.

CORRESPONDING LEVELS OF TAXONOMIES

The Soil Taxonomy and "Crop Climate Taxonomy" must be used at appropriate corresponding levels in the taxonomies to provide meaningful analytical units for agricultural planning and production potential assessment. We are currently describing PPAs at the associations of phases of subgroup level of Soil Taxonomy and at the secondary level of "Crop Climate Taxonomy."

Since both systems are hierarchical, we see other possibilities for linking the various data and analytical levels. Over time, research data, field trials, and other information from projects such as the "Benchmark Soil Project" can be accumulated at the series and family level and used to improve the knowledge in the appropriate phases of subgroup categories we use for national analysis. Similarly, global studies aggregated to higher levels of taxonomic detail can draw on such material for input. We hope to use Soil Taxonomy much as a file outline to accumulate data and eventually make it more accessible to users. Such a system, however, must be carefully safeguarded and never used without proper scientific interpretation.

GEOGRAPHIC DATA FILE

Masses of data are of little use to planners and analysts without some means to manipulate them. CRIES has developed an Agr.culture Resource Information System (ARIS) to store, retrieve, and manipulate mapped resource data. ARIS is composed of two parts: a process to digitize the various maps and a computer mapping system to analyze, summarize, and display the data.

A grid referencing system based upon Universal Trans Mercator (UTM) coordinates is used to assign each km^2 a unique cell address. As succeeding maps are digitized, map parameters for each map are recorded and stored for each grid cell. Our system emphasizes the use of manual procedures in the coding process. We have done this deliberately to develop technology that can be easily transferred and installed in developing countries without large investments in equipment. The system is quick, efficient, and dependable. Hardware requirements are minimal. All that is required is a keypunch machine, a small computer, and tape or disc storage. We are investigating putting the system on a "mini" computer.

The computer system consists of a series of program phases to perform specific operations on data. Outputs such as cross tabulations and computer maps are shown in Figures 2 and 3.

MERGING RESOURCE DATA AND ECONOMIC DATA

In nearly every planning situation, the conversion of economic and demographic data summarized by political boundaries to physiographic planning units plagues planners and analysts. This is particularly true of general land use and cropping information. Many statistical and judgmental processes have been developed and used in the U.S. Most involve the disaggregation of political boundary data to physiographic subunits through

C R O S S   T A B U L A T I O N   O F

LAND USE BY SOIL TYPE

LAND USE (COUNT / ROW PCT / COL PCT / TOT PCT) \ SOIL TYPE	1	2	3	4	ROW TOTAL
1	144. 31.4 40.2 6.2	230. 50.2 19.3 10.0	48. 10.5 8.4 2.1	36. 7.9 19.8 1.6	458. 100.0 19.9 19.9
2	83. 11.3 23.2 3.6	530. 72.4 44.5 23.0	79. 10.8 13.8 3.4	40. 5.5 22.0 1.7	732. 100.0 31.8 31.8
3	78. 9.4 21.8 3.4	398. 48.0 33.4 17.3	323. 38.9 56.3 14.0	31. 3.7 17.0 1.3	830. 100.0 36.0 36.0
4	53. 18.7 14.8 2.3	32. 11.3 2.7 1.4	124. 43.7 21.6 5.4	75. 26.4 41.2 3.6	284. 100.0 12.3 12.3
COLUMN TOTAL PCT. TOTAL	358. 15.5	1190. 51.7	574. 24.9	182. 7.9	2304. 100.

Fig. 2. Sample of a cross-tabulation table produced by the CROSSTABS phase.

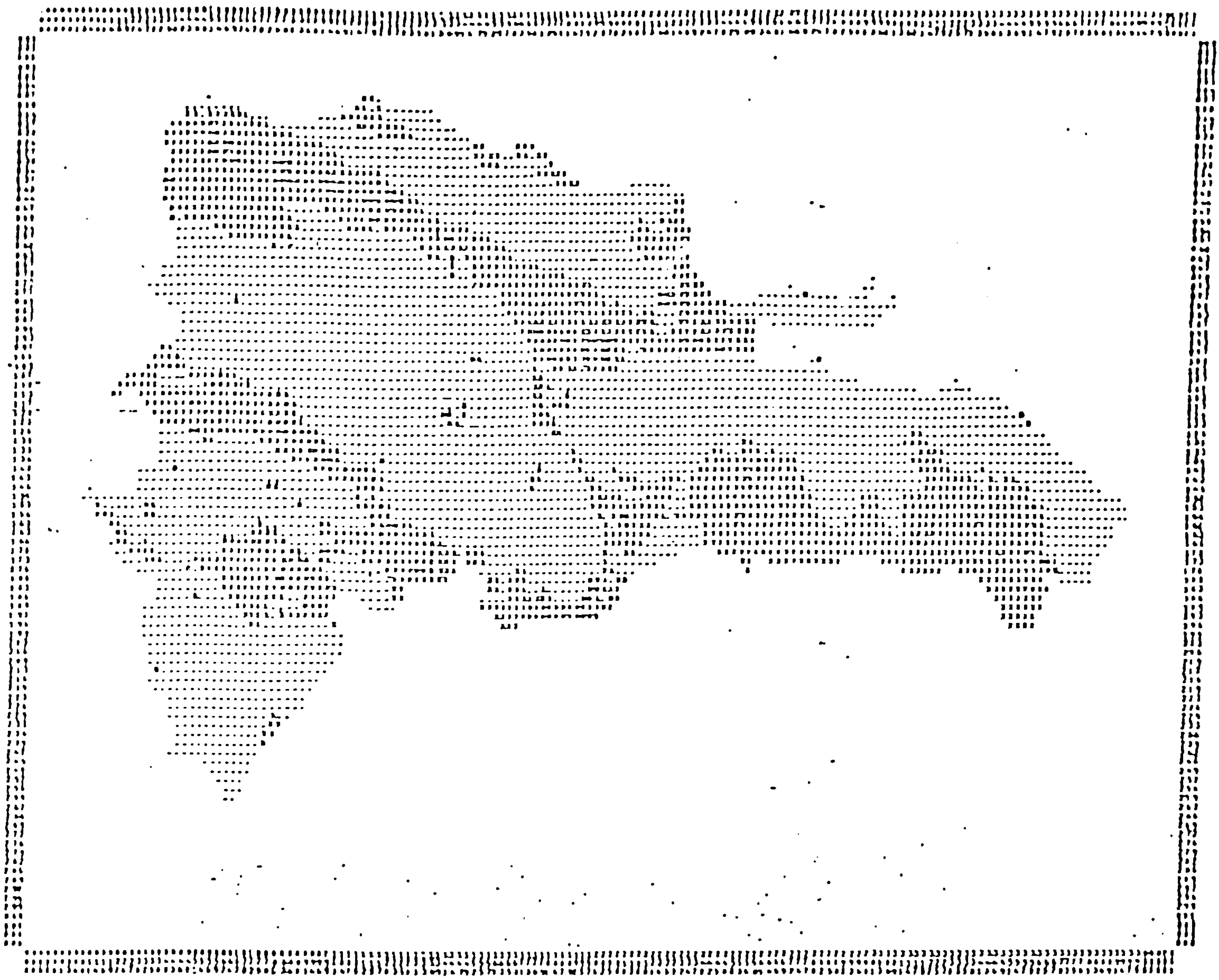

Fig. 3. Printer map depicting irrigated areas and areas of potential irrigation in the Dominican Republic.

the use of data sets such as the Conservation Needs Inventory (CNI) and informed judgment. The process creates estimates of crop use, etc. by soils and other physiographic boundaries that are controlled within known, published totals.

These problems are intensified in the developing world. Reliable country totals of crop hectarage and production are difficult to obtain and subcountry values are even less reliable. Moreover, the data and statistics that are available are usually tabulated on a crop harvested basis. With the occurrence of multiple and sequential cropping in the tropics, the crop use to a unit of available cropland ratio usually exceeds one but is difficult to precisely quantify from existing secondary sources.

CRIES' analysts are experimenting with several processes to develop estimates of land use and cropping patterns by RPUs. We are developing a process to interpret LANDSAT imagery visually to estimate general land use, cover types, and farming densities. We do this by identifying and describing typical types of agricultural use and/or cover in test sites. The gray tone levels of the test sites are measured and the readings used as inputs to a computer program which assigns a color to each band and sensitivity ranges for a color diazo mylar. After field checking, the resulting generalized use/cover map is digitized and added to ARIS.

We have had little success in identifying crops or crop types except in special situations. General land use information is far from ideal, but it does give us some basis for allocating individual crops to RPUs. Also, by using ARIS to overlay RPUs, political boundaries, and land use maps in the computer, we can get exact measurements of these land use categories by RPUs and provinces.

A second process we are working with is the incorporation of area-frame samples into the data process. AID has a large program with ESCS, Statistics [formerly the Statistical Reporting Service (SRS)] to establish area-frame samples in the developing world. The process is similar to the program in the U.S. which generates crop forecasts and annual acreage and production statistics. The procedure is very promising. ESCS, Statistics is working with digitally interpreted LANDSAT data and field enumeration of sample sites to expand the samples to regional and country totals with greater accuracy. We have a cooperative project in the Dominican Republic to adapt the sample-frame process to our data needs. We have located the sample plots in ARIS and will explore the use of sample data to develop crop allocators by RPU. Since the sample is designed to estimate regional and national totals, the samples by RPU will be less reliable than desirable but still very useful.

A special farm survey is planned in the Dominican Republic in 1979 to obtain detailed farm characteristics, production costs, and income data from these same samples. We are hoping we can add questions on land use by crops, combinations of crops, and sequences of crops to provide a better basis for allocating crops to RPU.

Since PPAs are unmapped, we have few options other than using the judgment of scientists in soils and agronomy and/or field technicians to initially allocate RPU totals to the individual PPAs. This is not different from the U.S. data situation where very little land use data are available by soils. In the U.S., however, we have much better data by political boundaries to work with.

CONCLUSION

In the U.S. we sample land for a Conservation Needs Inventory of soils, land use, and conservation practices by physiographic and political boundaries. We also sample (different area-frame sample) farms and land to produce annual land use and production data by political boundaries. We soil-map farms and have accumulated the information to do county soil surveys on about one-half of the counties in the U.S. Generalized soil maps are very scarce for large-area planning and the technology of aggregating either CNI or detailed soil mapping to broad analytical units is not well developed. Data sets are independent and difficult to merge without a great loss of reliability.

In developing countries, we have an opportunity to improve greatly on the integration of data sets. Why two independent samples? Why not use a single sample for a soil inventory and production data? Why not use the same soil system for detailed farm planning and aggregate analysis?

We think we have conceptualized the beginning of such a process. RPUs are functional planning and implementation regions. Area-frame samples are functional data units. Area-frame samples are stratified according to land use and type of agriculture. We are exploring the integration of a CRIES-type land inventory into the design of an area-frame sample so that expansion properties would apply to physiographic units as well as political boundaries. This could create planning data directly appropriate to planning units. Moreover, if the sample plots were soil mapped as in the CNI, estimates of soil capability and extent could also be expanded to planning regions as well as political boundaries and directly related to use and production data.

It will take many disciplines to accomplish this total integration. We will make mistakes but eventually it can be done. Workshops such as this can make a great contribution toward integrating the concepts and methodology necessary for success.

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QUESTIONS/COMMENTS (by R. W. Arnold):

The CRIES program appears to be headed toward a sound integration of resource information that may offer increased efficiency of effort. Would you comment on the possible ramifications to U.S. situations that might benefit from re-analyzing our existing inefficiencies in handling resource information? (I think it would be interesting to have some of your opinions also in the proceedings - if you so desire).

ANSWERS:

The U.S. system of incependent, uncoordinated resource data systems has plagued planners and analysts for years. I personally feel that an integrated data approach could materially improve the efficiency and the quality of U.S. resource analysis and planning.

QUESTIONS/COMMENTS (by T. R. Forbes):

What kinds of questions is the Government of the Dominican Republic asking the database?

ANSWERS:

Areas to be dropped from sugar cane production, for example, and changed to other cropping systems.

SESSION V

PRESENTATION OF SOIL RESOURCE INVENTORY INFORMATION TO PLANNERS

Chairman: S. Somasiri

Speakers

G. C. Thomasson - Cultural and Psychological Variables in the Preparation and Presentation of Information to Users of Soil Resource Inventories: An Exercise in Applied Anthropology

S. Panichapong - Soil Survey and Training Program for Laymen to Utilize in Thailand

D. Slusher - Soil Potentials and Their Use by Planners

L. L. Resler - Utilization and Presentation of Soil Resource Inventory Information for Land and Water Resource Planning

CULTURAL AND PSYCHOLOGICAL VARIABLES IN THE PREPARATION AND PRESENTATION OF INFORMATION TO USERS OF SOIL RESOURCE INVENTORIES: AN EXERCISE IN APPLIED ANTHROPOLOGY

Gordon C. Thomasson[1]

In recent years increasing attention has been given to participation as an essential variable in the overall process of planning for development. While many schemes have been attempted that have not included participation from the onset of the planning process, the number of such ventures that can, in retrospect, be termed a success is in fact small. While participation is not the panacea that will cure all the ills that can beset development projects, it does promise help in solving some of the problems that have been encountered. What follows is an intentionally vague outline of cultural and psychological variables that should be taken into account in order to facilitate more widespread and informed participation in the planning process on the project or scheme level by making Soil Resource Inventory (SRI) information more accessible and intelligable to its ultimate users.

I will present some general guides for effective information transfer that soil scientists, cartographers and planners might do well to consider. I am suggesting that in each project an effort must be made to tailor SRI information to the users' cultural understanding and technological adaptation to the ecology of their area, rather than expecting the users to adapt to some universal system of SRI information presentation. In order to maximize participation it probably will be necessary to call on social scientists such as anthropologists and psychologists to serve as an interface between sources of SRI information (soil scientists and cartographers) on the one hand and planners, those involved with implementation and participants, on the other. This task might be described as translation, if we use that word in a broad cultural rather than a linguistic sense.

SCALE AND POTENTIAL USERS

It is important, at this point, to recognize that SRI information can be gathered and presented at different scales in numerous formats according to the type and scale of land use planning that is intended. To be effective, SRI information transfer, as is the case with any other effort at inter-cultural or interdisciplinary communication, must proceed on the basis of who the (probable) intended users of the information will be. There is a fairly consistent relationship between map scale and level of use: the smaller the scale the more likely the project will involve national or international levels of planning. Whatever the scale of map or report being made or level of planning being done, those involved with SRI information transfer should be sensitive to such diverse variables as physiological differences, cultural backgrounds, and average educational levels of users, as well as the probable intended uses of the SRI information.

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[1] Research Assistant, Southeast Asia Program, Cornell University, Ithaca, New York 14853.

SMALL AND INTERMEDIATE SCALE MAPS, REPORTS AND PLANNING

Small-scale maps (<1:650,000), and reports generated from them, are generally prepared for and used by planners who are working on projects of national or international scope. Intermediate-scale maps, with scales of from 1:13,000 to 1:650,000, and reports deriving from them, are often used in smaller nations and within regions for general planning. A majority of the users of small- and intermediate-scale based information will be university-educated and members of what might be termed a global-technocratic culture. Their level of education and/or access to specialists who can interpret reports will enable them to sort through the peculiarities of typically presented SRI information with only a small amount of effort. With the exception of politicians involved in planning at these levels, there is a significant probability that the person, ethnic, and/or cultural background of planners may not correspond to that of the people ultimately involved in a specific development project. Differences in the educations received by planners at this level may create some problems in SRI information transfer. Former Dutch colonies preserve a style of education that is distinct from what were British, French, American, or German colonies, and this can result in difficulties with regard to both the form and content of SRI information presentation. For example, some countries such as the U.S. are only now converting to the metric system and thus may be less efficient in their use of international resources by virtue of their prior training. So even on the highest levels SRI information transfer should take into account local educational backgrounds if we wish to maximize the efficiency of information transfer. Larger questions regarding differences in types of education and preferred styles of information presentation remain to be researched.

Planning on intermediate levels will primarily be concerned with meeting national goals within regions, and feasibility will often be in terms of "cost-benefit" calculations that do not take into account social and long-term environmental costs. Intermediate planning, while often faced with the task of siting general areas for development, still uses SRI information as only one of a great many inputs to what is also a political process. Nevertheless, the results of such regional planning are often spread in two directions: to international agencies, for funding and technical assistance, and to colleagues and participants within the region in question, for eventual implementation. It is at this juncture that distinct styles of SRI information presentation can be most useful, if they are put in a format that is intelligible to those involved.

LARGE SCALE MAPS AND REPORTS

Large-scale maps (>1:13,000) and reports are, or should be, used when siting, planning, and implementing specific schemes. These cannot be simply enlargements of small-scale maps, but must be based on more extensive surveys or reviews of existing soil resource information. It is on this, the project level, that maximum participation is needed and is possible. Planning of individual parcels, siting of communities, development of infrastructure and related problems can only be done effectively with a maximum availability of relevant SRI information. However, the larger the scale and the more participants involved in the planning process, the less we can assume that western-style technical methods of data presentation will be effective. This is not to say that those involved are less intelligent. Rather it is to suggest that the particular type of training shared by a majority of those involved in national and regional planning cannot be taken for granted at the local level. It is here that significant improvements are possible in SRI information transfer that will facilitate more widespread participation in the planning process.

USERS OF LARGE SCALE MAPS

Technicians, Extension Agents, etc.

Besides those planners who are working at the project or scheme level, there will be a number of people who are more or less conversant with SRI information as it is now presented. These individuals may have a certificate or diploma, and often have had considerable experience in the field. Their cultural background, however, may not be from the current project area and they may not speak the local dialect. They will have a significant role in activities such as the siting of towns, locating parcels, and helping match crops and soils. They represent, depending on one's point of view, either the key or the major obstacle to widespread participation. If their help can be enlisted in making sure that SRI information is made useful on the local level, then a major hurdle will have been overcome. If, on the other hand, they are not encouraged to become, as it were bilingual, then the likelihood of meaningful participation is slight. Incentives and training must be made available to such individuals to assist them in facilitating participation. Their training as well as their position makes them the logical intermediaries between sources of SRI information and the ultimately intended audience.

Local Leaders

Depending on the country in question, local leaders may have had at least a high school education. Their cultural background is usually the same as that of the project participants. In most cases they will be able to speak the local dialect. They are an inevitable and usually valuable part of the process of developing infrastructure, siting of homes, and especially allocating lands to new settlers, etc. Needless to say, many opportunities for exploitation are to be found at this level. If an effort is made to make SRI information intelligible to everyone involved in the project, such exploitation will be more obvious and difficult.

Participants

Whether an existing agricultural area is to be irrigated or new areas are to be opened, if local or transmigrant populations are to be involved, or if new crops are to be introduced, the success of the project will finally depend on how those who are to work the land are integrated into the project. The level of formal education of participants will, more often than not, be low. They may or may not be literate; some will have completed an elementary education. When a project combines both urban and rural members (and no scheme should be attempted with purely urban populations), some mechanism should be established for training prior to entry into the project. The cultural and language backgrounds will hopefully be similar. Ideally, settlers will be locals, or from an ecologically similar area (Moran, 1976). The more diverse their origins and the less familiar they are with the type of agriculture being attempted, the less likely SRI information transfer will be effective, and both participation in and the success of the project will be jeopardized. The probable uses which project participants would have for SRI information include such diverse tasks as matching soils and crops, avoiding problems such as uncontrolled drainage of acid sulfate soils, siting homes with regard to both structural stability and sanitation, and generally integrating into the project as a whole.

The foregoing is intended to stress the need for and the problems inherent in involving the settler in participation. If SRI information transfer is attempted that disregards the low levels of formal schooling typical among participants, or if their culture and language are ignored, participation will be superficial and information transfer will be minimal. What follows are a few guidelines toward making SRI information intelligible and useful on the local level. It is intended as a sketchy model of how participation might, in general, be facilitated by paying attention to and taking advantage of the assets of local culture and indigenous technology, as well as making the most technical information more readily intelligible on the local level to the small farmer.

VARIABLES THAT CAN FACILITATE EFFECTIVE SRI INFORMATION TRANSFER

Physiological Variables

A prime example of a physiological variable that has not been considered in the transfer of SRI information involves color vision. Even in temperate regions visual deficiencies which involve the genetically caused absence or collapse of function of one or another type of receptor cells in the eye and result in red, green, or blue partial or total "color blindness" have not been taken into account in the perparation of many color map legends. (See for instance the current New York State Soils Map.) This is in spite of the fact that 4.3% of Caucasian populations have some color vision deficiencies.

Among populations located closer to the equator, another problem in color perception exists. It is known that among peoples indigenous to the tropics, apart from regular color blindness, a high degree of optical attenuation of short wave-length radiation is common and causes a significant lowering in the ability to discriminate between shades of blue and green. This results from what are in some cases dietary, and in other cases genetically caused, accumulations of pigment within the eye. The accumulation of intraocular pigmentation in indigenous populations near the equator is recognized to be an adaptive trade-off: differential sensitivity to blue-green visual phenomena is reduced among these peoples while there is an increased protection against the potentially carcinogenic higher incidence of ultraviolet and near-ultraviolet radiation common closer to the equator, as well as generally heightened visual acuity due to the filtration that occurs (Bornstein, 1975). This reduction in sensitivity to blue-green distinctions generally has not been taken into account in making map legends for use in the tropics. In many cultures decreased optical sensitivity to blue-green distinctions is reflected in the absence of such terms in those languages. While planners and government leaders with a significant amount of formal education may have learned that other cultures distinguish colors that their own language does not, and have learned to compensate for the handicap they would otherwise experience in using international materials, many people are not even aware there is a problem. For these people, the choice of two, at best marginally differentiated, colors to indicate very distinct soil conditions in a map legend may be quite inefficient.

Cultural Variables

Coupled with physiological variables there may be a number of cultural factors related to color that should be considered. In the United States Department of Agriculture's efforts to make information for land use planning more accessible, some color symbols common in the U.S. have been adopted. All of you are familiar with the traffic control signals at major intersections and throughout America. They employ three colors: red, yellow, and green. These are almost universally understood as meaning red = stop, yellow = caution, and green = go. I say almost, because color-blind individuals are taught that the top light = stop, the middle light = caution, and the bottom light = go. With that exception, the symbolism of these colors is widely known and understood. Land use maps are often coded using these colors to symbolize the suitability of the land for the intended use. In other cultures, even though they may have automobiles and traffic signals, there are other symbolic meanings attached to various colors which may be much more useful and widely understood if linked to particular soil characteristics in a map legend.

Ignoring color symbolism can create problems ranging from simple inefficiencies to violations of taboos. Taking local color symbolism into account can significantly increase the content communicated by the map legend itself, just as red = stop does in America. It also must be recognized that in many societies soils are named and differentiated on the basis of their color. While it might be difficult to use solid black or dark red for a soil map unit designation when a people name a particular soil by one of those colors, even crosshatching with faint lines in these colors can allow cognitive identification of such types of soil with soil names and map units by local users. Where lighter colors and color names are correlated in a culture, solid colors can be used on maps without loss of other important details. The main point is to try and correlate map legends with the local culture whenever possible. Local ethnocategories which, like "black", "yellow", and "red" soil names, also reflect significant agronomic distinctions, should not be ignored.

INDIGENOUS SOIL CLASSIFICATION SYSTEMS

Perhaps the most important way in which SRI information can be effectively transferred to participants and planners on the local level is if the data is integrated with the participants' often substantial knowledge of soils, rather than expecting them to adapt to one or another of the numerous and constantly changing scientific classification systems. It is not hard to hypothesize a locality which has had inputs successively from colonial French, American, FAO, and Russian development teams. Farmers living in such an area would have to spend a large amount of time simply learning new terminologies in order to understand the technicians. For example, if one examines the labels assigned to one "lateritic" pedon since the 1940s, the number of potential name changes is amazing to the non-soil scientist. The changes will continue (as the current committee to review the classification of Oxisols evidences) as well they should, given the constantly evolving nature of science, but to expect non-soil scientists to keep abreast of such developments would be as unreasonable as expecting soil scientists to be current on sociological jargon. It is obviously much more practical, whenever possible, to encode technical inputs within an indigenous and usually relatively stable soil classification system, so that immediately useful knowledge can be integrated within the local culture. This is important because while classifications and entire taxonomies can often change, sound soil management practices are much less likely to be completely overturned with the same frequency. Moreover, indigenous classification systems are usually quite sophisticated and well adapted to local conditions. Soil scientists may find a great deal worth learning from peoples who often are stores of millenia of practical empirical data about their own lands, even though their "science" is neither statistical nor published. Communication, ultimately, must be a two-way process.

> In Bangladesh, for example, farmers have their own traditional system of land classification . . . based on land levels in relation to flooding which govern the kinds of crops that can be grown. In this traditional system, "highland" (uchu jumi) is land lying above normal flood level which can be used for annual or perennial dryland crops (sugarcane, bananas, fruit trees). "Medium land" (madhyum jumi) is land flooded up to about six feet deep during the monsoon season. "Medium highland" (majhari uchu jumi) is land normally flooded only one to three feet deep during the monsoon season on which transplanted aman paddy rice can be grown (aus paddy rice and jute can also be grown on this land before the transplanting of the aman crop). "Medium lowland" (majhari nichu jumi) is land normally flooded up to three to six feet deep during the monsoon season, too deep for rice to be transplanted, but still suitable for broadcast rices and jute--broadcast (deep water or floating) aman paddy is the major crop, but aus paddy and jute can also be grown. "Lowland" (nichu jumi) is land normally flooded up to six to twelve or fifteen feet deep in the monsoon season. Broadcast aman paddy is the only crop that can be grown. Some farmers also recognize "bottom land" (khoj jumi), land too deeply flooded (more than 12-15 feet) for even deep water aman varieties to be grown, but suitable (in some cases) for boro paddy to be grown during the dry season. Depth and duration of flooding of course, is not the only land characteristic important to cropping, but it is certainly one of the most important considerations for use of some areas in Bangladesh. (Brammer, personal communication <u>in</u> Olson, 1977)

Within the Hanunoo system of swidden agriculture in the Philippines, soils are distinguished according to at least eight criteria: 1) moisture content, 2) sand content, 3) rock content, 4) general texture, 5) firmness, 6) structure, 7) structure in the wet season, and 8) color (Conklin, 1959).

Expecting peoples with this degree of sophistication to adapt to another system would be time-consuming at best. Malaysian farmers categorize soils in part on the basis of taste. These include "sweet" (*tanah payau*), "neutral" (*tanah tawan*) and "sour" (*tanah masan*) soils, and the classifications correlate significantly with pH levels (Weinstock, 1977).

Local knowledge should not be slighted in our effort to transfer SRI information. It should be remembered that over some 15 years the Soil Science Society of America has been revising and redefining words in order to produce its *Glossary of Soil Science Terms* (SSSA, 1978). Such narrowly focused language is unlikely to be understood without a lengthy apprenticeship or "in-training" period. As David Edwards points out regarding Jamaican farmers' knowledge concerning their soils: "Not surprisingly, much of their knowledge of these topics was clothed in a language different from that commonly employed by the soil scientist." Nevertheless, their sophistication is considerable.

> They referred to 'wash' rather than erosion. They said that rainfall water washes away the 'fat' or 'gum' (top soil), which is the best part of the soil and this has the effect of 'pooring' the land so that it becomes 'tired' and 'worn out.' The farmers also realized that most of the wash can be prevented in various ways. Sloping 'bare ground' can be covered by the vegetation of close-growing crops. Grass is particularly good; it rests the tired land. Tree crops help because their roots hold the soil and some shed leaves which form a protection layer on the ground. Mulching is commonly recognized as having a similar effect as well as 'feeding the land' and 'keeping it cool.' Trenches across the slope reduce damage by slowing down the water, and the fat or 'manure' deposited in them can be thrown back on to the ground above. Other obstructions to the flow of water are also recognized as an aid in reducing the rate of erosion. (Edwards, 1961)

Coupled with such understanding, concepts such as the "hot" or "cold" nature of soils and other indicators of soil chemistry and potential fertility could well be utilized. In Malaysia, certain vegetation is understood to indicate such factors.

> The *keduduk* bush indicates a high level of aluminum in the soil; the tree *pohon bakan* indicates an acid soil with stagnant standing water; and *lalang* grass (*imperata cylindrica*), *keriang* berry bushes, and the cashew tree are indicators of low fertility soils. (Weinstock, 1977)

The correlation of certain types of vegetation with soils makes possible other methods of SRI information transfer.

Iconographic Alternatives

In the United States there has been a tradition of using certain visual symbols to indicate actual or potential agronomic production on maps designed for popular use. These have included whole and partial ears of corn, heads of wheat, and other crops, keyed in the legend to thousands of bushels per symbol. Other possible symbols could include typical vessels used to store a particular crop, such as the kind of granary commonly built to store rice, a specific kind of pottery jar, or whatever. Suitability can be indicated in similar ways. Besides information about specific crops, symbols such as a recognizable or a stylized cashew tree or pohon bakan might be used in the Malaysian case, for example, to indicate potential problem sites and explain their nature quickly to participants. In many areas we also find types of soils correlated with specific weeds. In such cases, if the weeds could not be graphically represented, it might be worth considering naming that soil series (at least in local map legends) after the weed, and then giving other taxonomic designations in formal reports. With a minimum of effort such symbols and concepts could be made part of SRI information dissemination.

Other Aspects

Research into other cultures by social scientists can reveal a number of mechanisms for more efficient information transfer. These could include a number of folk classification systems (Conklin, 1972). Also, in a particular society there may be locally significant types of landmarks that would minimize the time needed for people unfamiliar with printed maps to orient and locate themselves. There may be traditional ways of indicating spatial relationships, the travel of the sun, elevation, etc. (Gladwin, 1970). Any of these might be a great help in facilitating map use as an aspect of understanding and participation.

There are also a number of other psychological and psycho-physiological variables that might be taken into account (Phillips, 1977). In all of these areas, however, the paramount consideration is maximizing the meaningfulness of the communication to its audience.

A MOMENTARY SUMMARY

This paper cannot end with a conclusion, but with a recommendation. It presupposes that the reason for SRI information transfer on large-scale or local project levels is to facilitate effective and just implementation of development projects, and that this can only be accomplished through active participation in the planning and implementation process by the farmers who will ultimately reside in the area. Active participation can be maximized by culturally matching or interfacing SRI information (and other data) to the culture of the participants involved in the planning process. Such applied anthropology programs, linked with and mediated through indigenous, traditionally based institutions of formal and nonformal education, promise a much greater degree of participation in planning and development than has heretofore been achieved (Conlin, 1974). It also may make possible much more fertile collaboration between traditional agriculturalists and modern scientists, with each group considering themselves the beneficiary.

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QUESTIONS/COMMENTS (by R. W. Arnold):

The people from Prairie View, Texas, train para-professional agriculturists who translate scientific information into the grammar and language structure of the American Negro. This need for bilingualism was misunderstood for many years but when the cultural differences were taken into account, they have developed a highly successful delivery system of assisting the small American Negro farmer.

ANSWERS:

The use of Black English Vernacular (BEV) or other dialects will certainly be appropriate in communicating with Black American agriculturists. It should, of course, be remembered that such dialects vary regionally, as well as with regard to crops, environment, etc. In fact, similar considerations should be made in extension work with the white rural poor. Techniques that prove useful with Black Americans have no guarantee of success when used with Black Africans. In each case the communicator must get to know (anthropologically), and learn how to communicate with the particular audience, and be as willing to learn from them as to teach them.

QUESTIONS/COMMENTS (by P.H.T. Beckett):

The points you make are clearly relevant, but social scientists have a reputation for being wild and uncontrollable.

What kinds of input to the production of an SRI may they be asked for, and how are they to be instructed to produce them, and in what form are they to present their findings?

ANSWERS:

It would be useful to ask applied anthropologists and rural sociologists if they can make inputs from traditional soil classification systems to Soil Resource Inventories from the outset of survey activities. This is a different problem, however, than the one I tried to address. My point is that these individuals can be of help in the transfer of SRI information. In both cases the method of involving them would be to give them examples (such as the ones I refer to) of traditional systems and asking them if, or to find out if, the culture in question has such a system. If the goal is transfer of SRI information and management techniques, then if you can explain your contribution to the social scientist and the benefits of that information to the farmers involved in terms the social scientist can understand, then the social scientist can aid you in getting that information to the people. It is true that some antropologists, in a type of academic colonial way, wish to keep the people they study "unspoiled." These "pure" anthropologists will be of little help. Others may question severely whether your inputs will in fact benefit the people--but if you can convince them then they will be quite helpful to you. My paper could be one way of explaining how the social scientist could contribute, and pointing to the kinds of questions they could explore, in order to facilitate both SRI information collection and transfer.

QUESTIONS/COMMENTS (by R.L. Tinsley):

My experience with small farmers in several Asian countries has indicated that many of the social-religious institutions are dynamic and subject to almost continuous change in response to economic stimulae. Although in the aggregate the small farmer may have a conservative resistance to change, there are usually a few individuals in any given area who are willing to experiment and take risks. This is all that is necessary to keep the system dynamic and effectively in tune with changing conditions. Although dynamic, farmers frequently do not have the resources to implement all their technical knowledge and skills. My most noticeable example is double cropping rice under rainfed conditions. In this case farmers did not have sufficient draft power to put more than a nominal part of their lands into double cropping each year even though soil and climatic information as contained in SRI reports would indicate the land potential is for double cropping. Changes in farming activity within what is possible with available resources can occur rapidly in response to economic changes. This usually will involve marketing infrastructure. It is not unusual for specific crops to be grown on less than ideal lands, contradicting SRI evaluation, lands on which an economic return remains positive even though other crops, that do not have the appropriate infrastructure support, would agronomically be better adopted.

ANSWERS:

Frequently, I have thought that economic development could most rapidly be encouraged by concentrating more on providing the economic support structure than the production agronomy. Generally, if a crop is going to be successfully introduced to farmers, basic agronomic skills are sufficient to get an economic, if sub-optimal, initial return. Refinement to optimal production levels can come later. SRI information would be most helpful in determining what is the best land use for project areas. Thus the appropriate economic stimuli and support structure are needed to encourage farmers to adopt the most ideal land use.

SOIL SURVEY AND TRAINING PROGRAM FOR LAYMEN TO UTILIZE IN THAILAND

S. Panichapong[1]

GENERAL BACKGROUND OF THAILAND

Thailand covers an area of approximately 550,000 km^2, the largest among mainland countries in Southeast Asia. It is bordered by Burma to the north and west, Laos to the north and east, Cambodia to the southeast, and the Gulf of Thailand to the south. The southern border connects with the Federation of Malaysia. Thailand has a population of approximately 44,272,693 with a rate of increase of about 2.7% per year over the last decade. The distribution of the people varies widely but is mostly concentrated in the plains around Bangkok, the capital city. Bangkok is a modern city with a population of nearly 5 million or about 10% of Thailand's total.

According to Moorman (1972), Thailand is divided into six physiographic regions: the North and West Continental Highlands, the Central Highlands, the Central Plains, the Northeast Plateau, the Southeast Coast, and the Southern Peninsula.

The Highlands to the north and the west are mountainous with most people living in the river valleys. The principle agricultural area (rice bowl) is the Central Plains which extends 300 miles from north to south and has a width of 100 to 150 miles. This area also is the most highly populated. The Southeast Coast and the Southern Peninsula, with relatively high rainfall, are two of most intensive fruit and para rubber growing areas.

Based on the latest survey of the Forestry Department, 37% of Thailand is forest and 63% has been cleared for agriculture, urban centers and highways. About 85% of the people earn their living by agriculture. Rice is the most important crop being cultivated and it occupies about 50% of cultivated land. Cassava is also produced in great quantities and is next to rice in export value. In recent years corn and sugarcane became important export crops. Para rubber is another economically important crop. Soybeans, peanuts, jute, tobacco, and fruits are commonly raised both for export and domestic use. Additionally there are about 10 million head of cattle and buffalo which become a source of considerable amounts of beef and pork for exporting. Finally, the gulf of Thailand and coastal waters provide an important source of fishery products.

HISTORY OF SOIL SURVEY IN THAILAND

The need for soil information for agricultural planning has been recognized in Thailand for many years. Crener (1937) should be credited

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with being the first person who systematically observed the soils of Thailand. Somewhat later a sense of direction was given to early soil survey work by R. L. Pendleton, who was appointed as Soil Technologist in the Royal Department of Agriculture and Fisheries in 1935. Although hampered by lack of staff, facilities -- such as reliable base maps and aerial photographs -- and the inaccessibility of much of the country at that time, Pendleton (1936) completed the first soil map of Thailand at a scale of 1:1,000,000. This map was published on a scale of 1:2,500,000 in 1949 and reprinted along with a mimeographed report in 1953. Detailed surveys, at that time, were also made for specific areas where planners needed information for special projects.

In the late 1950's officials who were planning agricultural development saw the usefulness of a detailed systematic survey of the soil resources of Thailand. Initially, they sought assistance from international agencies. In 1961, the Food and Agricultural Organization (FAO) of the United Nations assigned Dr. F. R. Moormann, a soil survey and classification specialist, to Thailand to train Thai pedologists and to help the Thai government organize a national soil survey division. The United States Operation Mission (USOM) has also assisted in the soil survey work in Thailand by contributing equipment, along with general financial and advisory support.

Before 1963, soil survey activities were segregated among three government agencies: the Department of Agriculture, the Department of Rice, and the Royal Irrigation Department. After that year the Council of Ministers assigned the responsibility of the national soil survey to the Department of Land Development in the then newly organized Ministry of National Development. Since then, the Soil Survey Division has been engaged in a systematic soil survey project throughout the country. The Royal Irrigation Department continues to make land classification surveys of irrigation projects based on the USBR system. The Department of Agriculture still maintains a small soil survey staff for special studies at experimental stations.

From 1963 to 1973, the Soil Survey Division had been assisted by the UNSF Project. With such a contribution, the soil survey activities in Thailand were strengthened and it has continued to become more effective since then. The Council of Ministers established the Ministry of National Development in 1972. As a result, the Department of Land Development, which includes the Soil Survey Division, was transferred to the Ministry of Agriculture and Co-operatives.

For the time being, the Soil Survey Division has 56 field parties mapping soils in many parts of Thailand, mostly at the detailed reconnaisance level.

KIND AND INTENSITY OF SOIL SURVEYS IN THAILAND

Soil surveys in Thailand have been made at any of several levels of intensity depending upon the nature of the area, its state of development, the time and personnel available, availability of base maps and aerial photographs, and the uses that are to be made of the information. The system used is mostly based upon the USDA Soil Survey Manual but it was also modified to fit our particular circumstance. Types of soil surveys used in Thailand are summarized in Table 1.

ACCOMPLISHMENT OF SOIL SURVEY DIVISION

Since 1963 the Soil Survey Division has completed soil surveys of various intensity as follows:

1) Exploratory survey conducted by Moormann and Rojanasoonthon from 1963-67. They published a general soil map of Thailand with a scale of 1:1,250,000 using as mapping units great soil groups and their associations as described by Dudal and Moormann (1964). The map has been used for the general estimation of soil conditions in Thailand. At present the Soil Survey Division is revising the soil map of Thailand by using soil taxonomy classification as the mapping unit and the published scale will be 1:1,000,000.

2) Reconnaissance survey of Peninsular Thailand for a rubber development project, was completed in 1972 for an area of approximately 7 million hectares. The mapping units employed in this survey were a combination of families, subgroups or great soil groups.

3) Detailed reconnaissance surveys have been the routine work for provincial survey throughout the country. The mapping units are soil series, soil variants, associations or complexes of soil series, undifferentiated soil groups, phases of taxonomic units and land types depending on the appropriation of the area. Average density of boring is 1 per 2 sq km. Printing scale is 1:100,000. After fifteen years, the total area which had been completed with this type of survey is about 42.5 million hectares, or 85% of the country. The result of the detailed reconnaisance survey has been used for provincial agricultural development planning and feasibility study of land settlement projects.

4) Semi-detailed surveys have been done according to the request of other government agencies such as The Royal Irrigation, Public Welfare Department, etc. Total area covered by this type of survey is about 0.9 million hectares of which most were for irrigation projects. The mapping units employed in this type of survey are soil series, soil variants, soil associations and complexes. Average density of boring is about 1.25 borings per hectare depending on complexity of the soil pattern and accessibility. The published mapping scale is 1:1,000 - 1:20,000.

5) Detailed surveys are the most intensive surveys that have been conducted in Thailand. They are made on request by research agencies, and irrigation and land consolidation projects. Soil phases are mostly used as the map units; but soil series and variants are also used in certain circumstances. Mapping scales vary up to 1:10,000 depending on the requirement and the complexity of the survey area. Average sampling intensity is 1 boring per 8-12 hectares. The area which has been surveyed by this method is about 2655 hectares. It is expected that more surveys of this type will be performed in the future.

Table 1. Soil mapping units for a basic soil survey at various intensity levels, suitable map scales, possible levels of interpretation and major uses of each.

Intensity Level	Suitable Field Mapping Scale	Suitable Publication Scale	Kind of Mapping Units Suitable for each Intensity Level	Minimum Area shown on Soil Map	Possible Intensity Level of Interpretation	Major Use
Special Very Detailed (very high intensity	Larger than 1:5,000	Larger than 1:5,000	Phases of soil types, soil series or soil variants using very narrow ranges of phase criteria.	<0.3 ha	Field management unit or soil suitability for specific crop or land use.	Research plots or detailed engineering uses.
Very Detailed (very high intensity)	1:2,000 to 1:10,000	1:5,000 to 1:10,000	Phases of soil types, soil series or soil variants and some complexes of same	0.5 to 1 ha	Field management unit or soil suitability group	Research, intensive farm management
Detailed (High intensity)	1:5,000 to 1:30,000	1:10,000 to 1:30,000	Phases of soil types, series or soil variants and some associations or complexes of same.	1 to 10 ha	Farm management unit or soil suitability group	Irrigation design and farm planning
Semi-detailed (medium intensity)	1:20,000 to 1:50,000	1:25,000 to 1:60,000	Soil series, soil variants, soil associations and soil complexes. In places some phases of above can be shown.	6 to 36 ha	Management subgroup, soil suitability group or land subclass	Area Planning and feasibility studies
Detailed reconnaisance (low intensity)	1:40,000 to 1:100,000	1:50,000 to 1:100,000	Soil families, soil series, association of soil series with some phases of each and some land types.	25 to 100 ha	Management subgroup or land subclass	General area planning
Reconnaissance (very low intensity)	1:75,000 to 1:200,000	1:100,000 to 1:500,000	Great Soil Groups, associations of Great Soil Groups and some soil series, soil families or subgroups or Great Soil Groups and some land types.	100 to 2,500 ha	Management group or land class	National and regional planning.

Table 1. (Continued)

Intensity Level	Suitable Field Mapping Scale	Suitable Publication Scale	Kind of Mapping Units Suitable for each Intensity Level	Minimum Area shown on Soil Map	Possible Intensity Level of Interpretation	Major Use
Exploratory	1:100,000 to 1:250,000	2:250,000 to 1:1,000,000	Great Soil Groups, associations of Great Soil Groups, some phases of both and land types.	625 to 10,000 ha	Broad land class (not more than 3-5 classes)	Determination of areas suitable for further study in National Planning.
Synthesis or Schematic	1:100,000 or smaller	1:1,000,000 or smaller	Great Soil Groups, associations of Great Soil Groups and some physiographic associations of kinds of soils.	10,000 ha or more	Broad land class (not more than 3 classes)	Broad generalizations of kinds of soils

Table 2 shows the types of survey being conducted in Thailand, accomplishment, cost, and use.

SOIL SURVEY INTERPRETATION

Since more than 80% of the Thai population make their living by farming, the proper use of the land is very important for the development of the country. Therefore, we need to know basic information about the soils and their behavior before making any decisions on land use. The only way to get this information is from soil maps that show areas of defined soil units and from a written description of the characteristics of each unit. Unfortunately there are many soils defined in such a way that many planners lacking a soil science background find it hard to understand them.

Many users of soil maps want more general and more direct information than that given by individual soil mapping units. When soils are grouped together for a specific purpose, such information can be more readily applied. Therefore, soil interpretation for agricultural use is required in order to bring out alternative management practices for each kind of soil. From these alternatives, we hope that planning officials, landowners, and cultivators can choose the one that is most proper.

There are two major methods of interpreting the soil survey information for agricultural use in Thailand. These include Land Capability Classification and Land Suitability Classification.

The Land Capability Classification is a grouping of soils according to their general capability for over-all agricultural use. Our classification system is a modification of the one used by the USDA, Soil Conservation Service. In this system there are two major categories or levels of soil groupings, namely class and subclass. The most general level of classification places all soils in eight capability classes. Risk of soil damage or the limitation in use becomes progressively greater from class U-I to U-VIII. The letter "U" stands for upland crops, i.e. annual crops other than rice.

Soils placed in class U-I have only minor limitations for growing upland crops during most of the year. In classes U-II and U-III, there are increasing limitations but these soils can have satisfactory yield under careful management. Limitations become more severe for soils in class U-IV, which are marginal in suitability. Soils in class U-V through U-VII are generally not suited for the cultivation of upland crops, but they may be capable for other uses such as grassland, woodland, and tree crops. Soils in class U-VIII do not produce economic returns in agriculture or commercial plant production.

The subclass level is more specific. The soils in each class are subdivided into subclasses according to the dominant kind of limitation. There are many kinds of limitations such as flooding hazards (f), soil limitations in the root zone (s), lack of moisture for plant growth (m), unfavorable topography (t), salinity or alkalinity (x), impeded drainage (d), and erosion (e). The dominant limitation is indicated by a small case letter following the class number, for example UIIf.

Table 2. Accomplishment of soil survey in Thailand and the cost of the survey

Intensity of Survey	Publication Mapping Scale	Total Acreage	Cost per hectare (U.S.$/hectare)	Project	Main purpose of Soil Maps
Exploratory (very low intensity)	1:1,250,000 and 1:2,500,000	51,398,500 ha (whole country)		Thailand soil map	Broad spatial information on kinds of soils in relation to their environment and agriculture
Reconnaissance (very low intensity)	1:750,000	7,018,900 ha		Reconnaissance soil survey of Peninsular Thailand	Regional development planning
Detailed reconnaissance (low intensity)	1:100,000	42,521,100 ha	$0.5	Provincial soil survey	Provincial and regional development planning; evaluation of large projects
Detailed reconnaissance and semi-detailed (low to medium intensity)	1:20,000 - 1:100,000	872,987 ha	Semi-detailed survey costs $1.0	Land-settlement project	Feasibility studies of land settlement projects; laying out land use planning within settlement areas for farmers
Semi-detailed and detailed survey (medium to high intensity)	1:10,000 - 1:20,000	84,732 ha	Detailed survey costs $1.5	Irrigation project	Evaluation of irrigation projects; use as a basis for irrigation system designs
Detailed and very detailed survey (high to very high intensity)	1:2,000 - 1:10,000	2,655 ha	Very detailed survey $2.0	Experiment station project	Agricultural experiments in soil conservation center and agricultural college

Most work in Thailand has used two levels of land classification. However, in many cases, this generalization is not specific enough for agricultural planners. This is because the adaptation of individual crop: to specific soils varies from crop to crop. Therefore, the various kinds of soils have been rated or grouped according to their suitability for the production of certain crops common to Thailand or to the surveyed areas. These classifications or ratings are called Land Suitability Classification. This classification is believed to give sufficient detail for regional and local moderately-detailed land use planning.

There are five land suitability classifications for various kinds of farming or land use alternatives, namely:

1. Flooded Annual Crop Farming (mostly applicable to paddy rice);
2. Non-flooded Annual Crop Farming;
3. Commercial Tree Crop Production;
4. Permanent Pasture and Rangeland Livestock Farming; and
5. Watershed Protective Vegetation Establishment and Upkeep.

The land suitability classification for each land use alternative has soils grouped into five land suitability classes, ranked according to degree of limitation to use, or to risk of damage. Soils that are grouped in land suitability Class I are most suited for use (under the considered land use alternative). Soils grouped in a Class II are less suited for use, and so on in decreasing order of suitability.

Within land suitability classes, soils are also grouped into land suitability subclasses according to the kinds of limitations. The kinds of limitations which dictate the subclass are almost the same as those used in Land Capability Classification, as previously described.

All of these interpretations with supporting explanation are attached to the soil survey report either in the form of a Land Capability or Land Suitability Classification Table or Map. However, the system of each land classification may have different assumptions and definitions depending upon intensity of the soil survey. For example, in interpreting general soil maps and reconnaissance maps, the dominant individual land capability or land suitability classes can be shown in general areas. On the other hand, the capability subclass or suitability subclass is the most useful unit for interpretation for semi-detailed survey. We certainly hope that these soil survey interpretations can fill the gap between the soil scientists who make the soil maps and the planners who know little about soil science.

While the primary purpose of soil survey in Thailand is to benefit agriculture, we have attempted to make interpretations for engineering as well. However, the usefulness of this effort is hampered by the lack of information concerning engineering properties of the soil. Therefore, at present we try to make the interpretation as simple as possible so that engineers can use our soil maps during the preliminary stage of planning. In the report there are maps showing accumulations of sand and gravel for subgrade material, indicating suitable locations for construction of highways and roads. Other properties of soils are illustrated, such as kind of substratum, depth and kind of bedrock, state of the water table, natural overland drainage systems, nature of the flooding regime, kinds of clay minerals, and the general topography.

SOIL SURVEY UTILIZATION IN THAILAND

Although many Thai people know what soil is used for, only a few realize its importance to the economy of the country especially in the sense of crop production. They do not even know how soils differ from place to place and how important such differences can be to crop development. They just recognize that a soil is a very simple earth material for supporting plant growth and that when the crop yield becomes low, fertilizer application is a solution to raise the yield. Therefore it is our duty to convince them that each kind of soil in Thailand has its own unique combination of characteristics and potential for use. We try to tell them that without knowledge of the soils, which can be obtained from soil survey, improvement in agricultural production will hardly be accomplished. Unfortunately, the manner of communication we have adopted in Thailand is by means of extension only. There has never been any legal enforcement about planning that says land users must use available information resulting from soil survey before making decisions. Only recently the government approved a new land use regulation that states "no land settlement project is permitted without soil survey and land capability classification work." Thus, soil survey utilization in Thailand is controlled to a certain extent while we try to present our information in a form which can be understood. A most significant problem is that people who know little about soils have authority in making decisions on land use policy.

Attempts have been made to convince the agricultural officials, laymen, planners, extension workers, farm advisers, farming engineers and foresters that soil information exists and that they can use it. The following has been done for several years:

1. Give first priority to the soil surveying that is requested by government agencies. We think that if anybody requests our service it means that they need information for planning. We must respond to their request promptly even if we have limited budget for both surveying and printing. We hope that our service can help them execute their project successfully and responsibly.

2. We incorporate the subject of soil survey in all training programs as requested by government agencies. Many agricultural agencies have their own in-service training programs. They ask us to present information about soils so that the subject can be taught effectively. On every occasion we try our best. We adjust our lecture to suit the backgrounds of the audience. Our lecture aims at giving them enough soil background so they can use our soil maps and soil interpretations. We help to teach students in various institutions about Thailand's soil resources. Through these efforts, we hope that our younger Thai generation will realize how important soil resources are to our daily lives as well as to the economy of the country.

3. Organizing training programs for provincial officers which include agriculturists, planners, engineers, and economists.

Although we have arranged the soil data into more simple forms for the users, there are yet complaints from those without a soil science background that such information is still too involved. Therefore, the soil survey division has set up a project for training government officials to use soil survey reports and maps. After the provincial soil survey (a detailed reconnaissance survey) has been completed, we will be ready to enact this program. We first contact the chief agriculture extension official of that province. If this training program is accepted, he writes an offical request to the governor to allow organization of the program for the province. When he gets permission he distributes invitations to all planners and administrators concerned about land use policy. We have 3 days for this training program. Two days are spent in session, the last day in the field. An example of a program is shown in Table 3.

One problem of this training project has been lack of inertia in most of the provincial agriculture extension personnel. They ignore our proposal because of lack of interest in the significant effect of soil properties on crop growth and management practices. This is due to a lack of basic knowledge in soil science. We are now turning our approach the other way around. Instead of direct contact to the provincial agriculture extension chiefs, we approach the Director General of the Agriculture Extension Department. By his authority he can order the provincial agriculture extension chiefs to organize training sessons. We hope that this coming fiscal year we can organize two levels of training projects. The first level is for personnel who have obtained a B.S. degree with some soil science background. The second level is for those who graduated from agriculture vocational colleges with very little or no background in soil science.

We also evaluate the result of each training program. So far, we found that during the first day of technical lecture their response is mostly negative. This indicates that most of them have had very little background in soil science. But on the second day they respond positively to the lectures. Therefore, this program as it now stands is not entirely useless. We hope that with some modifications of the program it will be worthwhile to continue. However, one should keep in mind that this program will not be perfect unless there is cooperation between the provincial officers and our division.

REFERENCE

Moormann, F.R., and S. Rojanasoonthon. 1972. The Soils of the Kingdom of Thailand. Soil Survey Report 72 A. Soil Survey Division, Land Development Department, Bangkok, Thailand.

Table 3. Time schedule for training program on utilization of soil survey for provincial development.

Date	Time	Program
1st day	0900 to 1000	Opening address by the governor
	1000 to 1200	What is the soil survey?
	1330 to 1430	Importance of soil to agriculture and soil formation
	1430 to 1530	Major characteristics of soils
	1530 to 1630	Soil classification
2nd day	0900 to 1000	Soil characteristics affecting plant growth
	1000 to 1100	Soil suitability classification
	1100 to 1200	Steps of soil survey
	1330 to 1430	Soil survey demonstration by slides
	1430 to 1620	Demonstration concerning how to read soil map, soil survey interpretation and soil survey report
3rd day	0900 to 1630	Field trip showing: a) Soil profile b) Measurement of some soil properties c) Soil and landscape relationship d) Soil and land use

SOIL POTENTIALS AND THEIR USE BY PLANNERS[1]

D. Slusher[2]

NATIONAL SOILS HANDBOOK - PART II

404 Soil Potential Ratings

Definition - Soil potential ratings are classes that indicate the relative quality of a soil for a particular use compared with other soils in a given area. Yield or performance level, the relative cost of applying modern technology to minimize the effects of any soil limitations, and the adverse effects of continuing limitations, if any, on social, economic, or environmental values are considered.

Soil potential ratings have been adopted as a form of soil interpretations:

-- To provide a common set of terms, applicable to all kinds of land use, for rating the quality of a soil for a particular use relative to other soils in the area.

-- To identify the corrective measures needed to overcome soil limitations and the degree to which the measures are feasible and effective.

-- To enable local preparation of soil interpretations, using local criteria to meet local needs.

-- To provide information about soils that emphasizes feasibility of use rather than avoidance of problems.

-- To assemble in one place information on soils, corrective measures, and the relative costs of corrective measures.

-- To make soil surveys and related information more applicable and easily used in resource planning.

-- To strengthen the resource planning effort through more effective communication of the inforamtion provided by soil surveys and properly relating that information to modern technologies.

Soil potential ratings help decision makers determine the relative suitability of soils for a given use. They are used with other resource information as a guide to making land use decisions. Soil potential ratings are used primarily for planning purposes and are not intended as

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[1]This paper presents Part II of Section 404, Soil Potential Ratings, of the National Soils Handbook now being drafted by the Soil Conservation Service of USDA.

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recommendations for soil use. Corrective measures listed are general guides for planning and are not to be applied at a specific location without onsite investigations for design and installation.

To develop soil potential ratings a systematic procedure is required to identify (a) measures for overcoming soil limitations, (b) the performance level of the soils, and (c) limitations continuing after corrective measures have been applied. This procedure must also provide for the use of a numerical system to derive a soil potential index and soil potential ratings. The information assembled is presented to users in soil map unit descriptions, tables, or maps.

The number of soil uses for which ratings are prepared varies from area to area. The importance of the soil use and the number of users of the information must both be considered. When preparing soil potential ratings for a given soil use, all soils in the area should be rated for that use. Soil potential ratings for all soil uses will seldom be needed in a given area.

The geographic area for which soil potential ratings are prepared is an area of importance to a particular group of users. The ratings are mainly to meet needs at a county or subcounty area but can be for any geographic area.

Soil potential ratings are prepared for soil map units regardless of map scale or composition of a unit. Components of multitaxa map units can be evaluated separately if needed to supplement the overall evaluation of a map unit. The soil uses for which soil potential ratings are prepared should be consistent with the detail of mapping.

The procedures in this section have been prepared as guides with contributions from specialists of many disciplines and cooperating agencies. Experience in their use will result in refinements and improvements that may result in revisions to this handbook. Systematic procedures are provided and the end product is defined. A maximum of flexibility is provided. Those who prepare soil potential ratings must be realistic, use good judgment, and be able to adapt the system to conditions and situations in their area.

404.1 Interdisciplinary Involvement

Soil uses for which soil potential ratings are prepared can be broadly categorized as agricultural and nonagricultural. For any use, the evaluations of soil potential must be made in collaboration with specialists in fields most closely related to that use.

(a) Agricultural uses. Agricultural uses include various farm crops, pastureland, rangeland, woodland, orchard, wildlife, etc. Ratings of soil potential for these uses help meet the needs of farmers and ranchers, conservation districts, planning commissions, government agencies, or other users of soil interpretations. Soil scientists, agronomists, foresters, soil conservationists, economists, engineers, range conservationists, biologists or others in local, state, or Federal agencies, or private enterprise are called on as needed to provide the expertise for preparing soil potential ratings for agricultural uses.

(b) Nonagricultural uses. Dwellings, roads, waste disposal, and sanitary facilities, etc., even when used on farms, are considered nonagricultural uses. SCS and conservation districts inform units of government and other agencies of the usefulness of soil potential ratings and encourage their preparation. SCS personnel provide leadership in the procedures and assist in identifying the properties of each kind of soil and the composition of soil map units. Technical experts from outside SCS, working closely with SCS specialists, must have a major role and concur in decisions on performance standards, the means and feasibility of overcoming soil limitations, and the indexes for the costs of corrective measures and the continuing limitations. They must concur in the criteria, the numerical values derived, and the breakpoints between rating classes. SCS coordinates this activity to insure that soil properties are properly identified, that the array is internally consistent in terms of soil properties, and that systematic procedures are followed.

(c) Steps in preparation of ratings. The following steps are suggested as a logical sequence for preparation and presentation of soil potential ratings.

1. Inform users, determine their needs, and initiate action.

2. Identify the technical specialists who will participate.

3. Hold conferences to review procedures and evaluate adequacy of data.

4. Collect additional data if needed.

5. Prepare soil potential ratings.

6. Review and approve ratings as needed.

7. Prepare ratings in final format.

8. Distribute ratings and train users.

404.2 Collection of Data

Before soil potential ratings can be prepared for a particular use, data must be available on the properties of the soils, the limitations the soil properties impose on the use, the composition of the soil map units, the kinds of corrective measures needed, the relative cost or difficulty of overcoming the limitations, if any, continuing after given practices are installed, and the level of performance. Many of the data needed are available in technical guides. Other data needed can be collected through observations made and recorded in the course of day-to-day activities or through systematic efforts of SCS personnel, cooperating agencies, local experts, or others.

The data needs must be appraised before soil potential ratings are prepared. If data are insufficient, a plan must be prepared for obtaining the needed information. The data needed, the individuals responsible for their collection, and the target dates for completion must be identified.

404.3 Definition of Soil Potential Classes

Relative terms are assigned to classes to indicate the potential of a soil for a particular use compared with that of other soils in the area. The same soil in a different area may have a different rating for a given use. The rating classes do not identify the most profitable soil use or imply recommendations for soil uses. A soil rated as having high potential for both woodland and cropland may be much more profitable in one use than in the other.

Five classes are provided for comparative ratings of soil potential: very high, high, medium, low, and very low. Very high potential is assigned to only those few soils having properties that make them exceptionally well suited to the particular use. Very low potential is assigned only to soils having properties so unfavorable for the use that they are virtually unsuited. The number of classes used in the final ratings depends on the range of potentials in the area and the degree of refinement needed. Three classes are enough for many areas.

In a few places only two classes of soil potential are needed because all soils in the area are either well suited or poorly suited to the use. It may be important to prepare soil potential ratings, however, to identify widely different kinds of treatments that are needed for different soils. If a wide array of potential is not present, only two rating classes may be needed; for example, high and medium or medium and low. Ratings of the potential of individual soils are generally not needed in those areas where all soils have the same rating for a given use.

Those preparing the ratings, by establishing the local standards, control the highest or lowest rating class in which a soil in the area can be placed. For example, if corn is not well adapted, then the best rating class for the area might be no better than medium. Another example might be an area where the best soils for dwellings would have medium potential because of high building costs. Thus, a rating of "high" may be avoided if it is felt that it is misleading. Similarly, if all soils in an area are well suited to a use, a "low" potential rating might have an undersirable connotation.

The rating classes are defined in terms of the production or performance expected of a soil if feasible measures are taken to overcome its limitations, the cost of such measures, and the magnitude of the limitations that remain after measures have been applied. Production or performance of each soil is compared with a standard established locally for each soil use (see Section 404.5). The following class terms and definitions are for nationwide use:

Very high potential. Production or performance is at or above local standards; because soil conditions are exceptionally favorable, installation or management costs are low and there are no soil limitations.

High potential. Production or performance is at or above the level of local standards; costs of measures for overcoming soil limitations are judged locally to be favorable in relation to the expected performance of yields; and soil limitations continuing after corrective measures are installed do not detract appreciably from environmental quality or economic returns.

Medium potential. Production or performance is somewhat below local standards; or costs of measures for overcoming soil limitations are high; or soil limitations continuing after corrective measures are installed detract from environmental quality or economic returns.

Low potential. Production or performance is significantly below local standards; or measures required to overcome soil limitations are very costly; or soil limitations continuing after corrective measures are installed detract appreciably from environmental quality of economic returns.

Very low potential. Production or performance is much below local standards; or there are severe soil limitations for which economically feasible measures are unavailable; or soil limitations continuing after corrective measures are installed seriously detract from environmental quality or economic returns.

404.4 Soil Uses and Kinds of Soil Map Units

Soil uses for which soil potential ratings are prepared should be consistent with the detail of mapping. Soil potential ratings for broad categories of soil uses, such as cropland, woodland, rangeland, or residential land, are appropriate for all levels of soil surveys regardless of the kinds of components that make up the soil map units. Ratings for the more specific soil uses, such as strawberries, avocados, dwellings, or septic tank filter fields, are appropriate for soil map units named as phases of soil series.

Soil potential ratings for the more specific soil uses are seldom appropriate for broadly defined soil map units consisting of associations of phases of series and phases of families or other high taxa. The principle of restricting interpretations for the more specific soil uses to soil map units consisting of phases of soil series should be generally followed. Soil potential ratings for broad categories of soil use are more appropriate for soil surveys in which the map units are broadly defined.

404.5 General Concept of the Soil Potential Index

The soil potential index (SPI) is a numerical rating of a soil's relative suitability or quality. It is used to rank soils from high to low, according to their potential. The SPI is derived from indexes of soil performance, cost of corrective measures, and costs established for continuing limitations. The SPI can be expressed by the equation:

$$SPI = P - (CM + CL)$$

where

P = Index of performance or yield as a locally established standard.

CM = Index of costs of corrective measures to overcome or minimize the effects of soil limtiations.

CL = Index of costs resulting from continuing limitations.

All index values used are of a general nature. A highly detailed economic analysis of costs and returns is not required.

The values for CM and CL must be on the same basis. If CM is on an annual basis, CL must also be on an annual basis. If CM is based on the total initial cost of corrective measures and CL is known only on an annual basis, then economic analysis is required to derive common values for comparison. Once a common basis is established for costs of CM and CL, they can be reduced to index values. The SPI can be based on a percentage of the cost or any other base desired.

(a) Performance or yield standard (P). P is an index of a performance or yield standard for the area. It is established and defined locally. The actual yield or performance of each soil is then compared to the standard. For some soils, the yield or performance level will exceed the standard. If so, SPI is adjusted upward on worksheets to reflect the higher yield or performance for the soil [Exhibit 404.6(c) (1), No. 1]. Substandard yield or performance is taken into account as a continuing limitation cost (CL).

In most situations, the standard chosen for P is above the performance level of the average soil in the area but it may be below that achieved on the very best soils. For example, a standard for corn in Bartholomew County, Indiana, might be set at 120 bushels per acre even though on a few of the very best soils this yield is exceeded. This is a performance index, and all soils in the area are evaluated by using this level of P in the equation. For soils that yield above the standard of 120 bushels per acre, SPI is increased by the amount the yield exceeds the standard. For example, for a soil with an estimated yield of 132 bushels per acre:

where P is 120, increase SPI by 12 (132 minus 120);

where P is 100, increase SPI by 10 $\left(\frac{132-120}{120} \times 100\right)^3$

For soils with yields less than the standard, the lower yield is considered a continuing limitation (CL) equal to a factor representing the amount the yield is below the standard. For example; for a soil with an estimated yield of 98 bushels per acre (where P is 100), CL is increased by 18 $\left(\frac{120-98}{120} \times 100\right)^3$ to account for the lower yield that is not overcome by corrective measures. These values or their equivalents if some other relative index is used are entered on worksheets for calculations of SPI.

Whether the crop is grown annually or less often because of need for crop rotation must be considered when defining P. The need to include in the rotation crops with low returns can be accounted for by increasing CL. P need not be an absolute measure such as estimated yield.

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[3] In these cases, an index value of 100 is used to represent a yield of 120 bushels per acre.

For structural measures for which performance is not measured in tons, bushels, cubic feet, or other yield levels, P is set at 100 or some other value that serves as a workable index.

(b) Cost of corrective measures (CM). CM is an index of added costs above a defined standard installation or management system that is commonly used if there are no soil limitations that must be overcome. At the standard level, the value of CM is zero; i.e., no deductions would be made in deriving SPI. In unusual situations where a soil is so uniquely suited that costs incurred to obtain the desired level of performance are less than the standard, CM may be a negative value and thus increases SPI.

Examples of costs of corrective measures for agricultural uses are those for terraces or drainage systems. Costs for such measures can be converted to an annual basis for index values compatible with values for P and CL. Whether or not the corrective measures have already been installed is normally not considered, unless it is determined locally that costs already incurred for major irrigation, drainage, or flood control projects should be disregarded.

Added expenses for measures such as increasing the size of a septic tank filter field, strengthening a foundation, or construction grading for site preparation are examples of corrective measure costs for nonagricultural uses. In many cases these kinds of costs may be handled as total initial costs rather than as prorated annual costs. [See Section 404.6(c)(1)(vi).]

Wherever possible, corrective measures are to be identified that will at least partially overcome soil limitations. Management techniques, as well as agronomic or engineering practices, are considered corrective measures. If wetness affects woodland harvest and drainage is not feasible, it is preferable to show, for example, scheduling of logging operations for dry seasons as a corrective measure rather than showing a continuing limitation of a wetness problem with no solution. An important aspect of the procedure for preparing soil potential ratings is that SCS or cooperating agencies assist in identifying technologies that are or, in the opinion of local experts, should be considered workable options locally. Also, we assist the local experts in properly relating those technologies or measures to kinds of soil.

(c) Cost of continuing limitations (CL). Limitations continuing after corrective measures have been applied are those that have adverse effects on social, economic, or environmental values. Distinctions between the three kinds of values need not be made. Continuing limitations that affect returns or profits are clearly economic. Those that result in pollution of air or water are social and environmental effects. CL is an index of costs resulting from such soil limitations.

Continuing soil limitations may be of three types (1) performance such as low yields; inconvenience; discomfort; probability of periodic failure; limitations resulting from the size, shape, or accessibility of an area; or associated soils that restrict a soil's use periods; (2) annual or periodic maintenance costs such as pumping to remove excess water, irrigation, maintenance of drainage or terrace systems, or pumping and removal of septic tank wastes; and (3) offsite damages from sediment or other forms of pollution. [See Section 404.6(c)(1)(vii).]

Examples illustrating the derivation of CL:

-- If the local performance standard is 2,000 pounds per acre, a potential production of only 1,500 pounds per acre from rangeland in a normal year, obtained through use of all feasible corrective measures for yield increase, is substandard by 500 pounds. Where P is 100, an appropriate index value for CL is 25 $(\frac{2000-1500}{2000} X100)$.

-- If flooding of a dwelling remains a probability after feasible measures are installed, an estimate of damage and inconvenience from a flood event divided by the frequency of flooding might provide an annual cost for conversion to index values. For example, damages of $6,000 might be estimated to result from floods occurring 1 year in 10. This represents an annual cost of $600 and a serious continuing limitation. An appropriate value for CL might be 60 if the index for P is 100.

Other values for CL are estimated on the basis of the costs to insure against damage (i.e., flood insurance), costs of maintenance, costs of substitute facilities during periods of malfunction, penalties that might result from offsite or environmental damages or combinations of these and others. Assignment of a cost index to some continuing limitations is of necessity arbitrary.

404.6 Procedures for Preparation

An early step in the procedures for preparing soil potential ratings is the assembly and evaluation of soil-related data on yield, performance level, local corrective measures, and limitations that continue after treatments are applied. Published soil surveys, soil handbooks, technical guides, research data, and information from sanitarians, contractors, builders, developers, and others are potential sources of data. The amount of useful data varies from area to area depending on the extent of soil use for a particular purpose.

(a) Selection of uses for which soil potential ratings will be prepared.

(1) Soils used extensively for the purpose being evaluated. Deriving SPI is most direct and most accurate if the soils have been used extensively for the purpose or crop being evaluated. The needed corrective measures are well known. The actual performance or yield represents an integration of the effects of corrective measures and soil properties and is also well known. Thus, there is no need to infer or derive relationships among properties, measures, and yields to arrive at the indexes.

(2) Soils not used for the purpose being evaluated. If soils are being evaluated for purposes for which they are not now used or are used in only a few places, then it is necessary to infer corrective measures and the other indexes that are needed. There are two basic approaches for such derivation.

If similar soils are used for the purpose being evaluated, the evaluations are based on the performance of the similar soils and the corrective measures needed to overcome their limitations. Adjustments can be made to slightly raise or lower the performance level or to modify the measures to account for properties more or less favorable than those of the similar soils.

If information on corrective measures and actual performance of similar soils is not available, those soil properties that affect the particular use are identified and the soils are evaluated on the basis of proved relationships between properties and performance. If this approach must be used, careful consideration should be given to whether ratings are needed or appropriate.

(b) Defining soil use, performance standards, and criteria for evaluation. The soil use must be defined, evaluation criteria prepared, and a local performance standard established [Exhibit 404.6(b), No. 1 and 2]. The definition sets further the conditions under which the soil potential ratings apply. In effect, the definitions state the assumptions under which the ratings apply; they must be carefully considered. Examples include:

-- For rating cropland, the kinds of crops grown and basic management systems used;

-- for dwellings, the density or size of lots;

-- for septic tank filter fields, whether or not a municipal water supply is assumed;

-- for numerous uses, the kind or size of equipment used, or methods of procedures followed in the installation of corrective measures.

A performance standard is established and included as a part of the definition.

Evaluation criteria are prepared that list the soil, site and other factors that affect the use [Exhibit 404.6(b),No. 1 and 2]. External features, such as size and shape of area, occurrence in relationship to other soils, regulations, and significant map unit inclusions or nonsoil areas such as rock outcrops that are characteristic of map units, may be included as factors.

The soil factors selected are those that affect yield or performance, require corrective measures, or create limitations to use. Those factors that are considered in rating taxonomic units by degree of limitation (National Soils Handbook, Section 403), are sufficient for some uses. For other uses, criteria for map units may be needed in addition to those for taxonomic units.

For each soil factor, a range of conditions that is related to the kind and relative cost of corrective measures needed to overcome or minimize the effect of the limitation [Exhibit 404.6(b), No. 3] is established. It may be helpful to assign degrees of limitations to each. If so, the coordinated ratings from the Soil Interpretations Record (SCS-Soils-5) are used. For some uses or some factors selected as evaluating criteria, coordinated soil limitation ratings are not available. For these, limitation ratings can be assigned locally. However, ratings of degree of limitation that have not been coordinated are not presented to users in text or tables even though they may have been used in preparing soil potential ratings. For some factors, it may be necessary to subdivide the ranges in properties used for rating soil limitations. For example, in evaluations for dwellings, slopes greater than 15 percent may need to be subdivided as 15-30, 30-50, and 50-80 percent. Even though all these slope classes present severe limitations, differences in the kinds and costs of corrective measures and continuing limitations may be significant for soil potential ratings.

(c) Evaluating map units dominated by phases of soil series. To illustrate one approach to a systematic procedure for preparing soil potential ratings, a worksheet is attached [Exhibit 404.6(c)]. Separate sheets are used for each map unit and for each soil use. Worksheets are to be prepared by states. Copies of completed worksheets are retained in SCS offices as documentation of the procedures used.

(1) General instructions for completing worksheets. General guidance for completing worksheets is given in this section. Examples of completed worksheets are provided for woodland [Exhibit 404.6(c)(1), No. 1]; for septic tank filter fields [Exhibit 404.6(c)(1), No. 2]; and for dwellings without basements [Exhibit 404.6(c)(1), No. 3].

(i) Map unit. Enter the name of the map unit. Soil potential ratings are prepared for the map unit whether a multitaxa or single taxon unit. Separate worksheets are suggested if two or more taxonomic units are named, but the final index for the unit depends on indexes of the components and the size, extent, and relationship of each component to another. Methods of properly integrating ratings of two or more taxonomic units into a rating for the soil map unit are to be prepared locally and must be documented for each soil map unit.

(ii) Evaluation factors. For each use enter on the worksheet the factors that affect the use as identified in the criteria for evaluation [Exhibit 404.6(b), No. 1 and 2].

(iii) Soil and site conditions. For each soil enter the class or range of each soil property or factor used as an evaluation factor; for example, shrink-swell - high; textural class - loam or sandy loam; unified soil classification - SM; and depth to bedrock - 20 to 40 inches.

(iv) Degree of limitation. (Optional). If limitation ratings are assigned they can be entered here. Such ratings may be of particular value to individuals outside SCS who are assisting with the ratings. If limitations are not used, then indicate in some way that a soil factor presents an adverse effect and requires further consideration in the evaluation.

(v) Effects on use. Factors rated as moderate or severe limitations or those indicated by other means impose one or more adverse effects on the performance or the installation of the facility, for example, erosion, surface seepage, equipment limitations, reduced yield, foundation failure. Enter the nature of these effects on the use or installation if no precautions or corrective measures are applied. List only the major effects that require correction.

(vi) Corrective measures. For each effect list one or more kinds of corrective measures that will overcome or minimize the effect of the soil limitation and enter the cost index. For example, measures to overcome the effect of a high water table on soybeans might be to delay planting until the water table recedes, to install tile drainage, and/or to provide drainage land grading. The same measure may overcome two or more limitations. If so, enter the cost index for that measure only once.

For soils with slight limitations, it may be desirable to identify a measure or set of measures to provide users with a complete list for all soils. "Conventional system" for septic tank fields and "conventional design" for foundations are examples. The standards for the conventions are set forth in the definition of the soil use.

As a general rule, no corrective measures are given for soils having slight limitations because these soils generally represent the standard. For some uses, however, there are variations in standard installations even though only slight limitations exist and it may be desirable to identify them. For example, because of variations in percolation rates, there is a significant difference in the size of septic tank filter fields required for soils having slight limitations. Entries on worksheets might show "conventional system, small field" or "conventional system, medium field" to make this distinction.

An index of the costs of corrective measures to overcome limitations is a major factor in accessing soil potential. Significant ranges of measure costs can be established and index numbers rather than actual dollar values can be assigned [Exhibit 404.6(b), No. 2]. This procedure can provide adequate distinctions between measure costs, provide for ease in evaluation, and avoid the implication of great precision. Cost indexes can be based on prorated annual costs, initial installation costs, or other systems, provided that they are expressed in units from the same scale that is used in the indexes for performance and continuing limitations.

It may also be helpful to prepare a set of locally derived corrective measures applicable to specified soil conditions, and their cost. Exhibit 404.6(b) No. 3 illustrates this procedure, but the corrective measures and costs shown are examples only and should not be used in preparing soil potential ratings without local modification.

(vii) Continuing limitations. Regardless of the corrective measures applied, a soil limitation may continue to cause problems because of maintenance cost, substandard performance, or offsite environmental effects. Low yields, maintenance of water disposal systems for erosion control or drainage, use restriction on steep slopes, and maintenance or adequacy of flood control systems are examples. Identify continuing limitations that are associated with alternative measures and indicate by a key phrase the kind of limitation remaining. Assign an index number from a set of values compatible with those used for the performance standard (P) and the measure costs (CM). For some soils, the properties responsible for substandard yields may not be known. If this is so, note the substandard yield as a continuing limitation without relating it to an evaluation factor and enter a cost index for CL [Exhibit 404.6(c)(1), No. 1, Cadeville soil].

(viii) Summary. For each corrective measure (CM) required to overcome an unfavorable soil factor, select the practical and locally accepted corrective measure and the local cost index for the measure and sum.

Sum the indexes for continuing limitations (CL) in the same fashion. Deduct the cost index for the measure (CM) and the cost index for the continuing limitation (CL) from the performance standard index (P) to determine the soil potential index (SPI) as illustrated in the worksheets in Exhibit 404.6(c)(1). Increase SPI as necessary to account for a performance or yield level that is above the standard [Exhibit 404.6(c)(1), No. 1, Quachita soil].

(2) Assignment of ratings. All map units are arrayed from high to low according to their soil potential index. The relative ranking of soils is evaluated against local knowledge. If inconsistencies exist the values used to arrive at SPI should be reevaluated.

To arrive at rating classes, divide the final numerical array on the basis of the definitions of rating classes (Section 404.3) and the tendency of numbers to cluster around certain ranges or show natural group separations [Exhibit 404.6(c)(1), No. 1]. It may not be desirable to indicate the numerical ratings to users since they may indicate a greater degree of refinement that can be defended.

(d) Evaluating broadly defined soil map units. For broadly defined soil map units, such as soil complexes, soil associations, or map units dominated by taxa above the series level, soil potential ratings are generally prepared only for broad categories of soil uses (Section 404.4). In the evaluation for such uses, consideration is given to one or more of the individual elements that make up the use. For example, the elements of residential soil use might be dwellings, local roads and streets, and shallow excavations. The following steps are suggested:

-- List the elements of the use being evaluated.

-- List significant component soils and their extent in each map unit.

-- Rate each component for each element of the use according to the guides given for phases of soil series.

-- Evaluate the map unit for the use according to the evaluation of each element for each component, giving due consideration to the extent and landscape relationship of each of the components.

(e) Dealing with regulations. Local regulations can affect the development of soils for some uses. If the regulations apply uniformly to certain units, they can be included in rating criteria. For example, if soil potential ratings are being prepared for cropland and regulations prohibit drainage of wetlands, it may be appropriate to include the regulated conditions as one of the rating criteria. In such cases, however, it must be possible to distinguish between wetland and nonwetland map units. A preferred alternative is to prepare the ratings as if there were no regulations and footnote worksheets and final presentations to indicate those soils on which the use is prohibited by regulations.

Dealing with regulated uses such as sanitary facilities that require approval by regulatory agencies need not be troublesome. Consideration of the alternatives and agreement on the procedures with those for whom soil potential ratings are being developed can result in useful soil potential ratings.

404.7 Terminology for Limitations and Corrective Measures

Ratings of soil potential are to be accompanied by a statement of the corrective measures required to overcome soil limitations. Broad categories of corrective measures are suggested for use with ratings for broad categories of soil uses and more specific corrective measures for the more specific uses. Choice of phrases or terms can best be determined locally on the basis of the properties of the soils and the kinds of corrective measures needed. The following examples of limitations, broad categories of corrective measures, and more specific corrective measures illustrate the differences but are not intended to dictate specific terms for use.

Limitations	Broad Categories of Corrective Measures	More Specific Corrective Measures
Wetness	Drainage	Surface drainage Tile drainage Drainage land grading
Steep slope	Construction grading	Cuts and fills
Erodes easily	Erosion control	Permanent vegetation Grassed waterways Terraces Conservation tillage
High shrink-swell	Strengthened foundation	Reinforced slab Extended footings Moisture control
Floods	Flood control	Raised foundation Dikes Improved channels
Low strength	Supported foundation	Widened footings Extended footings Slab foundation

Droughty	Irrigation	Sprinkler irrigation Furrow irrigation Border irrigation

404.8 Format for Presenting Soil Potential Ratings

Soil potential ratings must be effectively presented. All presentations must include the explanation of ratings (Exhibit 404.8, No.1) and local definitions of the rating classes (Section 404.3). Definitions of soil uses must also be included. Regardless of the method of presentation, the worksheets and criteria for evaluation that were used must be retained in the SCS office as documentation of the procedures. Participating agencies and names of technical specialists who participated, in addition to SCS specialists, are identified in all publications. Soil potential ratings are not presented without concurrence by the agency or agencies for whom they were prepared and who participated in their preparation. Soil potential ratings are not to be used by SCS unless the systematic procedures outlined in this handbook are followed.

Presentation may be in the narrative form, as in soil map unit descriptions, or in tables. As a minimum, all tables and discussions must identify the soil potential rating and the corrective measures needed to achieve the potential of each soil map unit (Exhibits 404.8, No. 2, 3, and 4). The most desirable format identifies the soil factors that adversely affect the use, the corrective measures, and a statement of any continuing limitations (Exhibit 404.8, No. 2). If soil limitations are presented in conjunction with soil potential ratings, as in Exhibit 404.8, No. 2, they should not be repeated for the soil use in other tables in the report.

The tables shown in Exhibits 404.8, No. 2, 3, and 4, can be modified to meet local needs as long as minimum content is included.

An example of a narrative statement in a map unit description of a phase of a soil series is as follows:

> This soil has high potential for septic tank filter fields if the field size is increased to compensate for the slow percolation rate.

A narrative statement in a map unit description of an association might be as follows:

> This association (or map unit) has high potential for residential use if foundations are strengthened and drainage is provided on Alpha soils or if dwellings are placed only on Beta soils.

Ratings for soil potential can be shown on colored maps, but they must be supported by tabular or narrative presentations that identify the corrective measures needed to achieve the potential and provide definitions of the soil uses and rating classes.

Soil Potential Ratings for Woodland (Beta County)

Definition: Soils managed for maximum average yearly growth per acre (cubic feet) assuming established stands for loblolly pine if adapted, otherwise the best adapted hardwood, not fertilized or irrigated. Yield standard = 130 cubic feet per acre average yearly growth. 1/

Evaluating Criteria:

Factors Affecting Use	Degree of Limitation 2/		
	Slight	Moderate	Severe
Slope (percent)	0 - 15	15 - 25	25 - 40
Depth to water table (feet)	>2.0	2.0 - 0.5	<0.5
Flooding	None or rare	---	Common
Available water capacity (inches per 5-foot depth)	>8	8 - 5	<5
Surface texture	Loamy	Sandy and clayey	---

Cost Index: A percentage of the value of the harvested crop rounded to the nearest whole number is used. Cost classes representing ranges of values are not used.

Performance Index: 100 (equivalent to the yield standard of 130 cubic feet per acre per year).

1/ The yield standard of 130 cubic feet per acre per year is set on the basis of the production of a locally preferred species (loblolly pine - site index 90) on good soils that are also extensive. As the most productive trees (preferred species) on some soils may be oak or some other hardwood, cubic feet per acre provides a more consistent measure of yield than site index. Standard yield tables are available to convert site index of specific trees to cubic feet per acre.

2/ Assignment of degree of limitation is optional; however, classes reflecting different levels or costs of corrective measures are helpful. The ranges under slight limitations will represent the standard or base level for which no corrective measures are given.

Soil Potential for Dwellings Without Basements

Definition: Single family residences; 1400 to 1800 square feet of living area; without basements; spread footings and/or slab construction; life span 50 years; and intensive use of yard for lawns, gardens, landscaping, and play areas. Ratings assume adequate waste disposal and lot sizes of one fourth acre or less.

Evaluating Criteria:

	Degree of Limitation		
Factors Affecting Use	Slight	Moderate	Severe
Depth to water table (inches)	>30	18-30	<18
Flooding	None	None	All
Slope (percent)	0-8	8-15	>15
Shrink-swell potential	Low	Moderate	High

Cost Index:

Index value 1/	Cost classes for corrective measures and continuing limitations (dollars) 2/
1	< 250
2	250-500
4	500-1000
8	1000-2000
12	2000-3000
16	3000-4000
20	4000-5000

Performance index: 100

1/ Index values in this example are arbitrarily set at 0.4 percent of the upper limit of each cost class.

2/ To be compatible with costs of corrective measures the cost of continuing limitations is established for the 50 year life span of the dwelling.

EXHIBIT 404.6(b) No. 3

List of Corrective Measures and Costs for Dwellings without Basements

This exhibit shows how local data might be summarized and made available as a ready reference for preparing soil potential ratings. Corrective measures likely to be needed can be anticipated and costs established for each. As soil potential ratings are prepared, additional measures may be identified that should be added to the list. The general technique applied to both agricultural and nonagricultural soil uses.

This example is only to illustrate a procedure. Corrective measures and costs illustrated are examples only and should not be used without modification to fit local situations.

Corrective measures are those to overcome or minimize soil limitations identified in evaluating criteria. Costs are based on an arbitrary local standard foundation area of approximately 1200 square feet and are those in excess of standard design where no soil limitations are identified. Index values are one percent of estimated costs.

Corrective Measures	Cost (dollars)	Index
Drainage of footing	300-500	4
Drainage of footing and slab	600-800	7
Excavation and grading		
8-15 percent slopes	100-300	2
15-30 percent slopes	300-500	4
Rock excavation and disposal (fractured limestone)		
0-8 percent slopes	1000-1400	12
8-15 percent slopes	700-900	8
Reinforced slab		
moderate shrink-swell potential	1500-2000	17
high shrink-swell potential	3600-4200	39
Areawide surface drainage (per lot)	100-200	2
Importing topsoil for lawn and garden	1000-1400	11

Examples of application of cost index.

a. Soil on 8 to 15 percent slopes with high shrink-swell potential requires:

Reinforced slab		39
Excavation and grading		2
CM	=	41

b. Soil on 0 to 1 percent slopes with high water table requires:

Areawide surface drainage		2
Drainage of footing and slab		7
CM	=	9

WORKSHEET FOR PREPARING SOIL POTENTIAL RATINGS

Soil Use: Area:

Mapping Unit:

Evaluation Factors	Soil and Site Conditions	Degree of Limitation	Effects On Use	Corrective Measures Kinds	Corrective Measures Index	Continuing Limitations Kind	Continuing Limitations Index
				Total		Total	

______ - ______ - ______ = ______

Performance Standard Index - Measure Cost Index - Continuing Limitation Cost Index = Soil Potential Index 1/

1/ If performance exceeds the standard increase SPI by that amount.

Exhibit 404.6(c)

EXHIBIT 404.6(c)(1) No. 1

Explanation of worksheets for preparing soil potential ratings (Woodland-Beta County)

A worksheet is prepared for each soil map unit.

The yield standard (130) is adjusted to a performance standard index of 100 to provide a range of soil potential indexes from 0 to 100. Productivity of 130 cubic feet per acre (loblolly pine, site index 90) meets the performance standard index of 100, e.g., the Guyton and Rustcn map units. Producitivity of 100 cubic feet per acre (loblolly pine, site index 80) is substandard performance 100/130 x 100 = 85 and is considered a continuing limitation if corrective measures fail to overcome the yield limitation, e.g., the Alaga and Cadeville map units. Productivity of 152 cubic feet per acre (loblolly pine, site index 100) is performance above the yield standard (Ouachita map unit). To reflect this yield level SPI is increased by 17 (152 -130/130 x 100 = 17).

Enter evaluation factors from table of rating criteria prepared for the soil use (Exhibit 404.6(b) No. 1).

Enter soil and site conditions for the map unit for each evaluation factor. Enter the degree of limitation from the table of evaluation criteria (Exhibit 404.6(b), No. 1).

Enter effects of the soil and site conditions to serve as a basis for identification of corrective measures.

Enter feasible alternative measures for overcoming the effects of limiting soil or site conditions. Technical guides are useful references. Note that measures are identified wherever possible to overcome effects of limitations in preference to carrying the problems on the unresolved continuing limitations.

In this example, index values for measures and continuing limitations are a percentage of the value of the harvested crops. Whether the costs occur only one time or several times in the period between planting and harvest is considered.

The factor that accounts for substandard yield of the Cadeville soil is not known. The substandard yield is noted as a continuing limitation without relation to a soil factor.

Index values for corrective measures (CM) and continuing limitations (CL) are summed for deduction from the performance standard index (P) to determine the soil potential index (SPI).

The soil potential indexes are arrayed from high to low and ratings assigned as follows:

SPI	Rating	Soil Map Unit
116	Very high	Ouachita silt loam
100	High	Ruston fine sandy loam, 1 to 3 percent slope
85	High	Guyton silt loam
78	Medium	Alaga loamy fine sand, 8 to 13 percent slope
77	Medium	Cadeville fine sandy loam, 15 to 25 percent slope

WORKSHEET FOR PREPARING SOIL POTENTIAL RATINGS

Soil Use: Woodland

Area: Beta County

Mapping Unit: Alaga loamy fine sand, 8 to 13 percent slopes

Yield standard 130 ft^3/ac/yr

Yield estimate 110 ft^3/ac/yr

Evaluation Factors	Soil and Site Conditions	Degree of Limitation	Effects On Use	Corrective Measures Kinds	Corrective Measures Index	Continuing Limitations Kind	Continuing Limitations Index
Slope (percent)	8-13%	Slight	None				
Depth to high water table (ft.)	> 5'	Slight	None				
Flooding	None	Slight	None				
Available water capacity (5 ft. depth)	< 5"	Severe	Reduced yield; seedling mortality	None Occasional replant	2/ 0 4	Moderate yield	3/ 15
Surface texture	Sandy	Moderate	Equipment limitation	Special equipment or schedule operations to avoid dry seasons	3		
				Total	7	Total	15

2/ Index values are a percentage of the value of the harvested crop

3/ Yield reduction is 15 percent of the standard $\left(\frac{130-110}{130} \times 100\right) = 15$

100 (Performance Standard Index) - 7 (Measure Cost Index) - 15 (Continuing Limitation Cost Index) = 78 (Soil Potential Index 1/)

1/ If performance exceeds the standard increase SPI by that amount.

WORKSHEET FOR PREPARING SOIL POTENTIAL RATINGS

Soil Use: Woodland

Area: Beta County

Mapping Unit: Cadeville fine sandy loam, 15 to 25 percent slopes

Yield standard 130 ft^3/ac/yr

Yield estimate 110 ft^3/ac/yr

Evaluation Factors	Soil and Site Conditions	Degree of Limitation	Effects On Use	Corrective Measures Kinds	Corrective Measures Index	Continuing Limitations Kind	Continuing Limitations Index
Slope (percent)	15-25%	Moderate	Equipment limitation, Erosion	Safety Precautions 2/	4	None	
Depth to high water table (ft.)	>2'	Slight	None	Road design	3	Road maintenance	1
Flooding	None	Slight	None				
Available water capacity (5 ft. depth)	>8"	Slight	None				
Surface texture	loamy	Slight	None				
						Moderate yield 3/	15
				Total	7	Total	16

2/ Special equipment not considered practical

3/ Substandard yield not accounted for in evaluation factors. Corrective measures not known. Yield is 15% below standard.

100 (Performance Standard Index) - 7 (Measure Cost Index) - 16 (Continuing Limitation Cost Index) = 77 (Soil Potential Index 1/)

1/ If performance exceeds the standard increase SPI by that amount.

WORKSHEET FOR PREPARING SOIL POTENTIAL RATINGS

Soil Use: Woodland

Area: Beta County

Mapping Unit: Guyton silt loam

Yield standard 130 ft^3/ac/yr

Yield estimate 130 ft^3/ac/yr

Evaluation Factors	Soil and Site Conditions	Degree of Limitation	Effects On Use	Corrective Measures: Kinds	Corrective Measures: Index	Continuing Limitations: Kind	Continuing Limitations: Index
Slope (percent)	0-1 %	Slight	None				
Depth to high water table (ft.)	< 0.5'	Severe	Equipment limitation	Special equipment or schedule operations to avoid wet seasons	10		
			Seedling mortality	Bedding or replant	5		
Flooding	None	Slight	None				
Available water capacity (5 ft. depth)	> 8"	Slight	None				
Surface texture	loamy	Slight	None				
				Total	15	Total	0

100 (Performance Standard Index) - 15 (Measure Cost Index) - 0 (Continuing Limitation Cost Index) = 85 (Soil Potential Index [1/])

1/ If performance exceeds the standard increase SPI by that amount.

WORKSHEET FOR PREPARING SOIL POTENTIAL RATINGS

Soil Use: Woodland

Area: Beta County

Mapping Unit: Ouachita silt loam

Yield standard 130 ft^3/ac/yr

Yield estimate 152 ft^3/ac/yr

Evaluation Factors	Soil and Site Conditions	Degree of Limitation	Effects On Use	Corrective Measures: Kinds	Corrective Measures: Index	Continuing Limitations: Kind	Continuing Limitations: Index
Slope (percent)	0-1%	Slight	None				
Depth to high water table (ft.)	>6'	Slight	None				
Flooding	None	Slight	None				
Available water capacity (5 ft. depth)	>8'	Slight	None				
Surface texture	loamy	Slight	None				
				Total	0	Total	0

100 (Performance Standard Index) - 0 (Measure Cost Index) - 0 (Continuing Limitation Cost Index) = 100+17=117 (Soil Potential Index 1/)

1/ If performance exceeds the standard increase SPI by that amount. $\left(\frac{152-130}{130} \times 100\right) = 17$

WORKSHEET FOR PREPARING SOIL POTENTIAL RATINGS

Soil Use: Woodland

Area: Beta County

Mapping Unit: Ruston fine sandy loam, 1 to 3 percent slopes

Yield standard 130 ft^3/ac/yr
Yield estimate 150 ft^3/ac/yr

Evaluation Factors	Soil and Site Conditions	Degree of Limitation	Effects On Use	Corrective Measures: Kinds	Corrective Measures: Index	Continuing Limitations: Kind	Continuing Limitations: Index
Slope	1-3%	Slight	None				
Depth to high water table (ft.)	>5'	Slight	None				
Flooding	None	Slight	None				
Available water capacity (5 ft. depth)	>8'	Slight	None				
Surface texture	loamy	Slight	None				
				Total	0	Total	0

100 (Performance Standard Index) - 0 (Measure Cost Index) - 0 (Continuing Limitation Cost Index) = 100 (Soil Potential Index 1/)

1/ If performance exceeds the standard increase SPI by that amount.

WORKSHEET FOR PREPARING SOIL POTENTIAL RATINGS

Soil Use: Septic tank filter fields

Area: Sigma County

Mapping Unit: Memphis silt loam, 12 to 20 percent slopes

Evaluation Factors 2/	Soil and Site Conditions	2/ Degree of Limitation	Effects On Use	Corrective Measures Kinds	Corrective Measures Index	Continuing Limitations Kind	Continuing Limitations Index
Percolation rate	45 min/in	Slight	None	Conventional system, medium field 3/	0	None	0
Water table	> 6'	Slight	None				
Flooding	None	Slight	None				
Slope	12-20 %	Moderate	Surface seepage	Slope design	10 4/	None	0
Stoniness	None	Slight	None				
Depth to rock or other impervious material	> 6'	Slight	None				
				Total	10	Total	0

2/ Local factors and ratings

3/ This system is the standard installation size

4/ Index number is percent above standard installation cost

100 (Performance Standard Index) - 10 (Measure Cost Index) - 0 (Continuing Limitation Cost Index) = 90 (Soil Potential Index 1/)

1/ If performance exceeds the standard increase SPI by that amount.

Exhibit 404.5(c)(1) No. 2

WORKSHEET FOR PREPARING SOIL POTENTIAL RATINGS

Soil Use: Dwellings without basements Area: Alpha County

Mapping Unit: *Calhoun silt loam*

Evaluation Factors	Soil and Site Conditions	Degree of Limitation	Effects On Use	Corrective Measures Kinds	Corrective Measures Index	Continuing Limitations Kind	Continuing Limitations Index
Depth to high water table	0-2' (perched)	Severe	Wet lawns, Construction Problems	Surface drainage Special drainage during construction	2 4	Maintain drainage Yard use restrictions in wet seasons	1 6
Flooding	None	Slight	None				
Slope	0-1 %	Slight	None				
Shrink-swell	Low	Slight	None				
				Total	6	Total	7

100 (Performance Standard Index) - 6 (Measure Cost Index) - 7 (Continuing Limitation Cost Index) = 87 (Soil Potential Index [1/])

[1/] If performance exceeds the standard increase SPI by that amount.

Exhibit 404.6(c)(1) No. 3

WORKSHEET FOR PREPARING SOIL POTENTIAL RATINGS

Soil Use: Dwellings without basements

Area: Alpha County

Mapping Unit: *Calloway silt loam*

Evaluation Factors	Soil and Site Conditions	Degree of Limitation	Effects On Use	Corrective Measures: Kinds	Corrective Measures: Index	Continuing Limitations: Kind	Continuing Limitations: Index
Depth to high water table	1 - 2½' (Perched)	Severe	Wet lawns Construction problems	Surface drainage Special drainage during construction	1 4	Maintain drainage	1
Flooding	None	Slight	None				
Slope	0.5-2%	Slight	None				
Shrink-swell	Moderate	Moderate	Foundation failure	Deepen and strengthen footings	4		
				Total	9	Total	1

100 (Performance Standard Index) - 9 (Measure Cost Index) - 1 (Continuing Limitation Cost Index) = 90 (Soil Potential Index 1/)

1/ If performance exceeds the standard increase SPI by that amount.

Exhibit 404.6(c)(1)
No. 3
-2-

WORKSHEET FOR PREPARING SOIL POTENTIAL RATINGS

Soil Use: Dwellings without basements

Area: Alpha County

Mapping Unit: Commerce silty clay loam

Evaluation Factors	Soil and Site Conditions	Degree of Limitation	Effects On Use	Corrective Measures Kinds	Corrective Measures Index	Continuing Limitations Kind	Continuing Limitations Index
Depth to high water table	1½-4'	Moderate	Wet lawns Construction problems	Surface drainage Special drainage during construction	1 2	Maintain drainage	1
Flooding	None	Slight	None				
Slope	0-2%	Slight	None				
Shrink-swell	Moderate	Moderate	Foundation failure	Strengthen footings and reinforce slab	6		
				Total	9	Total	1

100 (Performance Standard Index) - 9 (Measure Cost Index) - 1 (Continuing Limitation Cost Index) = 90 (Soil Potential Index 1/)

1/ If performance exceeds the standard increase SPI by that amount.

WORKSHEET FOR PREPARING SOIL POTENTIAL RATINGS

Soil Use: Dwellings without basements

Area: Alpha County

Mapping Unit: Dexter silt loam

Evaluation Factors	Soil and Site Conditions	Degree of Limitation	Effects On Use	Corrective Measures Kinds	Corrective Measures Index	Continuing Limitations Kind	Continuing Limitations Index
Depth to high water table	>6'	Slight	None				
Flooding	None	Slight	None				
Slope	1-3%	Slight	None				
Shrink-swell	Low	Slight	None				
				Total	0	Total	0

100 (Performance Standard Index) - 0 (Measure Cost Index) - 0 (Continuing Limitation Cost Index) = 100 (Soil Potential Index 1/)

1/ If performance exceeds the standard increase SPI by that amount.

WORKSHEET FOR PREPARING SOIL POTENTIAL RATINGS

Soil Use: Dwellings without basements

Area: Alpha County

Mapping Unit: *Memphis silt loam, 8 to 20 percent slopes*

Evaluation Factors	Soil and Site Conditions	Degree of Limitation	Effects On Use	Corrective Measures: Kinds	Corrective Measures: Index	Continuing Limitations: Kind	Continuing Limitations: Index
Depth to high water table	>6'	Slight	None				
Flooding	None	Slight	None				
Slope	8-20%	Moderate	Erosion, Construction Problems	Construction grading, shaping for water disposal	8	Maintain water disposal system yard use restriction	1 2
Shrink-swell	Low	Slight	None				
				Total	8	Total	3

100	-	8	-	3	=	89
Performance Standard Index		Measure Cost Index		Continuing Limitation Cost Index		Soil Potential Index 1/

1/ If performance exceeds the standard increase SPI by that amount.

WORKSHEET FOR PREPARING SOIL POTENTIAL RATINGS

Soil Use: Dwellings without basements

Area: Alpha County

Mapping Unit: Sharkey clay

Evaluation Factors	Soil and Site Conditions	Degree of Limitation	Effects On Use	Corrective Measures Kinds	Index	Continuing Limitations Kind	Index
Depth to high water table	0-2'	Severe	Wet lawns Construction problems	Surface drainage Special drainage during Construction	2 4	Maintain drainage Yard use restrictions in wet Seasons	1 10
Flooding	None	Slight	None				
Slope	0-1%	Slight	None				
Shrink-swell	Very high	Severe	Foundation failure	Deepen and strengthen footings; reinforce slab	8		
				Total	14	Total	11

100 (Performance Standard Index) - 14 (Measure Cost Index) - 11 (Continuing Limitation Cost Index) = 75 (Soil Potential Index 1/)

1/ If performance exceeds the standard increase SPI by that amount.

Explanation of Soil Potential Ratings for Use with Maps or Reports

The soil potential ratings indicate the comparative quality of each soil in the county for the specified uses. Because comparisons are made only among soils in this county, ratings of a given soil in another county may differ.

The ratings are based on a system developed for this county that included consideration of (1) yield or performance levels, (2) the difficulty or relative cost of corrective measures that will improve soil performance or yield, and (3) adverse social, economic or environmental effects of soil limitations, if any, that cannot be feasibly overcome.

The ratings do not constitute recommendations for soil use. They are to assist individuals, planning commissions, and others in arriving at wise land use decisions. Treatment measures are intended as a guide to planning and are not to be applied at a specific location without onsite investigations for design and installation.

The soil potential ratings used are defined as follows:

(To be followed by the definitions of those soil potential ratings used.)

TABLE 2. -- SOIL POTENTIAL RATINGS FOR SEPTIC TANK FILTER FIELDS

Soil name and map symbol	Limitations and restrictions	Soil potential and corrective treatment	Continuing limitations
1--Grenada silt loam, 0 to 2 percent slopes	Severe: percs slowly.	Medium: conventional system, alternate valve, large field, pump tank in wet season.	Monitor system for need to pump.
2--Jefferson gravelly loam, 5 to 12 percent slopes	Slight	Very high: conventional system, small field.	None
3--Linsdale silt loam, 0 to 2 percent slopes	Severe: wetness.	High: conventional system, medium field, area wide subsurface drainage.	Maintain drainage system.
4--Memphis silt loam, 2 to 6 percent slopes	Slight	High: conventional system, medium field.	None.
5--Memphis silt loam, 12 tc 20 percent slopes	Moderate: slope.	High: conventional system, medium field, slope design.	None.
6--Memphis silt loam, 25 to 30 percent slopes	Severe: slope.	Very low: no known system.	--
7--Talbott silt loam, 8 to 12 percent slopes	Severe: percs slowly, depth to rock.	Low: mound system.	None.
8--Waverly silt loam, 0 to 2 percent slopes	Severe: wetness.	Low: mound system.	None.

TABLE 3. -- SOIL POTENTIAL RATINGS FOR CROPLAND

Soil name and map symbol	Soil potential and corrective treatment	Continuing limitations
1--Caddo silt loam, 0 to 1 percent slopes	High: drainage, high fertilization rate.	Maintenance of drainage system.
2--Gore fine sandy loam, 8 to 12 percent slopes	Low: erosion control.	Maintenance of erosion control system, sub-standard yield.
3--Guyton silt loam	Medium: drainage, high fertilization rate.	Maintence of drainage system.
4--Guyton silt loam, frequently flooded	Very low: project type flood control, drainage.	Maintenance of drainage and flood control system.
5--Kisatchie soils, 15 to 30 percent soils	Very low: erosion control, high fertilization rate.	Maintenance of erosion control system, equipment limitations; substandard yield.
6--Norwood silt loam	Very high: drainage.	Maintenance of drainage system.
7--Ruston fine sandy loam, 3 to 5 percent slopes	High: erosion control.	Maintenance of erosion control system.
8--Ruston fine sandy loam, 8 to 12 percent slopes	Low: erosion control.	Maintenance of erosion control system, sub-standard yield.

TABLE 4. -- SOIL POTENTIAL RATINGS AND CORRECTIVE MEASURES FOR CROPLAND, PASTURELAND, WOODLAND, AND RESIDENTIAL LAND

Soil name	Cropland	Pastureland	Woodland	Residential land
1--Caddo silt loam, 0 to 1 percent slopes	High: drainage.	High: drainage, scheduled grazing to avoid wet conditions.	High: scheduled operations to avoid wetness.	Medium: drainage.
2--Gore fine sandy loam, 8 to 12 percent slopes	Low: erosion control.	Medium: erosion control.	Medium: scheduled operations to avoid wet conditions.	Medium: construction grading, water disposal, strengthened foundations.
3--Guyton silt loam	Medium: drainage.	Medium: drainage, scheduled grazing to avoid wet conditions.	High: scheduled operations to avoid wet conditions.	Low: drainage, diversions.
4--Guyton silt loam, frequently flooded	Very low: project type flood control.	Low: drainage, adapted water tolerant plants, scheduled grazing to avoid wet conditions.	High: scheduled operations to avoid wet conditions.	Very low: project type flood control, drainage.
5--Kisatchie soils, 15 to 30 percent slopes	Very low 1/	Low: reduced stocking rate.	Low: erosion control during site preparation and logging.	Low: construction grading, water disposal excavate rock.
6--Norwood silt loam	Very high	Very high	Very high	Very high
7--Ruston fine sandy loam, 3 to 8 percent slopes	High: erosion control.	Very high	High	Very high
8--Ruston fine sandy loam, 8 to 12 percent slopes	Low: erosion control.	Very high	High	High: construction grading, water disposal.

1/ Soil conditions are such that treatments are generally not warranted for this use.

UTILIZATION AND PRESENTATION OF SOIL RESOURCE INVENTORY INFORMATION FOR LAND AND WATER RESOURCE PLANNING

Luvern L. Resler[1]

Food production continues to be one of the most pressing problems of the world. Considering population projections, even greater increases in food requirements throughout the world can be expected. University representatives from Arizona, California, Colorado, and Utah, who make up the Consortium for International Development, state:

> "The green revolution, while providing a potential for important food supply increases, cannot reach that potential without substantial and sustained improvements in the management of available water and soil resources." (Consortium for International Development, 1975.)

This statement is especially true in the arid and subhumid areas of the world where there is insufficient precipitation to support a viable rainfed agriculture, but also has implications regarding rainfed agriculture.

The arid and subhumid regions comprise approximately one-sixth of the total land surface and a substantially greater portion of the world's potential for agricultural production. Full-service irrigation or systems for supplemental water service will have a leading role to play in meeting the food and fiber requirements generated by the world's population increase.

The Bureau of Reclamation recognizes that irrigation places special demands on conservation of our land and water resources. These demands arise because irrigation, along with other of man's activities, causes changes in the environment. As we alter the amount, quality, timing, and place of water use, we change the physical, chemical, and biological systems operating within the soil and sub-strata, and impact the broad environmental and social spectrum. The immediate changes are normally favorable, thereby fulfilling needs, providing new opportunities, and improving the standard of living and social well-being of the people. On the other hand, the long-term effects, which have been experienced by some developments, have been to degrade or destroy land resources. This can be avoided.

In the Bureau of Reclamation, it is recognized that to accomplish sound, acceptable resource planning and project development, a multidisciplinary team approach is required. The many facets and complex interactions involved with naturally occurring land and water systems make it imperative that open communication channels be established and maintained between cooperating-planning team members. Much of the study team's success depends upon the integration, organization, coordination, and knowledgeable information exchange that is involved in the activities of several disciplines including plant science, water suitability science, hydrology,

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drainage, engineering, environmental sciences, sociology, geology, soil science, and economics relative to land and water management. Therefore, information developed from gathered data needs to be pertinent to the problem-solving efforts and usable by all planning team members and decision-making bodies.

Planners of resource development projects have a social obligation and moral responsibility to assure that the changes brought about by their actions will be favorable over the long run.

LAND CLASSIFICATION

Land resource investigations in the Bureau of Reclamation are conducted primarily to define land areas capable of sustained, profitable agricultural production under irrigation. Irrigation suitability land classification is thus the systematic appraisal of lands and their designation by categories or classes on the basis of similar physical and chemical characteristics and related economic implications and conditions with respect to suitability for permanent, productive irrigation agriculture. A land classification survey is an economic and physical delineation of land into categories or land classes that ultimately represent repayment capacity or net farm income. The land classification investigations include other related land uses within a given project setting and their impacts upon nonproject areas.

To establish adequate background information and form a firm foundation upon which to build an understanding of land classification's specific needs, the following two definitions and associated terminology commonly used will be beneficial.

Arable Land

Arable land, when farmed in adequately sized units for the prevailing climatic and economic setting and provided with the essential onfarm improvements such as removing vegetation, leveling, soil reclamation, drainage, and irrigation-related facilities, will generate sufficient income under irrigation to pay farm production expenses; provide a reasonable return to farm family labor, management, and capital; and at least pay a portion of the operation, maintenance, and replacement costs of associated irrigation and drainage facilities.

Land Class

Land class is a designation for a body of land having soil, topography, and drainage characteristics resulting in a similar economic level of suitability for irrigation within a specific project setting. Land classes are mutually exclusive; i.e. pertinent factors are arranged in discrete, nonoverlapping, and determinate groups or divisions in the classification. Individual land classes are defined within a specific project setting, normally using three classes of arable land and one nonarable class.

Class 1. Lands suitable for sustained high yields of most climatically adapted crops under sustained irrigation with minimum costs of development and management associated with the land.

Class 2. Lands of moderate productivity, or requiring moderate costs for development and management because of slight-to-moderate limitations in land characteristics.

Class 3. Lands of restricted productivity for most crops, or lands requiring relatively high costs for development and management because of moderate-to-severe limitations in land characteristics.

Class 6. Lands which are unsuited for sustained irrigation due to excessively severe limitations in soils, topography, or drainage for a particular project setting.

These major classes, along with the associated subclasses evaluating land deficiencies, accommodate the normal land classification study needs.

Land classification focuses on a specific system for the production of food and fiber through irrigated agriculture. Land classification cannot and should not be directly applied by following a set of general land-class-determining factors or rules. Each potential project setting presents its own particular land classification requirements. The landscape complex, climatic variances, and the broad variety of economic, social, and institutional factors render the specification of a rigid system impractical. Land classification surveys should, therefore, be designed and land classes defined to meet specific development goals and economic requirements relevant to each project.

Therefore, formal static rules or regulations concerning the Bureau's system of land classification do not constitute a major portion of the body of information related to irrigation planning study applications. In this system of land selection for permanent, profitable water and land resources development, a set of basic principles has evolved that does have general application and can be used in perfecting a dynamic classification system for local specific needs. The principles have applicability to broad aspects of agronomic development, rainfed agriculture as well as irrigation.

Principles of Land Classification

The land classification resource planning survey should adhere, to the extent possible, to the time-tested classification principles (Bureau of Reclamation, 1953; Maletic, 1962; Maletic and Hutchings, 1967; Peters, 1975). These principles have been developed to guide the establishment of the specific classification system for selecting lands for a particular plan of development. In developing irrigation projects, land and water resources should be efficiently combined by an engineering and settlement plan that best meets defined, realistic, and attainable social and economic goals of the people.

Lands selected for development should be permanently productive under the change in environmental regime anticipated with irrigation. The introduction of irrigation shifts the natural balance established over time between water, land, vegetation, fauna, and man. Irrigation project planning, therefore, identifies and evaluates the changes, and the plans are formulated to assure that a successful, permanent agriculture will result. Principles that control classification of the potential project system may be identified as (1) prediction, (2) economic correlation, (3) arability-irrigability analysis, and (4) permanent-changeable factors.

Prediction principle. The land classes must express predictions of future soil-water-crop interactions expected to prevail under the new moisture regime resulting from the project. This involves identifying and evaluating the changes anticipated from water control, supply, drainage, and overall management relative to formulating plans to assure that a successful, permanent agriculture will result.

As with most of man's other agronomic activities, irrigation induces changes in the physical, chemical, and biological characteristics of the land. Many of the changes are interrelated and complex. It is not sufficient to just describe existing land characteristics and conditions. The process of data collection and synthesis into information should include prediction of the changes that will occur. Soil structure may be modified by changes in salinity, modification of exchangeable sodium percentage (ESP), variation of organic matter content and regimen, and alteration of clay minerals. Irrigation may induce shallow water table development, causing drainage problems and related salinity; changes in sodium concentrations and aeration conditions which influence crop growth; modification of slope and microrelief by landforming, and alteration of soil profile characteristics by deep plowing, chiseling, or addition of amendments. The irrigation water may cause favorable changes in the salinity of the soil through leaching or an unfavorable increase in salinity through high water tables or insufficient application of irrigation water. Depending upon water electrolyte concentration and ion species, the exchangeable sodium level of the soil may equilibrate at levels favoring water movement through the soil or it may increase, causing some soils to become impermeable. Calcium carbonate and gypsum may be precipitated or dissolved. Organic matter levels will change and new biological populations will develop in the soil.

Flooding a soil, as practiced under rice cultivation, instantly sets in motion a series of physical, microbiological, and chemical processes which influence crop growth. These include retardation of gaseous exchange between soil and air, reduction in the soil system, and the electrochemical changes accompanying the reduction. Carbon dioxide and other gases (nitrogen, methane, hydrogen) produced in the soil tend to accumulate, build up pressure, and escape as bubbles. There is a decrease in redox potential, potential change in pH, and an increase in specific conductance. Also the flooding causes denitrification; accumulation of ammonia; reduction of manganese, iron, and sulfate; accumulation of the decomposition products of anaerobic micro-organisms; and other secondary effects of reduction.

In accomplishing land classification surveys for selecting lands suitable for irrigation, the planning effort should include provisions for recognition and evaluation of the changes that will occur. This will require not only careful field studies of observable soil characteristics and qualities but also detailed measurements of the relevant attributes of the soil and substrata in the field and in the laboratory. Special problems may arise during the investigation of the land resources. Appropriate solutions must be brought to bear upon solving the problem. This would include cooperation between various disciplines in Federal, state, and local institutions and organizations well versed in basic and applied research.

It may require the establishment of research projects or the operation of development farms to test the compatibility of the soil and water and derivation of suitable cropping and management systems.

Economic correlation principle. In any particular project setting, the economic correlation principle states that the physical factors of soil characteristics and land conditions, including topography and drainage, are functionally related to economic parameters. A relative economic return will be realized when a specific parcel of land is put into production. Understanding some of the interrelationships and interdependencies of economics and soil science, as it applies to the land classification process, helps develop a clearer understanding of some of the economic implications of the judgment decisions land classifiers are required to make. As stated by Nielsen, "The field of economics simply deals with means and ends. Ends are the objectives of people and may deal with net income, consumer satisfactions, or physical production. Means are the physical resources, funds, organizations, or institutions which can be used to attain the various possible ends or objectives."

Economics is a science of choice between the alternatives regarding peoples' objectives and the resources with which they may be obtained. Choices made are influenced by the funds available, financing capabilities, and products or objectives desired.

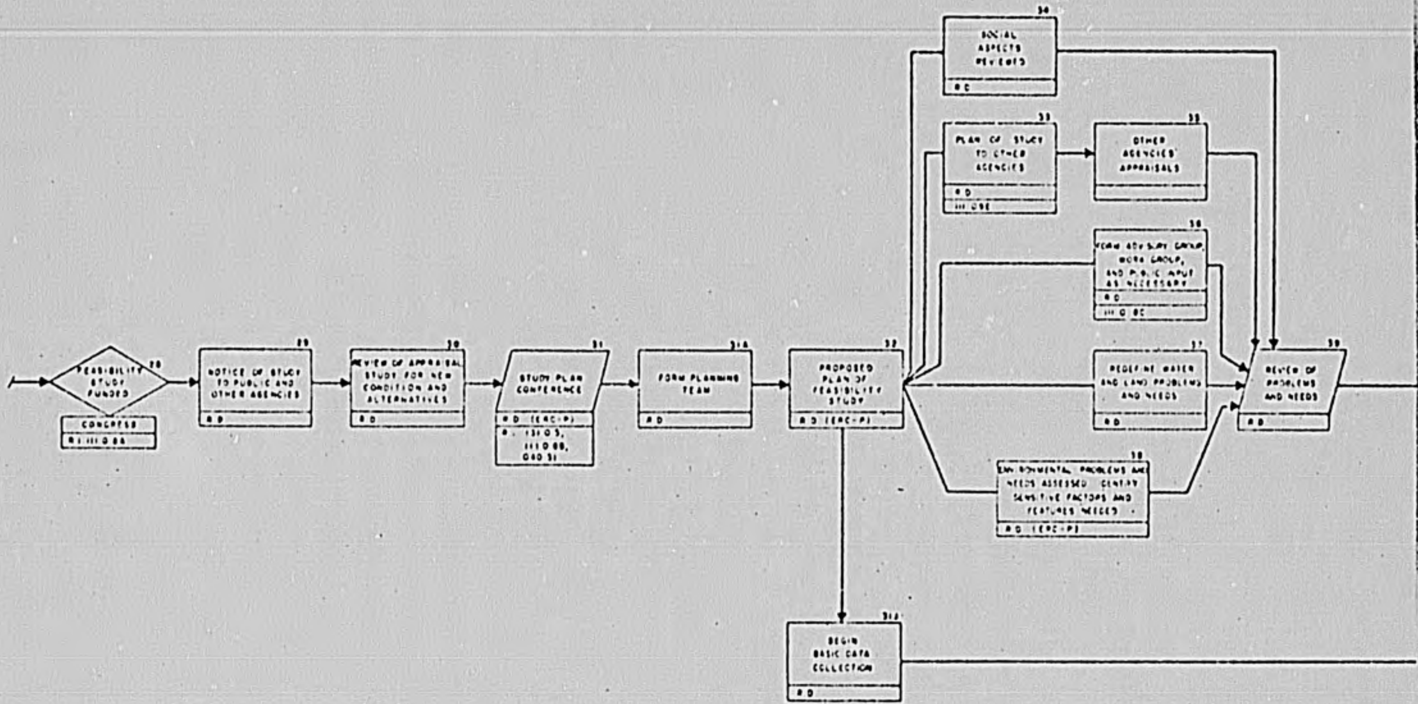
In water and land resource development the characteristics and qualities of lands that determine suitability for development through modification in water supply, control, management, and use vary with each project. The land-class-determining factors represent selected and correlated ranges for such soil resource inventory characteristics as texture; depth to bedrock, hardpan, sand, gravel, caliche or other root-limiting influences; structure; consistence; color and mottling; kinds and amounts of coarse fragments; and kind, thickness, and sequence of horizons. In addition, the prediction aspect of selecting arable lands requires quantifying laboratory and field measurements. Performance qualities are also either measured where possible or inferred. These would include factors such as fertility, productivity, erodibility, and drainability, as well as such measurable factors as infiltration rate, hydraulic conductivity, moisture characteristics, and moisture-holding capacity (Peters, 1977). If a pertinent land parameter is quantifiable, it should be measured rather than estimated.

In some systems of land classification the economic value is not critically defined--it may be merely implied in a qualitative manner usually in terms of anticipated productivity levels. In other systems such as that used by the U.S. Bureau of Reclamation the economic value is defined as payment capacity--the residual available to defray the cost of water after all other costs have been met by the farm operator (Bureau of Reclamation, 1953). Thus the major determination for development is between lands that are economically viable for development (arable) from those which are not (nonarable). Therefore, arable land is land which "when farmed in adequately sized units for the prevailing climatic and economic setting and provided with the essential onfarm improvements of removing vegetation, leveling, soil reclamation, drainage, and irrigation-related facilities will generate sufficient income under irrigation to pay all farm production expenses; provide a reasonable return to the farm family's labor, management, and capital; and at least pay the operation, maintenance, and replacement costs of associated irrigation and drainage facilities."

When land classes are defined as economic entities, then relevant and mappable land characteristics are chosen at a given time and place to comprise the set of land-class-determining factors. The class-limiting value of these physical characteristics will vary with the economic, ecological, technological, and institutional factors prevailing or expected to prevail in the area. As a consequence, land classes will express a local ranking of the lands for irrigation use. They may represent lands best suited, moderately suited, poorly suited, and unsuited for irrigation development. The physical basis for the ranking is adapted to the specific project environment. For example, in the northwestern United States lands with slopes up to 35 percent may be well suited for irrigation while on the Gulf Coastal Plain of Texas lands with slopes over 3 percent would be unsuited for irrigation. The differences are caused primarily by intensity of rainfall. In areas producing high economic returns more severe deficiencies in factors such as structure, texture, salinity level, sodic level, drainage, and microrelief can be tolerated than in areas producing low returns. Also social and political goals oftentimes dictate the degree of economic input desirable for agricultural development. An example might be irrigation project development in an economically depressed area to create more jobs for people, or in a country with ample funds available for development and a desire to be self-sufficient in food production.

Permanent and changeable factors principle. The permanent-changeable factors principle recognizes that for each setting there are land features and characteristics which will not be changed under irrigation and those which will, and that it is necessary to identify those which will be significantly altered. This identification, through economic studies and recognition of the land characteristics, permits establishment of a consistent set of specifications assuring uniform appraisal of land conditions in making the land classification survey. Most land factors, including soil depth, are changeable at a cost. Typical changeable factors include salinity, sodicity, titratable acidity and exchangeable aluminum, depths to water table, relief, brush and tree cover, rock cover, drainage, and flood hazard. It's not how "good" or how "bad" a resource is but what can be done with it.

Whether given characteristics will be changed usually depends upon economic considerations. The land classification survey must deal with two aspects of this principle. Can the change be accomplished, and what degree of change is economically feasible? This is largely dependent on the climatic and economic setting of the project.



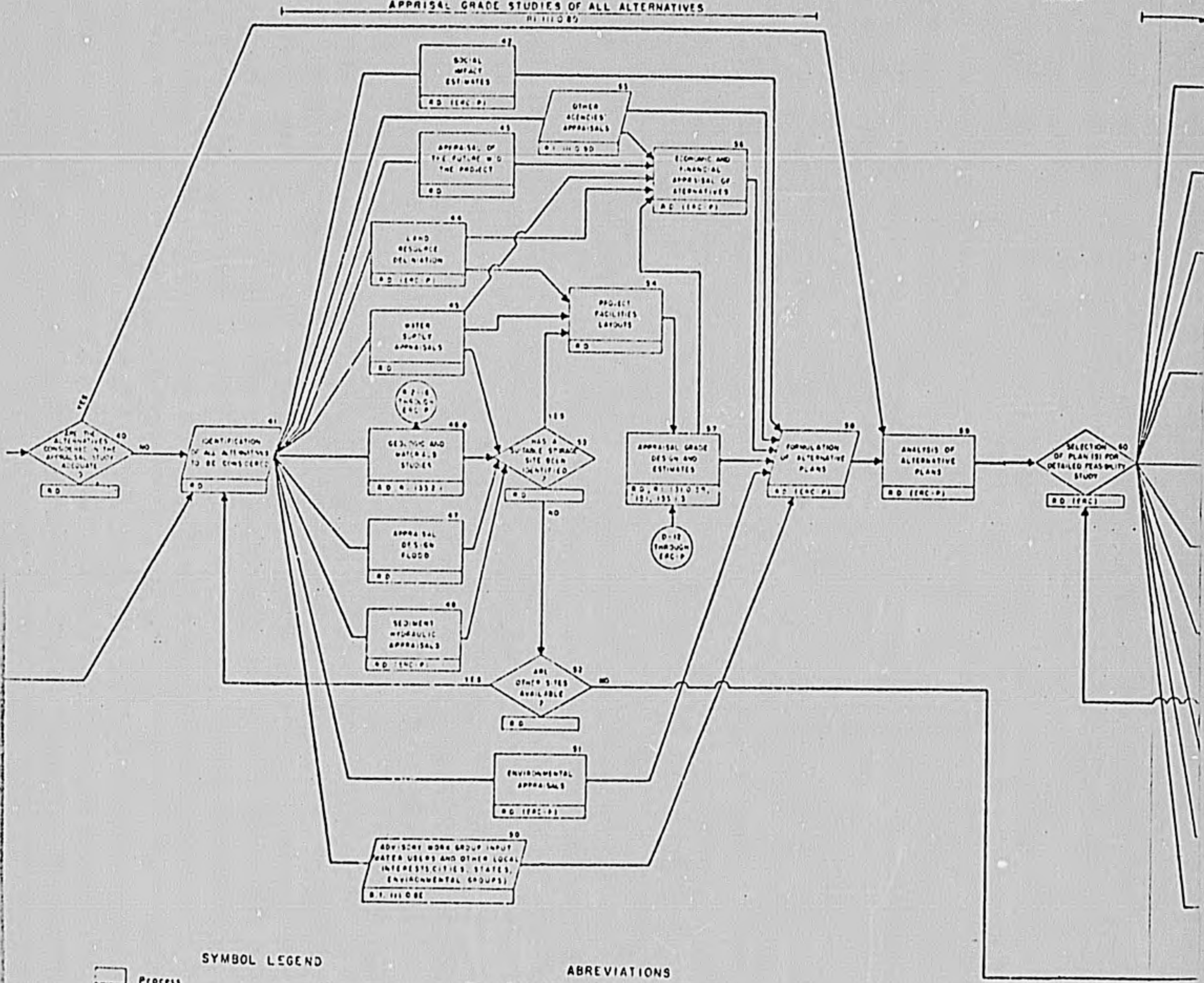
Note: The symbol (ERC-P) noting technical assistance and/or review provided by E&C-Planning has been shown where it most likely will be requested.
Assistance may be provided at any point in the planning process.

* Detail of Appraisal-Level Geologic Studies

Review available geologic maps and literature — RD
Field examination of locations of potential facilities — RD
Description of geologic conditions at facility sites — RD
Prepare appraisal geologic reports, as necessary — RD

PLANNING PROCESS F

FEASIBILITY INVESTIGATI



SYMBOL LEGEND

- Process
- Input, Output and/or Review
- Decision
- Inter-Connection with Another Functional Flow Chart
- Terminate Process
- Variable Time
- ( ) By Request - Technical Assistance and/or Review Provided by ERC-P or D

ABREVIATIONS

W	Commissioner's Office
RD	Regional Director
AR	Authorized Representative of the Contracting Officer
DI	Department of the Interior
ERC-	Engineering and Research Center
P	Planning Division
D	Design Division
C	Construction Division
ES	Engineering Support Division
O	Water Operation and Maintenance
E-I-S	Environmental Impact Statement
C-E-Q	Council of Environmental Quality

239B

FLOW CHART

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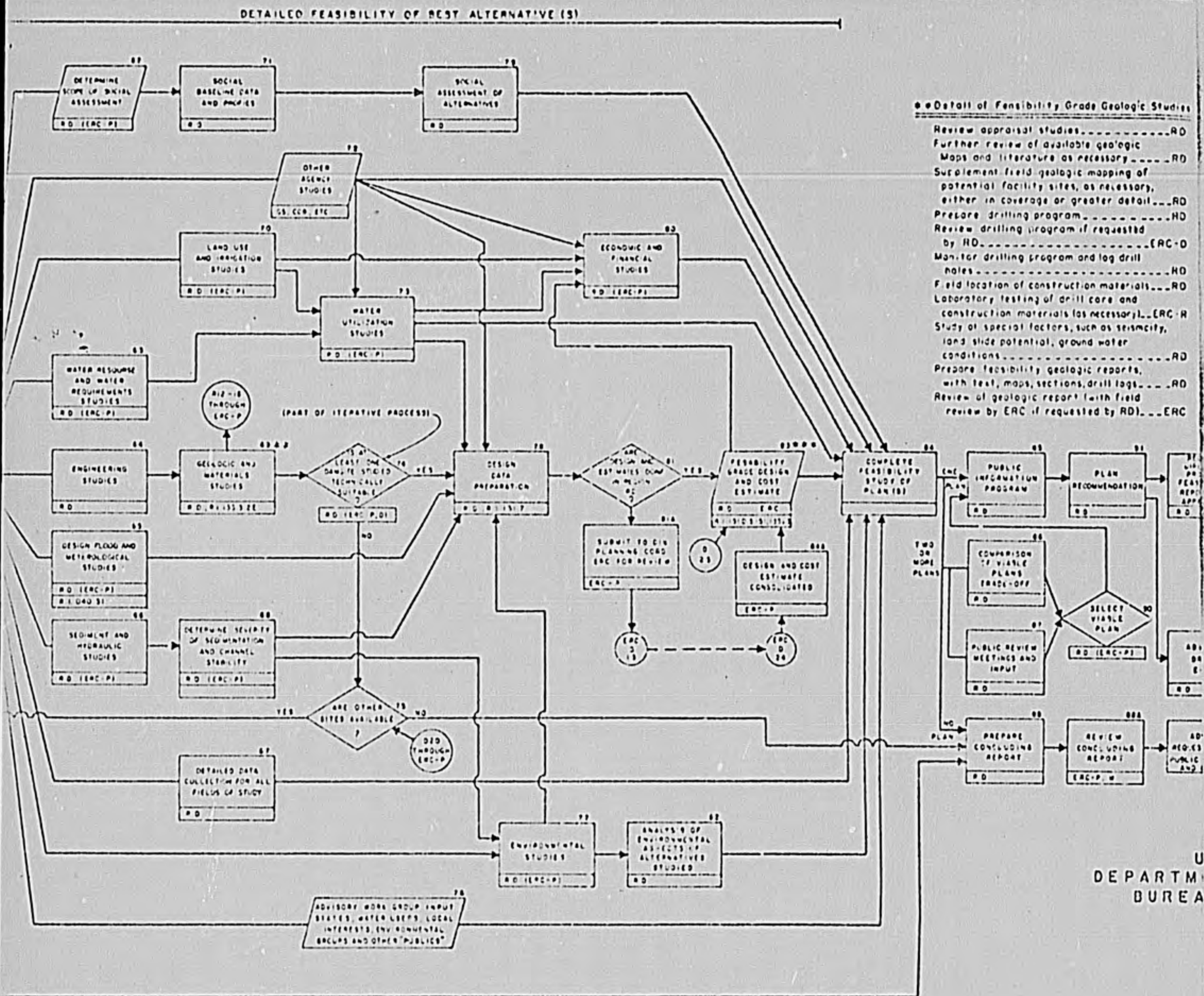

Detail of Feasibility Grade Geologic Studies

- Review appraisal studies .... RD
- Further review of available geologic Maps and literature as necessary ..... RD
- Supplement field geologic mapping of potential facility sites, as necessary, either in coverage or greater detail ... RD
- Prepare drilling program .... RD
- Review drilling program if requested by RD .... ERC-D
- Monitor drilling program and log drill holes .... RD
- Field location of construction materials ... RD
- Laboratory testing of drill core and construction materials (as necessary) .. ERC-R
- Study of special factors, such as seismicity, land slide potential, ground water conditions .... RD
- Prepare feasibility geologic reports, with text, maps, sections, drill logs .... RD
- Review of geologic report (with field review by ERC if requested by RD) ... ERC

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232 C

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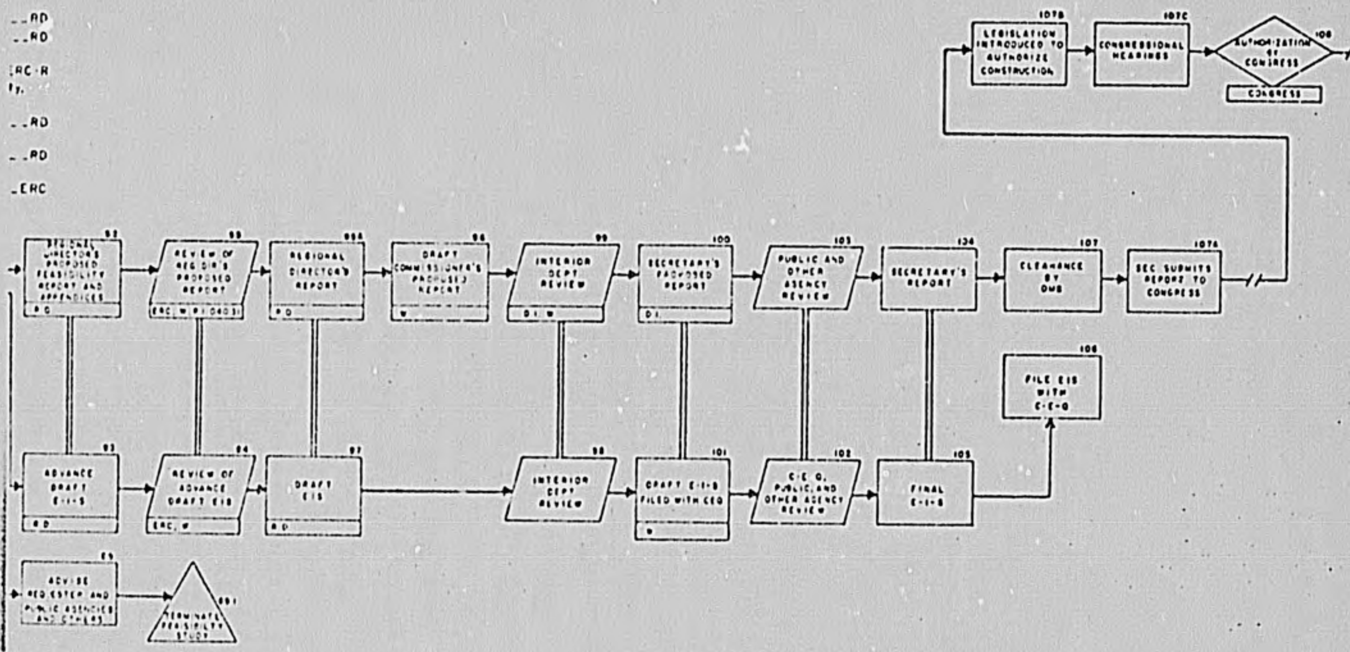

*** Dam feasibility designs and estimates are normally done at the ERC. Should the feasibility design and estimates be done in the region the procedures D-13 through D-24 shown on the Design Chart are also followed.

UNITED STATES
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REAU OF RECLAMATION
DECEMBER 2, 1976

232 D

Arability-irrigability area analysis principle. The arable area-irrigable area analysis principle relates to the procedure for selection of lands to be served and involves a two-step process. In the initial step, the arable area (land with sufficient farm productivity to warrant consideration) is identified. The second step involves the selection of the irrigable area, those lands capable of being served with irrigation water, from those lands determined to be arable and to be included in the plan of development. The selection of arable lands is based upon a determination that the land is capable of sustaining economically viable family farm operations under irrigation, assuming water control is provided. Water control may involve drainage in a humid area or water supply in an arid area. The selection of the irrigable area is guided by goals and objectives selected to guide plan formulation. The scope of plans is influenced by purposes and objectives to be served by a plan.

The application of plan formulation and evaluation criteria to the classification generally leads to successive elimination of identifiable increments of arable lands from the plan of development. Typical adjustments include: (1) elimination of noneconomic increments such as those that are too costly to serve, drain, or manage; (2) conformance of land area to utilizability, serviceability, and manageability; (3) exclusion of isolated segments, odd-shaped tracts, and severed areas that cannot be efficiently fitted into the farm unit pattern; (4) deletion of proposed public rights-of-way; and (5) exclusion of land areas that would contribute excessive salinity or other undesirable constituents to return flows. Of these factors, items (1) and (5) are goal-dependent.

Water suitability. In general, water quality evaluations may be approached by analysis of the environmental setting of the project in the context of predicted future water use. The suitability of water involves integrating land and water factors. In this process, land classification surveys are utilized to delineate land classes that would favorably respond to a water supply of a given quality. This selection of land as a potential part of development is then tested as to feasibility by application of plan formulation criteria.

Water quality standards per se are not applied in appraising the usability of water for irrigation. "Its usability depends on what can be done with the water if applied to a given soil under a particular set of circumstances. The successful long-term use of any irrigation water depends more on rainfall, leaching, irrigation water management, salt tolerance of crops, and soil management practices than upon water quality itself" (Fireman, 1960).

LAND SELECTION PROCEDURE

The most important phase of reclamation land classification is the separation of those lands which are suitable for irrigation development under the prevailing conditions from those which are not. This is the arability determination and is the initial step in the selection of land to be served for irrigation. The arable area remains constant and serves as the base from which the irrigable area is selected and provides a source of land data for use by other disciplines involved in the study.

Planning, developing, and maintaining water and land resources for agricultural production mainly involves providing control of water, both soil and groundwater. This is accomplished through installation and operation of facilities and implementation of measures; i.e. water supply and distribution, water and land use, management, and drainage. Formulation of plants can be efficiently guided by an effective system of economic land classification. The general principles followed in the Bureau of Reclamation are applied to fit land classification to the specific environmental situation including economic social, physical, cultural, and legal patterns existing in the area.

The principles described provide a basis for organizing land classification and related techniques into a process that permits selection of irrigable land within a specific project setting. Provision is made for coordinating the engineering, agricultural, economic, social, environmental, and other aspects of irrigation project development. In applying these principles, the Bureau of Reclamation (1953) has identified the various steps involved in performing the land classification survey. The steps are more or less related and should be developed concurrently to the extent that available information will permit. Methodology should be developed for application to local needs using the principles previously discussed. In several countries, there has been a tendency to adopt rather than adapt; i.e. to attempt transfer of procedures rather than develop systems based on the principles. Usually, the transfer approach will not work satisfactorily; thus it is essential to go through the rigors embodied in applying the principles.

In preparing for the land classification study, the matter of handling land development costs is determined. Methodology may vary between countries according to whether the government expects the farmer or landowner to pay for all development costs or if the government does all of the on-farm development with no direct cost to the farmer. Land classification is varied to show a reduced payment capacity in net farm income and lower land class where land development costs are borne by the farmer. When development costs are handled as a government expense, they do not influence the land class except when the maximum permissible expenditure would be exceeded.

Major types of land classification for project plan formulation include: (1) appraisal, (2) feasibility, (3) advanced planning (definite plan and preconstruction), (4) special studies, and (5) postconstruction. Of these, feasibility grade classifications are of primary importance in the planning process, and represent a standard by which other types of studies may be compared.

It is important that the type of land classification conducted, amount of detail, and accuracy required be consistent with the purpose of the investigation and be governed by the primary applications intended. All types shall be guided by amount of detail needed and the accuracy objective. This is governed by the relation of the mapping units, i.e., land classes, subclasses, and boundaries, to the features that are useful and significant to plan formulation of the irrigation project.

Generally, appraisal surveys are brief, preliminary studies mainly utilizing existing data. A feasibility survey is conducted to determine whether a project is worthy of construction and, if found worthy, to provide information for Congressional authorization in the plan of development utilized in the United States. An advanced planning survey is made in support of project construction and certification as to the adequacy of land classification studies in fulfillment of the Bureau of Reclamation's technical and legal responsibilities.

Appraisal Studies

Appraisal surveys are used to select areas which seemingly have development potential; thus they are a general delineation of lands suitable for irrigation. The detail of mapping is such that relative land quality designations will indicate, as a minimum, separation of arable lands for general farming or specialty crop areas from nonarable areas. The factors considered in an appraisal land classification study are generally the same as those considered in a feasibility study, but the quantity of data available is less, delineations are less precise, and the allowable degree of accuracy is lower. Generally, a minimum of field investigations are made, and a great degree of reliance is placed upon existing data or secondary or indirect sources of information. Irrigation method should be clearly specified for each appraisal study. Where different methods are required, an estimate of the area adaptable to each method will need to be developed. Water suitability for the involved lands along with drainage and return flow factors will be part of the study.

Feasibility Studies

The feasibility survey deals with the question of whether or not the project is worthy of construction. It shall provide land resource data of sufficient reliability and accuracy to make sound judgments and recommendations needed for decision-making regarding prospects for proceeding with authorization and development. This requires careful examination of land features to assure reasonable accuracy in the identification and delineation of arable and nonarable lands. A reasonably accurate determination of the overall area and associated land classes of projects or separate segments should be provided. Basic data with respect to soil and subsoil conditions, topography, and drainage shall be obtained in sufficient detail to meet the accuracy objective and to provide the additional land data required for drainage, return flow studies, and other investigational needs.

The land classes shall be based on the economics of production and the manner in which land development costs are handled within specific areas. Hence, the production and repayment potentials may differ significantly among such areas. All classes will not necessarily be found in any given agricultural setting. Three basic arable classes are normally used in the Bureau system to identify the arable lands according to their suitability for irrigation agriculture. Class 1 land has the highest level of irrigation suitability, hence the highest payment capacity. Class 2 has intermediate suitability and payment capacity. Class 3 has the lowest suitability and payment capacity. There are situations where Class 4 arable class is used to represent lands of very limited repayment potential that would only cover operation and maintenance costs. Two nonarable classes may be used: Class 5 lands are nonarable under existing conditions, but have potential value sufficient to warrant tentative segregation for special study prior to completion of the classification; and Class 6 lands are considered nonarable under existing project plans because of failure to meet the minimum requirements of at least paying operation, maintenance, and replacement (OM&R) costs as required for arable classes.

The number of classes mapped in a particular investigation depends upon the diversity of the land conditions encountered and their reflection in potential farm income. Four arable classes may be used in high income areas, but only one class may be justified in situations where crops are limited to low income production due to climate or other land characteristics. For each project, land class determining factors are selected and identified consistent primarily with national or agency policy and economic setting of the project.

Advance Planning Studies

Following authorization for development, advance planning detailed investigations are conducted to supply planning information required prior to construction and to serve as the basis for refining arable area delineations. These plans also supply information used in plan formulation, evaluation, canal sizing, determining farm unit water allotment, and repayment. Land use needs, other than for irrigation, which were established during the feasibility study are reexamined and firmed up during the preconstruction stage of investigations.

Special Studies

Study conditions may require land inventory investigations. These may be considered as a special type of appraisal land classification study. In some investigations, it is necessary or desirable to inventory lands within a given area which are capable of sustained production under irrigation. This inventory, where economic analyses are lacking, may be based upon physical and chemical characteristics irrespective of the economic feasibility analysis applicable to appraisal studies. In these cases, the requirement that arability implies an ability for the land to provide a reasonable return to the farm family as well as sufficient remaining income to at least pay OM&R costs under a specific plan of development is not necessarily applicable; instead, arability as used here implies only that the land if served with irrigation water is capable of sustained production of crops adaptable to the area at a level of yield considered normal for other irrigated lands of the general area.

Requirements for detail and types of data collected may vary but are generally similar to those outlined above for appraisal studies. Land inventories will normally be made only in cases where insufficient data exist to establish firm economic criteria or anticipated plans of development such as river basin investigation, or in situations where economics as normally used may have other applications.

Postconstruction Surveys

Postconstruction surveys are undertaken as required to accommodate changes in land classification resulting from actual construction. This normally involves adjustments with respect to exclusions and inclusions to the irrigable area. Exclusions and inclusions that may occur are changes in the service area affected by the allocated water supply and rights-of-way for canals, laterals, drains, and roads.

A final determination of irrigable lands cannot be made until farm unit boundaries have been established and the location and extent of facilities such as public roads, laterals, turnouts, and drainage facilities are established. This is usually done during the advance planning stages of investigation; but, because of changes in the system during construction, a review is usually necessary to adjust the irrigable area. Because these factors were considered in the initial establishment of the irrigable area, any corrections which may be necessary in determining the final irrigable lands should be relatively small.

At the end of the development period, a review of the irrigable area will be necessary to make final adjustments resulting from land development, changes in system, and "squaring" of fields. This will be the official project irrigable area to be used in the determination of contract requirements such as construction charges and water allotments.

PLANNING LAND AND WATER RESOURCE DEVELOPMENT

To improve and maintain sound economic bases for the general well-being of a population or the overall quality of life is an objective that ranks among the most important and rewarding of our day. The overriding consideration throughout multiobjective plan formulation, at all levels, is to reflect society's preferences for three major national objectives which are defined broadly as:

National Economic Development (NED)

The purpose of this objective is to increase the nation's output of goods and services and improve economic efficiency.

Environmental Quality (EQ)

This objective would be to enhance the quality of the environment by the protection, management, conservation, preservation, creation, restoration, or improvement of the quality of certain natural or cultural resources and ecological systems.

Regional Development (RD)

The objectives here would be to increase regional income and employment; distribution of population; improve the regional economic base and educational, cultural, and recreational opportunities; and enhance environmental conditions of the region and other specified components (Bureau of Reclamation, 1972).

As identified in multiobjective planning, the "well-being of people" is fundamental and cuts across the three objectives (op.cit.). In all instances social effects must be considered. The extent to which land and water planning efforts contribute either in a beneficial or adverse way in serving the three objectives, as well as impacts upon or by social factors, must be evaluated to provide the means of appraisal of projects and trade-offs among alternatives. Thus benefits and costs are evaluated either in monetary or nonmonetary terms for the four accounts: NED, EQ, RD, and social factors.

All plans, regardless of which objective is being emphasized, will have impacts on all four accounts that must be measured to the best of the planner's ability considering the detail of the study, the data base, and available procedural techniques (op.cit.).

Agencies involved in water and land resources planning and development normally consider joint use to serve such purposes as flood control, irrigation, municipal and industrial water supply, hydroelectric power, recreation, and fish and wildlife. It is also normal that agencies and requisite professional disciplines may inadvertently accentuate some purposes of development at the expense of others. Therefore, it is imperative that all the relevant disciplines' endeavors be coordinated and study efforts and results be mutually analyzed and, through interchange, a joint developmental approach reached.

The planning process flow chart that follows presents in a graphic way the interrelationships among requisite disciplines in relationship to time and accomplishments during the planning effort. This information is specific with respect to feasibility stage planning efforts within the Bureau of Reclamation but has application for consideration at other stages of the planning sequence.

Following an appraisal study and the determination of the need for feasibility grade investigations, again representative of federal, state, county, local government, associations and interested private groups, and individuals are invited to review previous work. Prior studies and future project direction plans are totally committed to open public participation. A refinement or redefinition of land and water developmental problems and needs must be accomplished through public involvement and application of sound multidisciplinary technical study procedures.

Soil resource inventory information, as it relates to specific land classification needs, along with accumulated lands data, are reviewed and applied to the identification of all alternatives to be considered. Additional lands data are collected in accordance with guideline specifications in the light of social, economic, and engineering study needs aligned with land classification requirements. Land classification studies have direct interactions with other requisite disciplines relative to: (1) water supply needs and appraisals, (2) appraisal of the future with and without project conditions, (3) social impact estimates, (4) economic and financial appraisal of alternatives, (5) project facilities layouts, (6) design and estimates of serving facilities, (7) formulation of alternative plans, (8) environmental study impacts and needs, and (9) final selection plans for additional studies.

Following completion of feasibility grade field investigations, data are compiled, analyses made, and interpretations and conclusions presented in feasibility reports covering all the study needs. This information is again routed through the public information program, any changes or additions considered, and following requisite reviews the proposals are submitted for legislative decision for construction authorization.

The general collection, presentation, and utilization of land resource data and information development, including soil resource inventory information, continues from the appraisal investigations through feasibility and preconstruction studies and is a part of the postconstruction and postdevelopment needs of land and water resource projects. The information generated is applicable to inventory requirements including: (1) irrigable land, (2) water management, (3) land use and size of farms, (4) land development, (5) payment capacity, (6) irrigation benefits, (7) irrigation and drainage systems, (8) land appraisal, (9) irrigation assessments, (10) environmental assessments, (11) return flow water quality, and (12) social impacts.

The fundamental requirement of the classification system addressed in this report is to define, for the time, place, and economic and social setting, what is to constitute a finding of irrigability and then to establish principles and procedures for land classification that permit a critical selection of the irrigable lands. Irrigation presents a unique capability with great promise for the future of many people. Planners have a moral duty and a technical responsibility to apply skillful planning techniques founded upon sound concepts of land and water use.

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SESSION VI

SOIL RESOURCE INVENTORY QUALITY CONTROL

Chairman: R. Tinsley

Speakers

Ir. J. Schelling - General Considerations on Ground Truth Checking or Quality Control

R. W. Arnold - Some Concepts of Ground Truth Checking as a Tool in Quality Control of Soil Resource Inventories

J. Lizarraga R. and L. Masson M. - Peruvian Experience on Integrated Surveys for Natural Resources and Development Planning

GENERAL CONSIDERATIONS ON GROUND TRUTH CHECKING OR QUALITY CONTROL

Ir. J. Schelling[1]

QUALITY

Quality or utility of a soil inventory is the extent to which it gives a satisfactory answer to the user's questions. In this paper quality is mainly limited to precision and accuracy. When the use is not clearly specified, or if only very general questions need to be answered, precision and accuracy need not satisfy very high standards. If the user has very specific questions, such as "What is the moisture supply in the growing season in mm?" the desired quality can be exactly specified. Clearly, the quality of the inventory depends on how well it can answer the user's requests at given levels of specificity or generality.

General quality means utility of the inventory to satisfy a large number of unspecified purposes. If all purposes could be specified beforehand, criteria could be chosen to evaluate the utility for each purpose separately. The single-purpose suitabilities could be combined into a general quality index, but if the qualities were strongly variable, such an overall index would have little meaning. General quality is not recommended as a quality criterion.

Specific quality can be expressed as the utility or degree of success of the inventory's application for specific purposes or uses. An example is the utility for the prediction of the level and variation of individual crop yields.

PURPOSES OF QUALITY CONTROL

When we are convinced that quality is important, a process of quality control is needed. Webster's dictionary defines quality control as: "an aggregate of functions designed to ensure adequate quality in manufactured products by initial critical study of engineering designs, materials, processes, equipment and workmanship, followed by periodic inspection and analysis of the results of inspection to determine causes for defects, and by removal of such causes."

Quality control involves two different parties, the authority that commissioned the survey, and the surveying agency. The first will be mainly interested in the quality of the end product. The latter will be interested in the possibilities of quality improvement, and in measures to ensure the overall quality by controlling the quality of separate parts of the survey procedure.

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[1]Deputy-Director of the Netherlands Soil Survey Institute at Wageningen, The Netherlands.

Quality of the End Product of the Survey

As the end product we can consider the soil map or some interpretation of the map as to its suitability for a purpose, e.g. a crop yield estimate. The quality assessment is only executed when the inventory is finished. The results of the quality estimation can be used in order to decide if the inventory is acceptable. The user will gain no insight into the causes of the specific quality that occurs.

Quality of Separate Stages of the Survey Procedure

The purpose of quality control can be to ascertain the quality of every stage of the survey procedure separately to indicate the causes of the quality of the end product. On the basis of this insight improved methods can be devised.

Another purpose can be to rectify the results that are below standard, such as estimates of clay content that are too low compared to laboratory analysis. These data can be rectified for every surveyor separately, providing he is consistently high or low, on the basis of sufficient data to establish the relation between his estimates and the results of the laboratory analysis. The first quality control method could be indicated as analytic, because it analyzes the quality of the separate steps of the survey procedure. The second method can be indicated as corrective quality control because it is aimed at the correction of flaws in the quality.

QUALITY CRITERIA

General Quality

Quality of mapping units is usually defined in terms of purity. Purity is measured as the percentage of the area of all delineations of a mapping unit, in which all differentiating characteristics of the defined component are within the defined limits. The purity indicated in the survey report is 85% (USA) or 70% (Neth.). The true purity, as measured on the basis of a sample, can differ considerably from these figures. When map unit purities are averaged over all occurring map units, the mean can be indicated as "map purity."

Purity is a quality criterion of very limited value. The following drawbacks can be mentioned:

A. No distinction can be made between the case where only one or where many characteristics are outside the required limits.

B. The degree of difference between the actual and the required value of a defining characteristic has no influence.

C. The relevance and importance of the characteristics is not taken into account.

D. The width or narrowness of classes is not taken into account.

Success-percentage is another general quality criterion. It can be defined as the number of characteristics, expressed as a percentage of the total number, that are estimated correctly in the population. It can be expressed in a probabilistic way. In the case of success-percentage only the first drawback mentioned for purity does not apply. Both criteria are very general, and use of the inventory is not considered.

Specific Quality

It is possible to use an adapted form of purity or success-percentage when quality estimation is for a specific purpose. In this case we consider only those characteristics that are relevant for the specific purpose. The only drawback that is eliminated in that case is the matter of relevance. All other drawbacks still apply.

Variance partitioning. The within-unit variance compared to the total variance over the map of relevant properties is a specific criterion of quality. For several relevent properties it can be averaged as a combined quality index. In the next section we will consider how this criterion could be used.

THE OBJECTS OF QUALITY CONTROL, AND SOME OF THE ASSOCIATED PROBLEMS

General

In Figure 1, the inventory is split up into two main parts: the soil survey, producing soil data; and the interpretation, producing interpretive data. General quality control will usually be applied to the output of the first part, the soil map or similar forms of soil data. Specific quality control can be applied to separate stages of the soil survey, to separate stages of the interpretation, or to interpretive data. If only a limited amount of control can be exercised it is preferable to do it on the interpretive data, since this is the most important part for the user.

Specific Quality Control of Stages of the Soil Survey Procedure

In Figure 2, corresponding to the left hand side of Figure 1, a schematic view is given of the steps in the soil survey procedure. Since this procedure can be different for each separate survey method, we will give only a few examples of some of these steps to illustrate the possibilities or difficulties of quality control.

The first step in almost every method will be the distinction of layers or horizons for each observation point (auger hole or pit). Different surveyors may divide into layers or horizons in diverse ways. This is a very difficult subject for quality control. Another example is the estimation of the values of soil characteristics for each horizon, e.g. clay content. For a set of soil samples, have surveyors estimate the values of the soil parameters independent of each other, and we could analyze the samples in the laboratory. The results could be compared, and it might be possible to calculate correction factors for each surveyor, thus improving the original estimates.

We will now consider the last step in the procedure, the complete soil map. On the basis of a sample we can calculate the quality for the criterion of our choice (purity, success %, or variance). See Section 3.8 of the "Guidelines for Soil Resource Inventory Characterization."

Interpretation

The interpretation (the right hand side of Figure 1, elaborated in Figure 3) can be considered as a string of models, linked by a set of products, in which the output of each model is the input of the next model. The steps are similar to those of FAO (1976) and Beek (1978).

The quality of the end product (either soil qualities, suitability or yield, or economic value) can be established. If we analyze the different steps in this string it is apparent that both the quality of the inputs and the quality of the models influence the quality of the products. The models can be fairly primitive, such as a "lookup" table, for instance with each soil unit and the level of each soil quality. A more precise model is a mathematical function (e.g. a x % clay + b x % organic matter + c = mm available moisture). A very sophisticated kind of model is, for instance, a computer simulation model for water supply to a crop, from the groundwater and unsaturated flow, based on dynamic variables.

It is essential to verify the models for the range of relevant variables that occur in the survey area. In order to limit the amount of work needed for quality control, a sensitivity analysis of the model is important. This analysis is a test to find out the effect of different levels of the separate inputs on the output. Only those inputs that have a considerable influence on the output of the model are relevant for quality control.

SAMPLING SCHEMES

The selection of an adequate sampling scheme (including sample size) is a matter of statistical requirements, costs and manpower, accessibility of the terrain, and the requirements of the user. Statistical requirements are the random aspect of the sample; it should be representative for the population of objects under consideration. Usually for purposes of map quality some form of stratification is chosen. No general rules can be given for this choice.

Since costs and manpower will impose severe restrictions on the quality control, the necessary work should be kept to a minimum. The accessibility of the terrain may be so difficult that the surveyor is severely restricted in his movements. In that case, traverses or transects can be used for quality control. Such a sampling scheme requires a specific estimation procedure. The requirements of the user will indicate the aspects of quality control and the required accuracy. When all relevant details have been considered, a suitable sampling procedure can be chosen.

USING THE RESULTS OF QUALITY CONTROL

How the User Benefits from Quality Control

For the user the outcome of the quality control indicates the limitations in the application of the inventory. When we have more experience with quality control, it may be possible to set quality standards when commissioning surveys and to accept or reject on the basis of a quality check by an independent authority.

How the Survey Organization can Benefit from Quality Control

Analytic quality control applied to surveys executed by different methods can highlight methodological weaknesses. Corrective quality control enables observations to be adjusted during the course of the survey, and thus improves the quality.

It is evident that any correction of values of soil properties should also lead to correction of subsequent steps in the survey and interpretation procedure. This implies that it makes little sense to execute any of these later steps before corrections have been completed. This is evident, for instance, when the purity criterion is used and if on the basis of the sampling, purity values have to be corrected considerably.

For the individual surveyor and the survey organization quality control can lead to a considerable increase in knowledge about survey methods, and thus to their improvement in the future. Since survey methods are among the most neglected subjects of research, this can prove to be a very rewarding subject of investigation.

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Fig 1

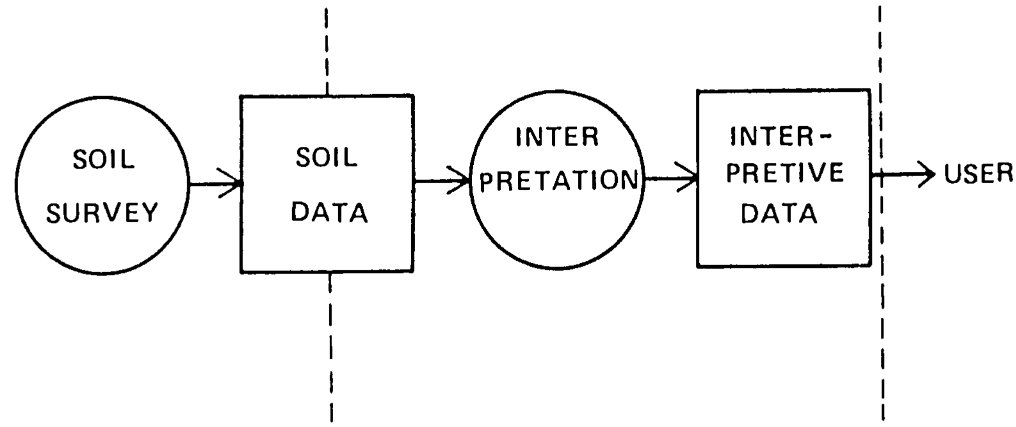


Fig. 2

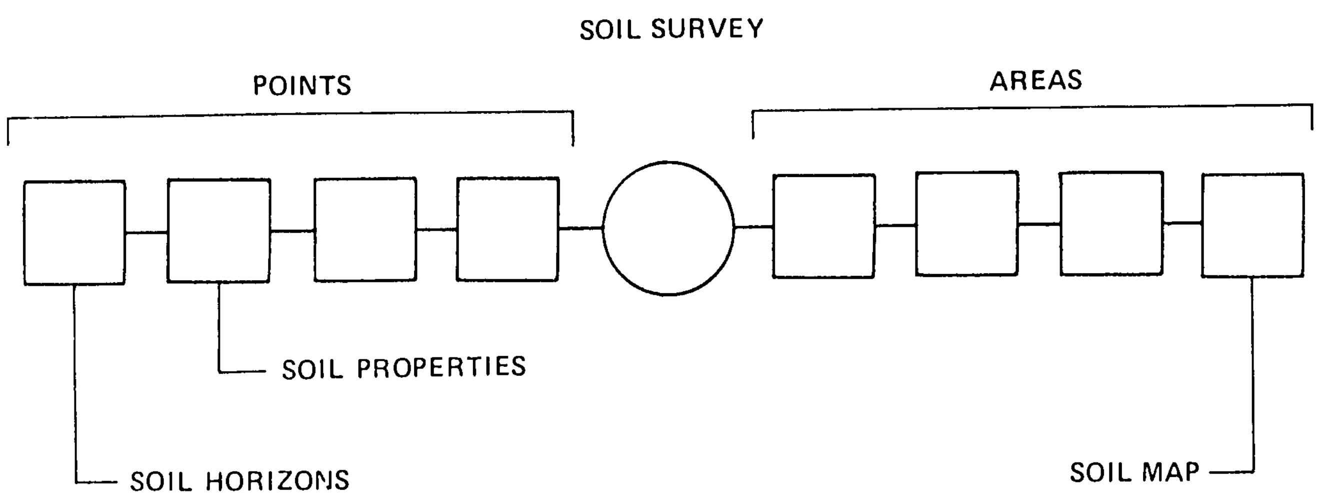
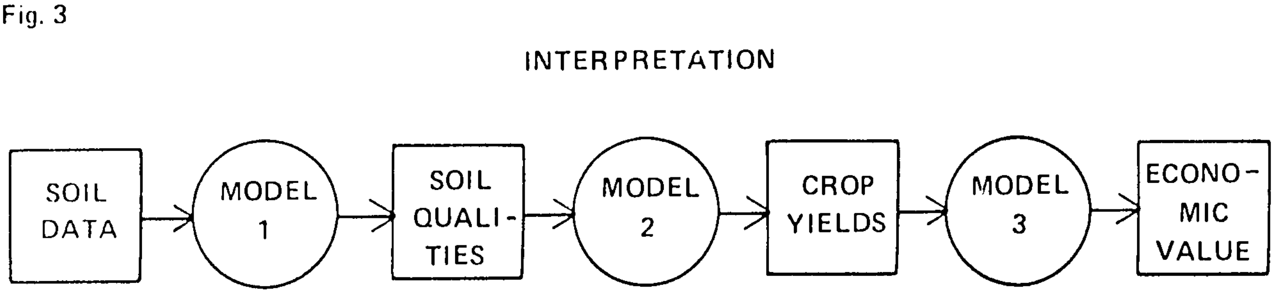


Fig. 3



QUESTIONS/COMMENTS (by R. Fauck):

The true purity is measured on the basis of a sample released by a random method. Do you try to define true purity on each of the main units of the legend?

ANSWERS:

Since the total area of the different mapping units is only high for a limited number of units, it is only possible to measure purity for these units. For the units that occupy a small area it is not feasible to estimate purity.

SOME CONCEPTS OF GROUND TRUTH CHECKING AS A TOOL IN QUALITY CONTROL OF SOIL RESOURCE INVENTORIES

R. W. Arnold

CORRELATION AS A CONTROL MECHANISM

In any ongoing soil resource inventory, the procedure of soil correlation embodies most of the elements of quality control. A review of existing support information - other maps, reports, and background data - aids in reducing efforts that might otherwise duplicate such work. Developing a meaningful plan of work that spells out the objectives of the inventory and provides a framework for its conduct gives direction and purpose to the endeavor. The preliminary legend can be examined and checked, and potential problems anticipated. As work progresses the backstop information and initial interpretations can be tested with users and for internal reliability. Field maps and techniques, base maps for publication and formats for the final products are all scrutinized throughout the inventory.

As Dr. Schelling clearly pointed out, there are many points or stages that receive attention, or can receive attention. In some places insufficient time and effort is given to soil correlation and eventually quality is adversely affected. A single project may have everything done right -it is a success - and yet the results may apply only to that limited project. It may take years to go back and obtain the extra information that would have helped someone else in another place or at a different time.

PUBLISHED SURVEYS REFLECT MODELS

When we deal with existing published soil resource inventories the rules of the game are changed. You can't take corrective measures to improve the inventory because the work has already been done. The lack of information on how quality was controlled made a checklist a must. Competent soil scientists can then "second guess" what might have happened and consequently they can make judgments about the adequacy of an existing inventory for new or additional interpretations.

Fortunately soil survey is a discipline based on models, and all pedologists build models, test models, and revise models as their main daily task. The approach is a learned skill, and there are truly craftsmen among the cadre of pedologists struggling with a continuum that is to be parceled into seemingly discrete separate units in the landscape. Soil maps, like all other maps, are abstractions of reality. They represent the models of soil geographers whose basic skills are derived from knowledge of stratigraphy, geomorphology, pattern recognition, probability, and correlations, and whose expertise is determined by powers of observation and empirical relationships and a desire to be as right as possible, for the circumstances.

Mankind has made relatively few soils, thank goodness, because man appears to be far less predictable than nature. On the other hand, man seldom accepts land as he finds it and has modified the developmental and distributional processes on the earth's surface to varying degrees and for varying periods of time. Models are developed to explain and predict, thus man himself defined soils and their occurrence as simplified models of an extremely complex ecologically balanced system and suddenly was faced with variability. Some he could predict or account for, but much of it still escapes his imperfect models.

What happens when we ground truth an existing soil resource inventory? Conceptually we reconstruct the models that were used: the model of soil itself, the model of classification, the model of landscape-soil relationships, even the model of probability and reliability. How much easier it would be if these models had been stated and had been a part of the documents of the inventory. But never mind, a challenge to the intellect is almost always rewarding. And as Dr. Schelling noted - a sensitivity analysis may be in order.

CONCEPT OF BASE MAP ACCURACY

Does the choice of a base map influence the utility of a soil resource inventory? Surely it does at some level of use, or at some scale. How much of something is better placed in a graph or a table, but where is best placed on a map. The relation of the map and the ground location can make or break some decisions. Fragiochrepts dominate a portion of the Northeastern United States and accurate location relative to Hapludolls in the Midwestern states is generally not required. But if you have a small parcel for a house and the soils are dominantly Fragiochrepts it is darned important to know where they are because of the severe limitations they impose on construction.

Base maps need enough ground control reference points for the decisions requiring location considerations. As so strikingly illustrated in the Sri Lanka slides, a map as a model of location of a single-bullock padi is ridiculous. The man on the land has more knowledge of reality of location than any abstraction can hope to impart.

Map accuracy standards are used in most parts of the world. How do published soil maps stand up to such standards? How do you check this for maps where the representation of location will have an influence? The details are shown in the posters so let me briefly explain how we approached the question. Accurate location of well-defined points determine the level of acceptance, yet it is a sampling and therefore subject to error and probability. Generally if 90% of well-defined points on the ground are placed within small tolerance areas on the map it meets an acceptable level of accuracy. But what is the accuracy of the map for location? Assume 10 points out of 10 points are within the tolerance area. The lower confidence limit, with only a 1 in 20 chance of being wrong, is about 72% and the upper limit is 100% - thus the map is at least 72% accurate for ground control reference points. If 9 out of 10 were O.K., the at least statement lowers to about 60% and the upper limit is about 96%.

If you want to be at least 85% accurate (this is lower confidence limit) 19 times out of 20 then you'll need about 18 points, all of them within tolerance.

RELEVANCE OF LOCATIONAL ACCURACY

Want to field check a point, or a location, by yourself? Sight a compass bearing and using your calibrated step go find it. We have calculated how far you can go and how wide the acceptable width (or tolerance area) will be when you get there for a number of map scales, and for deviations you might make following the compass. We don't recommend such checking but it gives you a sense of what some users are up against. More importantly you can estimate how far apart reference points can be for any scale of map and still give an acceptably accurate map for locational purposes. In turn the number of recognizable reference points can be used to estimate levels of usefulness of the base map for locational purposes. And this we do recommend. One quickly appreciates the value of air photo backgrounds for resource maps - they usually have sufficient points to permit reliable judgments of relative location.

An interesting aspect of locational accuracy is the impact on errors associated with small delineations on maps. Minimum-size and least-size delineations often indicate the amount of detail that may exist in the field and suggest the level of intensity of observations necessary to show the areas. Generally they are areas of marked contrast that affect the use or management of the land. Slight displacements or exaggerations of these small areas generate enormous errors of size and composition when related to ground truth. Don't be dismayed - unless you are adding up hundredths or tenths of hectares and expect those numbers to have great significance. The model used to map soil bodies of highly contrasting and often limiting sets of properties is one that emphasizes the importance of calling attention to such conditions. The line on the map may represent 15 meters and a gully is only 5 meters wide but the fact it is 10 meters deep and disrupts all normal mechanized activities seems important enough to call to someone's attention. The map can be as good as the model and if the model is relevant for the purpose - use it.

SPATIAL VARIABILITY

Let us briefly consider the sensitive side of a pedologist. Although he didn't create nature nor the laws of distribution, he is sensitive about his portrayal of reality and tends to be apologetic for the large amount of variability that exists. People in laboratories and greenhouses control their experiments, replicate their trials, minimize spurious results by mass action and smugly point a finger of shame at the large amount of inclusions measured in delineations of soil map units. The experiments of pedologists are a lot more fun, however. They test their models with every line drawn or imagined. They find mismatches of concept and reality and it leads to improved models. And suddenly the vision comes! A slow aching realization that variability is the fundamental property of nature, and all we need do is report our findings objectively and honestly and check the sensitivity of these results relative to the predicted outcomes. Who cares how many samples are needed to reach 90% accuracy - or the number of transects to estimate the composition of a unit to within plus or minus 10% of the population's mean? These are indirect ways of indicating variability.

The composition of map delineations can be presented as statements of confidence limits - the at least statement and the at most statement based on the available information obtained from some random sampling scheme. Graphical solutions relieve the ground truth checker of the burden of formalized, messy calculations, restores his morale and places him once again in the position of intellectually unravelling man's models of nature. Some models are better than others, whereas some can't be improved because reality and map scales are terribly mismatched.

THE CHALLENGE OF INTERPRETATION

Most of you will assume that I've been referring to taxonomic composition of soil map units. Because soil maps are named with a taxonomy it is an important test of adequacy of the naming and description of those delineated areas. However, in an appraisal of adequacy of a soil resource inventory for a specific purpose, or many specific purposes as the case may be, it was pointed out that soil properties and qualities relevant and crucial or critical for that purpose need to be evaluated.

The list of relevant features must first be decided upon before the ground-truth checking begins. Then each field observation can include as many of those parameters as is possible. The testing of taxonomic models, vegetation models, landscape models, property models, suitability models, limitation models and others can be done. Each interpretation, each set of included features, and each predictive model associated with the existing delineations in an inventory can be stated in terms of confidence limits at given probability levels.

Who sets the acceptable level of accuracy, of reliability, of adequacy? The users do, of course! Educating them in the ways of the probabilities of nature likely is our biggest challenge ahead.

PERUVIAN EXPERIENCE ON INTEGRATED SURVEYS FOR NATURAL RESOURCES AND DEVELOPMENT PLANNING

Jose Lizarraga R. and Luis Masson M.

The National Office for the Evaluation of Natural Resources (ONERN -Oficina Nacional de Evaluacion de Recursos Naturales), is a Peruvian governmental agency which has the responsibility of doing the inventory of natural resources of the country, with economic and social objectives. As part of its inter-ministry activity, ONERN cooperates with the National Planning Institute in policy formulation for conservation and use of natural resources; ONERN is also charged with studying, at a national level, the relationship between man and the environment, and the proposal of preservation alternatives.

ONERN was established in July, 1962. After almost 17 years it has evaluated 43 million hectares, 33.5% of the country's total surface. Such information is contained in 48 reports and over 800 maps of different scales.

ONERN's advisory and planning activities are very intensive. Because of the nature of its work, ONERN participates strongly in inter-ministry committees for economic development projects. Furthermore, a second approximation of Peru's Ecological Map has been concluded. Actually, national inventories of soils and water resources are being prepared, as well as a diagnosis of erosion problems.

In the course of its work, ONERN uses the most modern technology, including remote sensing. Radar remote sensing has been very useful in studying the country's jungle areas, where aerophotographic missions had been almost impossible because of cloudy weather.

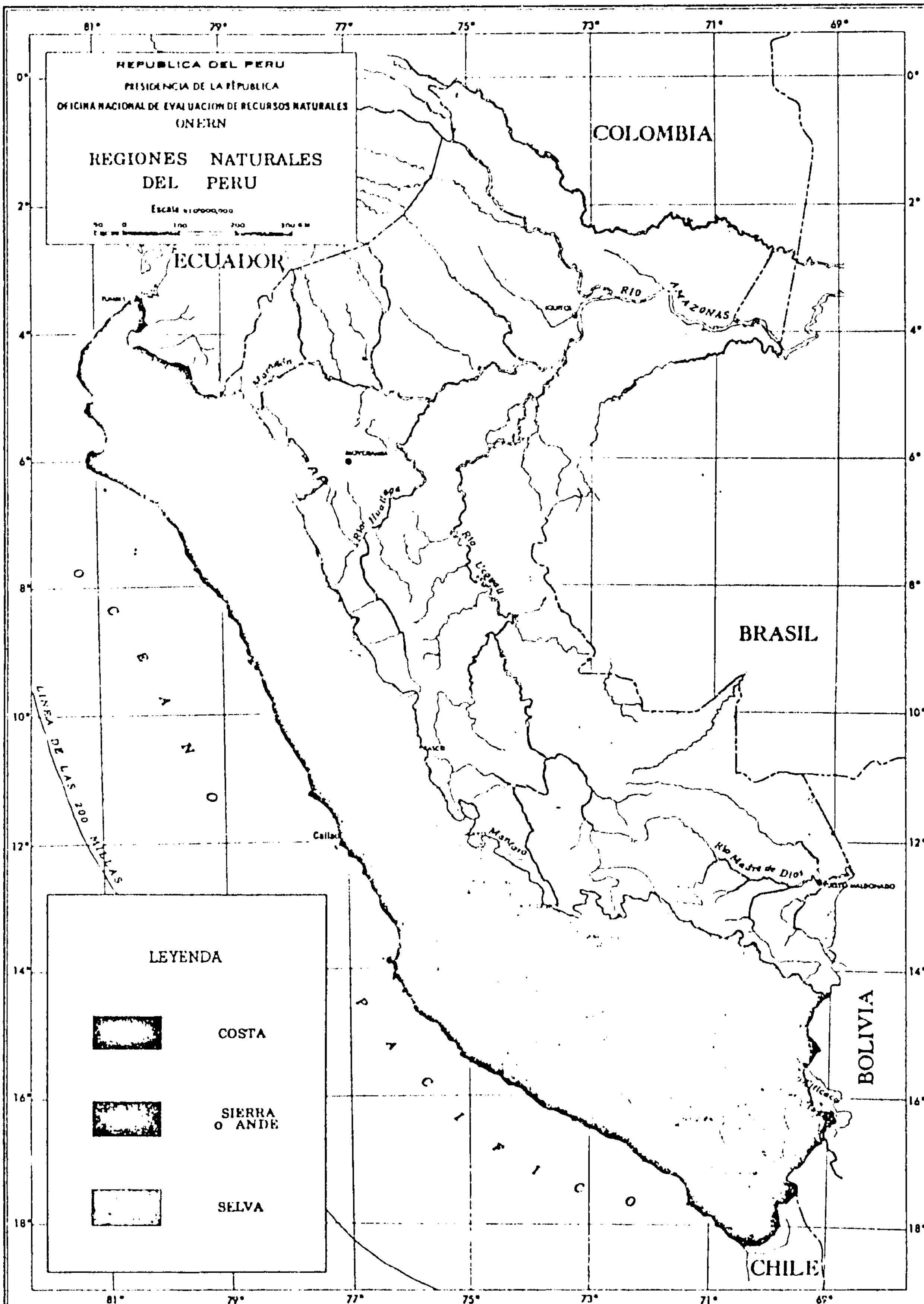
Finally, ONERN is also the Peruvian center of important international projects, such as "Man and Biosphere" (MAB) and "International Referral System" (IRS), both of the United Nations.

GEOGRAPHIC ASPECTS OF PERU

To better understand the nature of ONERN's activities, an explanation of Peru's geography is necessary. Peru is a country with extremely contrasting geographical characteristics which include a variable group of natural resources. Three natural regions identify the Peruvian geography: the coast, the sierra (highlands), and the jungle, with an inclusion of a fourth region, the ocean, up to 200 miles (Map no. 1).

The Coast

The arid coast is located as a basement of the occidental side of the Andes mountains (Figure 1). It includes three well-defined subregions: the irrigated valleys, the coastal desert, and the occidental slope of the Andes. The irrigated valleys are real oases with short amounts of agricultural land, although 50% of the agricultural production of the country is originated there. The coastal desert is formed by plains or "tablazos" that are


REPUBLICA DEL PERU
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REGIONES NATURALES DEL PERU
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COLOMBIA
BRASIL
BOLIVIA
CHILE
Rio Amazonas
Rio Huallaga
Rio Ucayali
Rio Madre de Dios
Callao
OCEANO PACIFICO
LINEA DE LAS 200 MILLAS
LEYENDA
COSTA
SIERRA O ANDE
SELVA
81°
79°
77°
75°
73°
71°
69°
0°
2°
4°
6°
8°
10°
12°
14°
16°
18°

MAPA No 1

intersected by the irrigated valleys. The coastal "lomas" are associated with this subregion but in special conditions of humidity and winter fogs which allow the appearance of a temporal vegetation, mainly shrubs and grasses. Finally, the occidental slope of the Andes is a subregion where the 52 rivers that flow to the Pacific Ocean form. It has very steep slopes with erosion problems.

The Sierra

The sierra (highlands), formed by the Andes mountain range, varies between 1200 and approximately 6000 meters over sea level. It is formed by inter-Andean valleys, high plains and mountains, some with eternal snow covers which condition the existence of a great number of lakes and lagoons. Its semiarid climate is characterized by great temperature variations between day and night. Climate and roughness of the terrain are factors that limit its use. Population is high, with mainly subsistence and mining activities.

The Jungle

The oriental region of the country, it covers 60% of Peru's territory. It presents two very defined physiographic areas: high jungle and low jungle. The former is located on the oriental side of the Andes with steep slopes and fast rivers; the latter, also called "Amazonic plain," has a soft relief with wide and slow rivers. The main characteristic is its heavy rains and high temperature.

Territorial Sea

Its main characteristic is the presence of the Humboldt current which has great influence on the climate and marine resources. Today the territorial sea is of major importance because of the possibility of marine mineral resources.

METHODOLOGY

Since the beginning of its activities, ONERN has been using integrated survey methodology for evaluating natural resources, which is considered the best for economic and social development purposes. It should be remarked that integrated surveys are not the simple addition of partial disciplines, but their coordinated study. This methodology considers interdependence among different resources and their relationship with social and economic aspects, for example, soils and climate with ecology; soils and geology with physiography; soils, water, vegetation and wildlife; and all these related to man. It is important to say that information produced is considered as a means for economic and social development. ONERN's experiences demonstrate that data from integrated surveys are very helpful, not only for economic, but also for scientific purposes. For example, the second approximation of Peru's Ecological Map would not have been possible in a short period of time without the information obtained through integrated surveys. This map is a very important tool used by Peruvian planners. The use of information from any area is considered according to environmental conditions of the area.

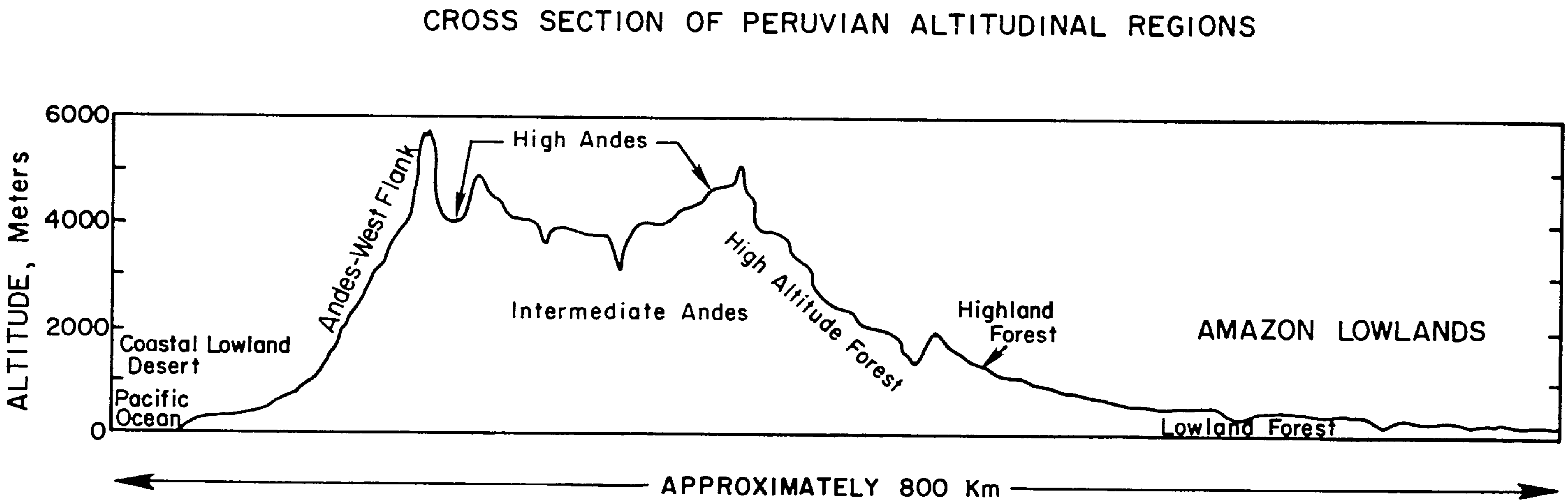

Fig. 1. Distribucion de las tierras bajas del Peru. (Distribution of the lowlands of Peru.) Transverse section.

As an example, the Peruvian geography reality forces the application of a great amount of "flexibility" in the methodologies applied for integrated surveys, trying to give more importance to the most relevant resources in each region. In the surveys carried out in arid areas priority is given to water resources, which is the main problem in the region; in the humid tropic area, priority should be assigned to some other resource like forestry, while in the highlands it should be given to mining and grazing activities, according to the socio-economic importance assigned to it.

At the same time, the parameters should vary in accordance with the region where they are used; it is impossible to uniformize them for the whole territory because of the great geographical and ecological differences existing in the country.

Usually ONERN's integrated methodology includes four different study levels, which constitute a continuous process: exploratory, reconnaissance, meso-detailed, and detailed levels.

Exploratory studies are only used in areas without any information. Reconnaissance level studies (also called "prefeasibility" by planners and economists) are used in reduced surface areas (such as local basins) for determining natural resource potentials, their development possibilities, and identification of projects. Meso-detailed and detailed levels are included in the "feasibility" range, which requires a complete knowledge of different resources as well as a selection for project development including design of construction plans.

COMMENTS ON SOIL RESOURCE INVENTORIES AND PLANNING FOR DEVELOPMENT

One of the main problems being observed is an apparent lack of dialogue between soil scientists and planners. It seems as if soil research or inventories are performed as final products in a developing process. For this reason, it is suggested that soil scientists receive planning training.

A problem inherent to integrated surveys is that every specialist considers his discipline as the most important of all and gives less importance to the others, without considering that the importance is the same for all of them. One of the main aspects that should be considered is the criteria to select the team members and especially the team leader. This point is of primary importance for the purpose of an integrated survey team and should deserve even more attention than the technical knowledge aspects.

It should be understood that each scientist or technician is potentially a planner, because their work is a step in a planning process. But it seems they are not aware of that. Soil scientists should understand that soil inventories are only the means in a process to obtain a final product.

Developing countries have great stress placed on their economic growth processes. In such countries, time should not be lost in sophisticated long-term research projects. Population growth should be considered as the most important factor in the developing processes, because famine worsens from year to year. For that reason, research answers should be immediate. Practical and simple research projects with quick answers should be preferred over sophisticated academic research.

QUESTIONS/COMMENTS (by R. Fauck):

In your integrated surveys do you get data on soil erodibility?

ANSWERS:

Yes. We include erodibility data in our reports. Our erosion problems are very great. In our Andean region it has been estimated that 50-60% of the soils have erosion problems. Our reports include erosion problems maps, with their degree of severity.

SESSION VII

IMPROVING THE DIALOGUE BETWEEN PLANNERS AND TECHNICIANS

Chairman: L. Resler

Speakers

M. C. Laker - The Value of Soil Resource Inventories in National Research Planning

R. S. Murthy - Value of Soil Resource Inventory for Regional Research Planning in India

A. S. Lieberman - Technology Transfer Programs on Land Use and Natural Resources Inventories and Information Systems

H. Eswaran - Commissioning of Soil Surveys

THE VALUE OF SOIL RESOURCE INVENTORIES IN NATIONAL RESEARCH PLANNING

M. C. Laker[1]

Evaluations of soil resource inventories usually deal with their usefulness for the physical planning of land (e.g. regional planning, project planning, farm planning) or for the operational planning (management planning) of farming units (See Soil Resource Inventory Study Group, 1978). This paper deals with the value of soil resource inventories for research planning.

The emphasis will be on agricultural research, firstly because agricultural development forms the mainstay of rural development processes, and secondly because it is the field in which the author has some experience. The main focus will be on agricultural research in (and for) less developed areas.

PRINCIPLES RELATED TO AGRICULTURAL RESEARCH IN LESS DEVELOPED AREAS

The following are three of the most important principles required for effective agricultural research in less developed areas:

1. The research must be development and/or problem orientated. This means that all research must be directly aimed at bringing about development or solving existing identified problems - irrespective of whether it is "basic" or "applied" research. Less developed countries do not have the time and trained manpower (and the vast majority also not the finances) to indulge in the luxuries of "academic" research. This does not mean that their research should be of inferior quality. On the contrary, the quality of research must be very high. In addition, problem-orientated research is more challenging and often requires higher degrees of ingenuity than purely "academic" research.

2. The research must be conducted in such a way that the maximum reliability and geographic scope can be achieved in regard to technology transfer (i.e. in regard to practical application of research results).

3. To be truly efficient, the majority of development- or problem-orientated research requires at least some degree of interdisciplinary cooperation. A large proportion of the research actually requires a major degree of interdisciplinary liaison.

SOIL RESOURCE INVENTORIES IN RELATION TO RESEARCH UTILITY AND EFFICIENCY

Research workers from a variety of disciplines are involved in soil-oriented research. Only a few selected examples can be indicated here:

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Soil Scientists

Various types of soil scientists, e.g. soil chemists, soil physicists, soil microbiologists, etc., conduct research on such aspects as interactions between plant nutrients and soils (with a view to evaluating nutrient availability, efficiencies of fertilizers, etc.) and soil-water relationships (with a view to irrigation planning, rainfed cropping planning, etc.).

Crop Scientists

Various types of crop scientists, including horticulturalists, geneticists, etc., conduct research on such aspects as adaptability of different species and cultivars (varieties) of crops to different environments (including different soils); comparison of various crop production techniques; etc.

Rangeland and Animal Scientists

Carrying capacities and nutritive values of natural veld, nutrient element deficiencies, etc. are research topics which are soil-related (See, for example, Kubota, 1977).

Agricultural Engineers

The suitability of different soils for the construction of earth dams and irrigation canals is but one of the numerous soil-related topics in this field (e.g. Scotney, McPhee and Russell, 1975).

Agricultural Economists

Research regarding the economics of different farming systems; evaluation of the relative profitabilities of different classes and types of tractors and other implements, etc. are all soil-related.

Research results which are soil-related, i.e. which are affected by the nature of the soil at the point where the research was conducted, are of little (if any) value for planning or extension purposes if the nature of the soil (or soils) on which the results were obtained are not clearly indicated. Without adequate characterization of the conditions prevailing at the point where the research was conducted (i.e. soil, climate, etc.) it is impossible to make a reasonably reliable prediction of the validity of the results for any other area of land.

Unfortunately, a very large proportion of the research data collected from many parts of the world by agronomists, economists, soil chemists and soil physicists in the past is "characterized" by the lack or inadequacy of soils information. At the most, some analysis of the topsoil was sometimes given. This lack of appreciation for the need of adequate background soils information is undoubtedly a major factor responsible for the type of situation described by Protz (1977): "The soil management literature was reviewed for specific soil properties affecting each crop. Precious little information was available beyond the standard----this crop grows best on deep, well-drained, friable, highly fertile soil ---- Obviously, if a decision was to be reached on which crop had the best chance of economic success on the poorer soils, more specific soils criteria were required."

A number of important practical implications arise, such as the following example: A group of planners must draw up recommendations regarding the development of an underdeveloped area. Masses of relevant information on which they could base reliable decisions are available from research elsewhere in the country or from other parts of the world. Because these relevant data are not supported by adequate background soils and other environmental information they can not identify it and use it advantageously. Instead of being able to make estimates, they must now base their decisions on "guesstimates." This may well lead to failure of the project and misery to the rural people involved.

On the other hand, it is of just as little use if the soils on which experiments are conducted are described in detail but there are no, or insufficient, soil resource inventories available for the rest of the county, region, or country. An extension officer may know that the research findings can only be extrapolated to land areas similar to that on which the research was conducted. If he does not have an indication of where in his extension ward such similar areas occur, then the research is of little or no benefit to him (and to the farmers whom he serves). The money spent on the research can be written off as a complete waste or loss.

Such unavailability of soil resource inventories may even lead to drastic misinterpretations and incorrect recommendations such as the following example: In the province of Natal in the Republic of South Africa a very severe potassium deficiency was identified in certain soils of the regional research station at Cedara. Good yields required high potassium applications. Based on these results, high levels of potassium fertilizers were recommended for large parts of the region. After many years it was realized that the potassium-deficient soils actually cover only an odd minority of the region. Many farmers were actually wasting large sums of money by buying the potassium fertilizers (Graven, Professor of Agronomy, University of Fort Hare, Alice, Republic of South Africa --- personal communication).

This example leads to another aspect related to the interrelationships between soil resource inventories and research planning: In many cases new soil resource inventories reveal that existing experimental plots are actually located on soils that are sub-dominant, or even rare, in the region served by these experimental stations. Reliable extrapolation of research results from these plots is, therefore, very limited. Meanwhile no reliable information is available for the major part of the region. Alternatively, the soil of the experiment site may be a dominant soil in the area, but may not be generally used by farmers for the production of the crop on which the research is concentrated. If the objective of the research is to supply information to these farmers, then this research is a failure.

Categories of research of which the "delivery factor" depends upon soil resource inventories include, inter alia, the following:

Literature Research

Scanning existing literature for applicable information upon which reliable planning or advisory (extension) decisions can be made, is a fast and inexpensive type of research.

Basic Laboratory and Greenhouse Research

Ensuring that samples are collected at representative sites and that the soils at these sites are described adequately increases the utility of the research.

Field Experimentation

The benefits from soil resource inventories are obvious and have already been discussed in this paper.

Observational Research

Much useful information for planning and advisory purposes can be obtained from systematic and well-planned observations about crop-soil relationships under normal farming conditions. Extrapolations from such observations are meaningful only if the soil characteristics at each point of observation are well described and if a soil resource inventory is available for the area where the data are to be used for planning or advisory purposes.

Demonstration Experiments

Although these are not actual research, they form a very important link in the process of "delivering" research information to farmers. The value of such an experiment is low when it is conducted on a rare soil. Even if it is conducted on a dominant soil every farmer needs to know whether the results of such a demonstration are applicable to any specific area of land on his farm.

Although crop-soil research was used as an example in the previous discussions, the same principles are valid for all other soil-related research.

RESEARCH PLANNING AIMED AT MAXIMIZING THE EFFICIENCY OF SOIL-RELATED RESEARCH

Taking into account that there are apparently at present only about six countries in the world that are net exporters of food and that populations are growing fast, it becomes clear that time is the most important factor demanding maximum efficiency from soil-related research. This need for maximum efficiency is amplified by the limited trained manpower and research funds available in many parts of the world.

A high efficiency means that extrapolation of the research data must have both (i) a relatively large potential geographical scope, and (ii) a high degree of reliability in regard to those land areas to which it can be extrapolated.

Planning future soil-related research so as to achieve maximum efficiency means that all possible care must be taken to (i) avoid the types of mistakes, and (ii) follow the types of guidelines outlined in the previous section of this paper. Reaching of these ideals is dependent upon three prerequisites: (i) availability of high quality soil resource inventories, (ii) an effective soil classification system, and (iii) correct attitudes by all scientists doing soil-related research towards soil resource inventories and soil classification.

Availability of Soil Resource Inventories

The way in which soil resource inventories can (and should) guide research planning can best be illustrated by two examples:

1. Vink (1975) correctly advocates the establishment of "pilot projects" in all areas where the present land use is vastly different from what the potential future land uses are. He also stresses that, due to high costs and other limitations, these projects can only be conducted on a limited number of different "land units." It is obvious that such pilot projects can only be efficient if it is ensured that the research is done on the dominant soils in the study region with potential for the specific farming enterprise under investigation. Less reliable extrapolations then only have to be done to subdominant or rare soils. Without a soil resource inventory the dominant soils cannot be identified, nor can the pilot projects be sited correctly on representative locations.

2. During a recent exploratory soil survey of the Ciskei, an area on the southeast coast of South Africa, the author identified a large proportion of the arable soils as having a very low potential for maize, but a moderate (to high in some places) potential for small-grain cereals such as wheat (Hensley and Laker, 1978). At present South Africa as a whole is, furthermore, producing a large surplus of maize, with additional maize areas which can be developed. Wheat shortages are expected in the foreseeable future, however.

At present the traditional small farmers in the Ciskei are trying to produce maize on these lands (with disastrous effects). There are two factors mitigating against wheat production: (i) the traditional attitudes of the farmers, and (ii) severe incidences of rust infestation. The research needs have clearly been revealed by the soil resource inventory: (i) plant breeding research to develop wheat cultivars which are adapted to this specific area and are rust-resistant, and (ii) sociological and extension research to identify strategies to persuade the farmers to adopt wheat production instead of maize production.

An Effective Soil Classification System

Soil resource inventories which are not based on well-designed soil classification systems have relatively low utility. A well-designed soil classification system must have the following characteristics:

1. It must be comprehensive, i.e. it should be capable of accommodating all of the soils to be found in a country. "Parochial classifications of a farm, a district, or a region can serve a very useful purpose

for a time, but because of their restricted vision they do not serve the needs of soil users on a country-wide basis. A national perspective is required directly by many agriculturalists, ecologists and resource scientists and, indirectly, by all." (MacVicar et al., 1977).

2. Class definitions must be clear, rigorous, mutually exclusive, and based on factual statements of soil properties (Hensley, Senior Lecturer, Department of Soil Science, University of Fort Hare, Alice, Republic of South Africa -- personal communication; MacVicar et al., 1977). This is especially important for the lower categories of classification, i.e. at series level and one level above series level.

3. Only soil characteristics that are easy to measure and to comprehend must be used for the definition of diagnostic horizons and soil classes. Criteria to be avoided include those that are difficult to measure or are not always measurable because they require sophisticated or continuous long-term measurements and those which "involve speculation (such as genetic history)" (MacVicar et al., 1977). An important aim is to have a system that is simple enough to enable para-professionals or technicians in soil science, and even non-soil scientists, to make accurate soil identification in the field (MacVicar et al., 1977).

4. The classification system must be well-structured, so that the similarities and differences between soils can easily be understood. The aim is to find a simple way to permit more accurate communication about soils and to promote a better understanding of the relationships that exist among soils, and between soils and the environment (MacVicar et al., 1977).

In summary it can be said that the soil classification system must be practical. With this it is not meant that it must be a "technical" or purely "utilitarian" system. Such systems in the end really have low utility (Kellogg, 1961; Laker, 1978). A soil classification system must give "non-specialist users in many spheres the confidence and perspective to exploit soils information more fully." Only then can it promote "the development of a sound basis for predicting soil behavior and management responses under defined conditions." (Quotations from MacVicar et al., 1977).

If a country does not possess a soil classification system which satisfies these requirements, especially in the lower categories, then the development of such a classification system should be a very high research priority. (Note: A useful classification system need not be a local one, but may be a foreign one that is applicable to local conditions).

Correct Attitudes Towards Soil Resource Inventories and Soil Classification

Planning of soil-related research in such a way that maximum efficiency is acquired is impossible if the scientist conducting the research does not have a positive attitude towards soil resource inventories or soil classification. The correct positive attitudes can only be developed by means of a realistic perception of both the advantages and the limitations of high quality soil resource inventories and systematic soil classification systems. Unfortunately a large proportion of the scientists involved in soil-related research seem to have a strongly biased outlook on soil resource inventories.

On the one hand many non-soil scientists and soil specialists in other fields than pedology are so preoccupied with the limitations of soil resource inventories based on systematic soil classification that they overlook the potential advantages of such inventories. As a result of this bias they plan their research without taking soil resource information into account at all, with detrimental effects on the efficiency of their research.

On the other hand many potential users of soil resource inventories are antagonized by the highly presumptuous claims by some pedologists about all the "instant wonders" that could supposedly be achieved by the use of soil resource information. Soil resource inventories and soil classification systems are not magical things. They are only scientific tools, but very useful tools if used judiciously. Only when the indicated biases are eliminated, will . researcher give soil resource inventories their rightful place in the planning of soil-related research.

CONCLUSIONS AND STRATEGY PROPOSALS

The well-known, disconcerting gap between agricultural research and the extension of its results can be traced largely to the absence of a reliable basis for extrapolation (MacVicar et al., 1977). A well-designed soil classification system, high quality soil resource inventories, and optimal exploitation of these during the planning of soil-related research are essential prerequisites for the establishment of a reliable basis for the extrapolation of research data.

A strategy consisting of three major steps (which could in terms of time overlap each other) is proposed:

1. Development of a well-designed, systematic and comprehensive soil classification system in the lower categories (series and one level above series) for each subcontinent. It must have all the attributes (simplicity, etc.) described earlier in this paper. The author and his colleagues have had the opportunity to use the new South African soil classification system (MacVicar et al., 1977) for advisory purposes in regard to project planning and even production planning and have seen the tremendous practical value of such a system in regard to data extrapolation.

Every country does not have to have its own system. The geographical scope of technology transfer and data extrapolation widens appreciably if all the countries having similar general soil patterns in a specific subcontinent are using the same system. Cultural and linguistic similarities between the countries involved will enhance the efficiency of technology transfer.

The FAO could make a tremendous contribution by identifying and demarcating these "pedo-subcontinents" and by guiding the development of lower category soil classification systems for each. (The author cannot foresee a humanly comprehensible and practically useful single soil classification system for the world as a whole in the lower categories. If all the systems are well-designed, then it will be fairly easy to "translate" from one system to another when necessary.) Much emphasis is placed on the lower categories, because these are the truly practically useful categories.

2. Compilation of soil resource inventories, using such a well-designed classificaton system. To be successful, the defintions, etc. embodied in the system must be rigorously applied by everybody using the system. (Carelessness and negligence lead to much confusion and loss of confidence in soil resource inventories by non-pedologists.) Very rigorous correlation is also required to ensure that everybody using the system is using it correctly. This may be a problem where more than one country is using the same system.

3. "Selling" the classification system to non-pedologists by discussing it with them during its development and taking note of any good suggestions from their side; explaining the final product to them and planning soil resource inventories together with them. The main objective is to entice them to exploit soil resource information optimally when planning their research.

In South Africa such a series of exercises have been proceeding during the last two decades. The need for a systematic soil classification system for the country was recognized and one was drawn up (MacVicar et al., 1977), using the general principles outlined in the "7th Approximation" (Soil Survey Staff, 1960) as a blueprint to copy. Overlapping with the development of this system, "pedosystem" mapping of the country as a whole is now being conducted on a scale of 1:250,000 (MacVicar et al., 1974). It is almost completed. Picking up momentum now is a project of "norm" collection (i.e. collection of quantitative data regarding crop performance for different crops, etc.) which is done countrywide on an "ecotope" basis. According to MacVicar et al. (1974) an ecotope is an area of land that is defined so narrowly in terms of soil, macroclimate, and slope that in terms of the potential yield class for each feasible farming enterprise or the production techniques needed for each such enterprise, there is a significant difference between one ecotope and any other. Various non-soil scientists are participating on this project. Furthermore, soil scientists have explained the aims, characteristics, etc. of the classification system and the pedosystem survey by means of short courses, meetings, and personal deliberations to non-soil scientists. The result is that a large percentage of them have accepted it and are using it to great advantage in the planning of their research and the extrapolation of research data.

ACKNOWLEDGEMENT

Many of the ideas contained in this paper originated or crystallized during discussions with Mr. M. Hensley, Senior Lecturer in Soil Science at the University of Fort Hare. The author wishes to thank Mr. Hensley for his stimulating thoughts and support.

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QUESTIONS/COMMENTS (by M. Drosdoff)

I question the use of the word "must" in connection with your emphasis on problem-oriented research as opposed to "academic" research. I believe that in developing countries a certain amount of "academic" or "basic" research is important to develop research skills and stimulate and motivate the development of scientists.

You want to persuade farmers in certain areas who are largely subsistence farmers to grow wheat instead of maize which is not adapted to the area. What if the farmers prefer miaze and beans for their staple food supply rather than wheat?

ANSWERS:

Perhaps I was too emphatic when I used the word "must." But I believe that the research should be put in perspective and priority given to problem-oriented research and most of the research resources should go for solving practical problems.

It would be preferable for the farmers to grow wheat which is better adapted and sell the wheat and buy the maize if that is the preferred food.

QUESTIONS/COMMENTS (by S. Somasiri)

The problem is that agricultural research needs the better judgment of the researcher and an attempt to understand the real problems of the farmer. For some researchers what they see may not be real problems and there is personal judgment in making such decisions, is there not? The researcher must get involved with the farmer to see his agricultural problems.

ANSWERS:

I fully agree. Your last sentence is the critical point. If the researcher does not do this, then he can forget about solving the problems of the farmer. Any researcher who does not honestly do what you say in that sentence, and claim to the outside world that he is trying to help the farmer, is fooling himself (or deliberately misleading the outside world).

VALUE OF SOIL RESOURCE INVENTORY FOR REGIONAL RESEARCH PLANNING IN INDIA

R. S. Murthy[1]

SOIL RESOURCE INVENTORY, A HIGH PRIORITY

The importance of resource surveys, inventory, and preparation of soil maps and other interpretive maps for the various agricultural research and development programs in India has been realized. Accordingly, a high priority has been accorded by the Indian Council of Agricultural Research to complete the reconnaissance soil survey of the country and compile a soil map of India on 1:1 million scale. This work is in progress and such a map is expected to be ready by the year 1985. Soils will be classified according to Soil Taxonomy (Soil Survey Staff, 1975), which has been reproduced in a less expensive edition to make it available to all soil survey workers in India.

THE INDIAN SITUATION

India is a large country, less than half the size of the United States but containing twice the population (1979 - 631 million; 1986 - 705 million). Out of 306 million hectares under various land uses, 151 million hectares are agricultural lands and 65 million hectares are forests. Even with high levels of management and technology, it will be rather difficult to meet food demands unless additional lands are brought under cultivation, saline and alkali lands are reclaimed, and ravines and eroded lands are made productive. There are areas which have high agricultural potential but are still lying unexplored and unexploited. Rapid soil survey and inventory of such areas will help identify and assess the availability of lands for agricultural production. The National Bureau of Soil Survey and Land Use Planning is presently engaged in this task.

ORGANIZATION

As far as methodology of survey, mapping, inventory, reporting, etc. are concerned, the same principles and guidelines discussed in this workshop are being followed by the Bureau in India. The Ministry of Agriculture and Irrigation has three Departments:

(i) The Department of Agriculture, through the Land and Water Division, undertakes detailed soil surveys of watersheds for development programs. Priority areas are demarcated for soil conservation by using aerial photographs. Those areas which need immediate attention are surveyed in detail by using aerial photographs (1:20,000 scale) or Cadastral maps (8" = 1 mile scale). Grouping of soil units into land capability classes for purposes of making management recommendations are included in the soil survey report.

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[1]National Bureau of Soil Survey and Land Use Planning, Nagpur, India.

(ii) The Department of Agricultural Research and Education Services/ the Indian Council of Agricultural Research, comprised of about 30 research institutes for different disciplines in agricultural sciences, plant sciences and animal sciences; All-India Coordinated Research Projects; and agricultural universities. The National Bureau of Soil Survey and Land Use Planning is one of the institutes of the I.C.A.R. This bureau conducts standard soil surveys, mapping, correlation, classification, and interpretation on a countrywide basis.

(iii) The Department of Rural Development deals mainly with the integrated development in different rural districts to generate employment and eradicate poverty.

The state soil survey organizations are primarily concerned with the detailed soil surveys of the command area development programs, drought-prone area programs, reclamation projects, etc., for which 50 percent subsidy is granted by the government of India. There are state Soil Survey Coordination Committees which review the soil survey programs, plan joint field visits for correlation, exchange soil series descriptions, and discuss problems in mapping, soil classification, etc.

OBJECTIVES AND PROGRAMS

The National Bureau of Soil Survey and Land Use Planning has four Regional Centers: Delhi for the Northern Alluvial Plains, Nagpur for the Central Plateau of black soils, Bangalore for red and laterite soils of the Southern Peninsula, and Calcutta for red and laterite soils of the eastern region. Two additional Centers are proposed for the western arid and desert soils and the northeastern hill soils. The Regional Centers in charge of soil correlations are provided with field operational units for conducting soil surveys and mapping, laboratory facilities for soil characterization and classification, and a cartographic unit for processing field sheets and preparing final maps. All these activities are being coordinated through the Division of Soil Correlation and Classification at headquarters; the Pedology Division for conducting genetic studies of Benchmark Soils supported by clay mineralogy, micromorphology etc.; the Cartography Division for map editing and reproduction; an Aerial Photointerpretation and Remote Sensing Division for preparation of suitable base maps for survey, mapping, and supply of photointerpretation legends to the field units; and a Land Use Planning Division for preparation of land use plans in consultation with the user agencies and Divisions of the Bureau.

As surveys are completed, the Bureau issues soil survey reports and maps to potential users. One of the problems experienced in the past has been that the reports were not put into full use because they were too technical. The user agencies found them hard to understand for lack of sufficient experience in the subject. The Land Use Planning Division of the Bureau is intended to keep a liaison between the survey organization and user agencies and help in the preparation and utilization of land use plans in the implementation of projects.

LEVEL OF PLANNING

At the national level, information is available on the land resource regions and divisions: A map of India on a scale of 1:6 million shows the delineation of 52 land resource regions and 231 land resource divisions. Maps on geology, vegetation, and soils are also published on the same scale. For administrators/planners these maps are adequate to give a broad picture of the various resources of the country with regard to their location, extent, quality, etc. From the regional level down to the operational and micro levels where implementation is important, information becomes inadequate. Scales of maps need to be much larger and inventory has to be more elaborate. Surveys, therefore, need to be of a higher intensity. The reconnaissance soil surveys, soil and other interpretive maps that are being carried out by this Bureau need to be prepared on different scales to meet the requirements of operational agencies, regional planners and decision-makers at the highest level.

METHODOLOGY AND RATIONALE OF SURVEY AND MAPPING

The unit of mapping for reconnaissance soil surveys is Taluk/Tahsil, which is a convenient administrative unit. Each district consists of a number of Taluks/Tahsils and all the districts together make up the state. The base maps used for reconnaissance soil survey are 1" = 1 mile scale. Topographical maps of India or aerial photographs are on a 1:50,000 or 1:63,000 scale. The unit of soil mapping is soil series/series associations. The reconnaissance maps show, besides soil series boundaries, erosion features, saline and alkali-affected areas, waterlogged and marshy lands, problem (high water table, poor drainage) and potential areas, present land use, etc. Depending upon the extent and availability of funds, problem and potential areas will be considered for detailed soil survey, using base maps with 1:20,000 scale or cadastral maps with 8" to 16" = 1 mile scale.

REGIONAL PLANNING - FOCUS

For regional planning, district soil maps compiled on scales of 1" = 4 miles or 1" = 8 miles are necessary. The mapping units contained in 1" = 1 mile scale, by abstraction and synthesis, are grouped into soil families and subgroups, respectively. Regions may be administrative, resource, or agro-ecological. Regions may cut through states and sometimes extend to more than one state. Broad present land uses (agricultural cultivated lands, forest lands, community grazing lands, irrigated lands if any and waste lands) are plotted on the map. A suggested land use map is also prepared which contains the soil series characteristics (both morphological and physicochemical), inherent potentialities, availability of water for irrigation, and acceptability of crops to the farmers. Such a map helps in projecting an integrated land use for the district/region as a whole, identifying potential lands for agricultural use, grass land development, orchards, dairy farming and animal husbandry activities, and forestry including farm forestry and afforestation programs to protect the soil from erosion. If irrigation facilities are available, suitable cropping patterns are suggested to utilize water judiciously and get additional income from the lands. In addition, fertilizers and crop rotations are also recommended.

Unlike the farm plans that are generally prepared by the Soil Conservation Survey Staff in the United States, Indian conditions make it unfeasible to prepare land use plans for individual farms. This is so because in India the fields are very small; farmers are not educated to understand and appreciate the value of such plans; and adoption of improve practices on an individual field basis becomes difficult. This is one of the reasons why watershed development programs cannot be satisfactorily implemented. If the watershed comprises predominantly agricultural lands, the number of farmers involved is so large that it poses problems.

The regional planners therefore have to take advantage of soil maps and land use plans to locate areas which can be further improved and production augmented. It will help them in the allocation of funds for development programs and procurement of various inputs.

The role of soil resource inventory in regional planning is therefore extremely important, particularly so in developing countries. Depending upon the country's soil and water resources, many agricultural development programs can be intensified, land use policies can be streamlined, and a realistic estimate of agricultural production can be made. Such inventories will also prove handy in the implementation of integrated rural development programs, which is the country's immediate need.

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TECHNOLOGY TRANSFER PROGRAMS ON LAND USE AND NATURAL RESOURCES INVENTORIES AND INFORMATION SYSTEMS

Arthur S. Lieberman[1]

This paper has been prepared to recommend the creation of joint programs for technology transfer on land use and natural resource inventories and information systems. Such joint programs could contribute to the understanding of appropriate land use capabilities. The focus would involve the transfer of knowledge and skills about inventories and systems related to resource development, management, and physical planning, to individual countries and regions thereof. In enabling the individual countries to better inventory their resources and to create and/or enhance information systems on land use and natural resources, such programs would make a major contribution towards planning of the earth's resources.

ADVANCES IN REGIONAL LANDSCAPE PLANNING

Within the last decade, regional-scale landscape planning has become an integral part of the profession of landscape architecture. Methodologies involved in working with landscape planning at the regional scale reflect a rapidly expanding professional frontier. Landscape planners' approaches to regional landscape inventories and information systems for physical planning have begun to provide formidable tools for physical planners and decision-makers to use.

During the same period, major advances have occurred in employing remote sensing in its several forms in the analysis of natural ecosystems and land use. Concurrently, geographically r ferenced land use information retrieval systems, of both the low-cost, labor-intensive, and the computerized types, have been developed. Landscape planners are intimately involved in utilizing and enhancing these capacities in their international work.

These recent approaches to regional landscape planning have several attributes in common. First, they responded to significant landscape problems and opportunities of the 1960's, and attempted to improve metropolitan development as well as metropolitan and rural recreation/open space opportunities. Second, they included the input of scientists and/or used scientific classification and evaluation techniques. (As a result soil scientists, geologists, foresters and ecologists and their techniques were extremely influencial during this decade.)

"While landscape planners were incorporating established scientific developments into their planning models, scientists were developing inventory and evaluation techniques of increasing accuracy to measure landscape resource and hazard parameters. In these studies key attributes of these resource land hazard parameters were inventoried and evaluated in quantitative terms " (Ferris and Fabos, 1974).

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During the last decade, two concurrent developments, (1) the articulation of resource inventory analysis and planning methodologies of an increasingly sophisticated nature, and (2) the achievement of considerably improved technological capabilities in remote sensing, have provided a backdrop for exploring elements of a functional information system for land use planning and natural resources management. During this same period, computer technology has developed logarithmically.

These relatively recent capabilities provide opportunities in inventory analysis, planning, development, and management of global physical resources.

SPECIFIC OBJECTIVES OF THE INTERNATIONAL TECHNOLOGY TRANSFER PROGRAMS

The programs the author is encouraging would provide training for participants from individual countries. (It is proposed that each country's participants would be receiving training as a group, to enable easy transmission and reception of material by the trainees, in language and materials suitable to their learning needs.)

Training periods would include access to international literature on inventorying of natural resources, evaluation of land use suitability, ecologically based regional planning, remote sensing in its several forms and its application in information systems for physical planning, photogrammetry, computer science, monitoring and prediction of environmental impacts, and ecological management of natural systems.

THE GOALS

To enable effective ecologically based land use planning and natural resources management to occur, an updated land use and natural resources information compilation, storage, and retrieval system must be available to physical planners and decision-makers in national and local government offices and agencies, as well as to planning firms and academic research and teaching institutions. The proposed programs for technology transfer would relate to resource information needs of planning professionals, professionals engaged in resource management, and land use and resource management decision-makers in the government (and in private firms) in each of the countries with which the Center works. Next, consideration would be given to information systems with focus upon a coordination of resource information that would serve to utilize locations possessing data on land use or specific natural resource factors (such as soil and water). A sequential scheme could then be considered for making such a system operational as an on-going dynamic resource information base at central and satellite locations. Finally, a detailed format for training professional planners and resource managers (all information users) could be prepared and consideration given to communications techniques and pretesting with selected groups and individuals in the country concerned.

THE NATURE OF THE TRAINEES

The envisioned program in technology transfer would relate to the following individuals from countries involved: (1) professional planners, (2) professionals engaged in resource management, (3) government and private land use and resource management decision-makers.

DISCIPLINARY AREAS POTENTIALLY INVOLVED

At least nine disciplinary areas are envisioned as potentially involved in such programs:

1. Ecologically based regional planning
2. Ecology of natural eco-systems
3. Remote sensing and its applications
4. International communication and extension education
5. Land use and natural resource information systems
6. Mapping and photogrammetry
7. Agricultural resources
8. Forestry resources
9. Computer science

POTENTIAL COURSE OFFERINGS

Courses which could potentially be offered to trainees taking the program are listed below. The total program would run approximately three months, the length of each course being two or three weeks, as indicated.

1. Ecologically Based Regional Planning Methodologies
2. Ecology of Natural Systems
3. Remote Sensing, its Uses and Application in Resource Analysis and Inventory, and as an Aid to Physical Planning and Resource Management
4. Land Survey and Terrain Analysis/Soil Classification
5. Mapping and Photogrammetry
6. Consideration of Land Use and Natural Resource Inventories and Information Systems for the Country Involved
7. Computer Technology, Costs, Benefits, Requirements [applies to considerations of course (6)]
8. Communications and Extension Education for Users of Land Use and Natural Resource Inventories and Information Systems in the Country Involved.

The course on Ecologically Based Regional Planning Methodologies (2 weeks) would be concerned with the applicability for specific purposes in the country involved, of selected approaches to resource analysis and planning from several leading locations. Many of these currently are in North America, Europe and Australia. It is recognized and emphasized that African, Asian, and Central and South American approaches must be researched and introduced as they are developed into the teaching program. One example is a case study in South America on land evaluation and resource planning appropriate to mountain regions of the American tropics which appeared as a

Cornell University doctoral dissertation (Hawes, 1978). In addition, studies on convergent ecosystems conducted under the International Biological Programme should be included, an example being the comparative study on vegetation of California and Chile (Thrower and Bradbury, 1977).

Course #2, Ecology of Natural Systems (2 weeks) would cover implications for natural resource development, utilization and management in terms of the country involved.

Course #3, Remote Sensing, its Uses and Application in Resource Analysis and Inventory, and as an Aid to Physical Planning and Resource Management (2-3 weeks), is intended to explore the appropriateness of various forms of remote sensing.

In this regard one recalls the brief summary of scientific and social significance of remote sensing from a 1967 report (Belcher et al., 1967). They wrote:

> In developing the lists of applications of remote sensing information for this report, we were impressed by a small number of uses that are, or soon will be, feasible, which offer unusual promise of truly great benefits on a world-wide basis. These applications are of greater than ordinary significance because of their effect on human suffering and economic development, or because they promise outstanding beneficial returns in relation to the cost of the problems involved.
>
> The following areas of application appear to have possible benefits that would qualify them uniquely as an outstanding significance to the well-being of man:
>
> 1. Resource evaluation and planning
> 2. Rural transportation development
> 3. World food budget
> 4. Educational applications
> 5. Soil classification and mapping
> 6. Disaster applications
> 7. Discovery of new species of economic plants with tolerance or resistance to diseases and insects
> 8. Medical research, through applications to unique problems in fields of veterinary medicine."

A doctoral dissertation (Senykoff, 1978) at Cornell has identified some important considerations relative to encouraging the acquisition of remote sensing equipment in developing nations and shows the ability to gain much from low-cost processing of satellite imagery contrasted with more capital-intensive approaches.

Course #4, Land Survey and Terrain Analysis, would last 2 weeks, and course #5, Mapping and Photogrammetry, the same length of time.

Course #6, Consideration of Land Use and Natural Resource Information Systems for the Country Involved (2-3 weeks) is intended to explore computerized and manual factors related to the appropriateness of such systems.

Course #7, Computer Technology, Costs, Benefits, Requirements, (1 week) would be applied to considerations of course #6, and is intended to raise questions about the needs for investment in computer technology in relation to the specific country's information needs.

Course #8, Communications and Extension Education for Users of Land Use and Natural Resource Inventories and Information Systems in the Country Involved, (1-2 weeks) would be so planned as to enable filtering of conversancy and knowledge to users at several levels, not just at the upper echelons in the government and private sector.

RESEARCH TO SUPPORT THE PROGRAM

The program can serve, and will need to explore through research, two key areas:

1. Adaptability of existing methodologies to host country, and

2. Relevance of techniques for urbanization and settlement policies.

THE QUESTION OF LENGTH OF COURSES

On the matter of the length of the individual courses, the author finds relevant the following section from a recent publication of the National Academy of Sciences (1977). Although concerned with training in resource sensing from space for developing nations, it has pertinence for other subject matter of the proposed technology transfer program as well.

> Shortage of trained personnel is the primary factor limiting the ability of developing countries to assimilate the technology. There is need for programs to inform policymakers, planners, and resource managers of the potentials of the technology; for short-term, in-depth training of scientists and resource specialists to enable them to analyze satellite data applicable to their resource sectors; and for longer-term academic training for those who will be involved with its technically more demanding aspects. To accommodate the larger number of people who will have to be trained in the next decade, educational institutions will need to modify their orientation and enlarge their capacities in this field.

A SPECIFIC PROPOSAL FOR A PILOT PROGRAM

A specific proposal has been advanced by the author for the creation of a joint pilot program of technology transfer on land use and natural resource inventories and information systems, in which Cornell University would be a major partner. This proposed program incorporates the elements presented in this paper, and would focus on trainees from the Mediterranean Basin, Africa, the Middle East, and Latin America. The specifics of that proposal lie beyond the purposes of this presentation, however, and will not be considered today.

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COMMISSIONING OF SOIL SURVEYS

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An important component of regional development projects is soil surveys. Soil surveys may form the initial step in the project or may be made simultaneously with other evaluations. Many countries have the capability of making their own soil surveys while others require assistance. In some instances, despite the availability of a soil survey organization, the country may be obliged to contract a soil survey. One example of such a situation is in a land development or an agrarian reform project, where the soil survey is an important component of the project and the contractor insists that the soil survey be part and parcel of the contract. Second, frequently the pace of the development in a country is so rapid that the local organization is not capable of meeting all the demands. Soil surveys are then contracted out. A third example is when one government agency requests another - usually the soil survey department - to survey an area for them.

The cost of all these surveys are a function of the area, the objectives of the survey and if local or foreign expertise is used. In every case, costs are sufficiently significant to require a legal contract to be signed. In the event that a loan is obtained to meet the cost of the development program, the loaning agencies require guarantees and indirectly force the country to hire reputable firms! The author is not qualified to provide the legal framework for commissioning soil surveys, but the main objective in this contribution is to highlight the legal points that deserve attention.

In many less developed countries (LDCs), soil surveys are contracted with few or no specifications. A frequent invalid assumption is that the clients know what to do. Hence the need for guidelines for commissioning soil surveys.

A related consideration is verification of the survey. In the absence of reliable methods for verification, it is of little use to draw up detailed specifications. Guidelines for verification are also not available. Consequently, the second objective of this contribution is to evaluate some of the aspects of verification.

Every soil survey project, especially those which are commissioned and less so for those which form the systematic inventory of the country, is in a sense unique. As a result no one set of specifications will serve all projects and perhaps no given set of verification procedures will be universally suitable. Both the specifications and verifications must be designed for each project and the contractor must be informed in advance.

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SPECIFICATIONS

The most critical consideration prior to commissioning a survey is to state the objectives clearly. Beckett and Bie (1978), in their study of surveys in Australia, conclude that many were commissioned with no clear idea of what the survey was to answer, and as a result most of these have remained unused. Frequently the client does not know what is needed to meet the objectives. If funds are available, a consulting firm is requested to draw up the specifications. In some cases, the client leaves it to the contractor to decide how best to meet the need.

The following sections are a partial list of aspects to be considered in developing specifications. Appendix I gives an example of specifications drawn up for a soil survey project. It is part of an actual contract in which the names of countries, organizations, etc. have been fictionalized and some changes made in the contents. Appendix II, which is related to the same project, indicates considerations for selection of a contractor. Appendix III gives an example of a contract for a small land use planning project.

Scale of the Survey Map

The scale at which the final map is published is a function of many factors, the objectives of the soil survey being one of the most important. Many of the other features included in the specifications are also a function of the scale. The useful scales for some objectives are given in Table 1. The choice of the exact scale is in addition a function of other ancillary information on facilities available. The most important of these is availability of toposheets or other base maps.

Depending on the objective, the scale of the field map may also be stipulated. An alternative is to stipulate the scale of the field map and state the factor by which the final map may vary, e.g. the base map is on a scale 1:25,000 and the final map may not be smaller than three times this scale. For example, the field map is 1:25,000 and final map is 1:50,000. Both these requirements imply a certain level of accuracy.

Map Legend

The legend of a map should normally conform to the current practice in the country, unless the nature of the survey requires the creation of a new legend or the current legend is inadequate. The kind of mapping units employed is partly a function of the variability of the soils and of scale. The kind of mapping units, i.e. phases of soil series, soil series or some category of a taxonomy, should be stipulated in the specifications. The kind of taxonomy to be used may also be specified.

Density of Observations

The surveyor makes several kinds of observations; two of the more important kinds are "auger" and "pit" observations. It is useful to stipulate the number of each of these kinds of observations per unit area. They need not be uniformly spaced over the entire area. The surveyor is also required to note in his field book details on the soil at each observation

Table 1. Objectives of survey in relation to some components of a soil survey.

Objectives	Class of Survey[a]	Approximate Publishing Scale of Map	Category of Map	Minimum size Mapping Unit (ha)	Approximate Cost[b] ($/ha)
A. Master Planning:					
1. National	Order V	1:1,000,000	Exploratory	4000	0.2
2. Regional	Order IV	1:500,000	Macro-reconnaisance	1000	1
3. Cultural Systems	Order III	1:100,000	Meso-reconnaisance	40	2
B. Project Planning for:					
1. Land Settlement Schemes	Order III	1:50,000	Macro-detailed	10	3
2. Large scale farm units	Order II	1:25,000	Meso-detailed	2.5	5
3. Agricultural development projects	Order II	1:25,000	Meso-detailed	2.5	5
C. Operational Planning:					
1. Siting fields for management practices	Order II	1:20,000	Meso-detailed	1.6	10
2. Siting drainage and irrigation systems	Order I	1:10,000	Ultra-detailed	0.4	20
3. Siting experimental plots	Order 1	1:5,000	Ultra-detailed	0.1	30
4. Siting buildings (urban areas)	Order 1	1:1,000	Ultra-detailed	0.03	40

[a] See Rourke (1977) for orders of soil survey.

[b] 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.

point and to indicate all these points on a map. Both the field book and the traverse map are submitted to the client on completion of the project.

Only a minimum number of auger and pit observations need to be stipulated. The objective is to ensure that the whole area was traversed. This may not be so important in large scale maps, but it is relevant in small scale maps and particularly under jungle conditions where there is no alternative but to do a rigid grid survey.

Due to terrain conditions, objectives and other factors, it may not be feasible to attain a uniform density of observations for the whole area. Consequently a reliability map, which is usually an inset in the final map, must be included to show the areas where the survey is accurate and where it is less accurate. The reasons for this variation are included in the soil survey report. Specifications should require a reliability map.

Field Methodology

Some procedures are more appropriate for a given scale than others. It may only be necessary to specify the field methodology in large-scale surveys.

Ancillary Information to be Provided

In an agricultural development project, especially in a remote or jungle area, the surveyor may be one of the few people who have viewed the area prior to cultivation. He is thus in a position to provide a considerable amount of basic data. A complete checklist in the range of information that could be compiled is attached (Appendix I). It is not practical to require the surveyor to compile all this information but the specifications could require him to compile some of these if feasible. An alternative is to select some of the more important features from the checklist for compilation.

Soil Correlation

Surveyors working for the first time in a foreign country have problems in using the local classification of mapping units. It may take six months to a year before they are fully conversant and this depends mainly on the amount of information that already exists. The previous experience of the surveyor also determines how quickly he adjusts to the new environment. Moving from a glaciated area to the humid tropics, or changing from a large-scale map to a very small-scale survey, involves a re-education process. Frequently, the duration of the project does not give sufficient time for this adaptation and the consequences are reflected in the quality of the survey.

As a result, mapping experience in a similar environment may be an important criterion for choosing the surveyor. Even if the person has experience, the inherent problems of a new environment require some form of assistance. This is achieved by correlation with local surveyors. The soil correlation exercises are mutually beneficial. The client obtains a good understanding of the nature of the soils and the program of the work. The recommendations of the project are executed by the local staff. A report on the soils is available but in addition, first hand information from correlation trips is very valuable. Correlation also implies that the area is mapped consistent with current local practices.

Thus soil correlation is an important stipulation in the project specifications.

Descriptions and Analyses of Soils

Guidelines for the number of profiles to be described and the types of analyses to be performed are given in Table 2 (Eswaran, 1977). Tables 3 and 4 (Seldon and Walker, 1968) give examples of specifications designed by the United States Bureau of Reclamation for land classification. The need for such descriptions and analyses cannot be overemphasized. In commissioning soil surveys, the minimum number of profiles to be described and analyzed is stipulated.

Report

The report is the only means for providing a permanent record of the findings of the soil survey. Ideally there should be two reports. The first is a technical report which gives all scientific details of the soil resources of the area. The second is a more general report specifically directed to planners, focusing on the problems and possibilities of the area in terms of the objectives. It should give a set of alternatives for the planners to help them make their decisions.

VERIFICATION OF SOIL SURVEYS

Verification or adherence to the project specifications may be judged qualitatively or quantitatively. It is more or less impossible to check that all the auger observations and soil pits were done, and to the full depth, particularly in inaccessible country. However, by insisting that sampling sites be currently recorded, some spot checks may be possible. In addition, by requiring standard descriptions, these can be checked later to see if they appear valid. Too many or too few descriptions in a work day appear suspicious. A very experienced soil scientist is needed to make this evaluation of the survey.

The quality and reliability of the map and report are more difficult to evaluate. Many doubts on this may be unnecessary if an experienced scientist is project leader -- this is one of the reasons for the information required in Appendix II. Sampling and statistical analysis of results is one way of quantitatively verifying the survey. Though the methodology of such procedures are available (Webster, 1978), it is doubtful that they will stand a legal test. This is due to the inherent difficulties in mapping. It is well known that the percentage of profiles falling correctly within the defined range of soil characteristics of the mapped series or mapping unit is usually much lower than what would be considered reasonable. The concept of "purity of mapping units" is a good mental exercise which is difficult to achieve in practice.

Table 2a. Class I type of analyses in relation to objectives.

Analyses required for *Soil Taxonomy*	
A. General analyses required for all horizons and profiles:	
1. Particle size distribution	
2. Organic carbon, nitrogen	
3. Cation exchange capacity (NH_4OAc, pH 7)	
4. Exchangeable bases: Ca, Mg, Na, K	
5. pH in H_2O and 1N KCl (1:1)	
6. 1N KCl-extractable Al	
7. $BaCl_2$- Triethanolamine (pH 8.2) H^+	
8. CBD-extractable Fe_2O_3 and examples	
B. Analyses and examples of a few selected profiles to test specific requirements of *Taxonomy*:	
1. Bulk density	Andepts, "Huma" suborders and GG
2. pH in 1N NaF	Andepts, Spodosols
3. 15 bar H_2O	Inceptisols, Alfisols, Ultisols, Oxisols
4. Cation exchange capacity by 1N NH_4Cl	Oxisols
5. COLE value	Vertisols, Vertic SG
6. Conductivity	Aridisols, some families
7. $CaCO_3$, $CaSO_4$	Aridisols, Mollisols
C. Analyses required on a few selected horizons to test specific requirements of *Taxonomy*:	
1. P_2O_5	Anthropic horizon
2. Pyrophosphate-extractable Fe, Al	Spodic horizon
3. Fine/coarse clay ratio	Argillic horizon
4. Mineralogy of clay	Argillic horizon
5. Mineralogy of fine sand	Soil families

Table 2b. Class II types of analyses in relation to objectives.

Analyses performed for specific objectives or problems. (Generally performed on site, on undisturbed samples or on auger samples.)
A. Physical and engineering properties: 1. Infiltration 2. Permeability 3. Available water 4. Bearing capacity 5. Other engineering properties
B. Chemical properties of soils: 1. Salinity, alkalinity 2. pH fresh, dry, or with oxidizers 3. Toxic substances (As, B, Cr, Fe and Sulphides) 4. Fertility-related properties employing different kinds of extractants 5. Eh
C. Chemical properties of water at site or incoming water: 1. Suspended solids 2. Dissolved salts (electric, SAR) 3. Toxic substances (B, Mg, Cl^-, SO_4^-, CO_3^{--}, HCO_3^-) 4. pH

Table 2c. Class III type of analyses in relation to objectives.

Analyses performed for genetic studies.
1. Extraction or dissolution techniques 2. Mineralogical 3. Micromorphological 4. Equilibration (The above are performed in addition to some or all of Class I and II analyses.)

Table 3A. Bureau of Reclamation--An area in the Central Great Plains, USA, detailed land classification specifications, gravity type irrigation.

Land Characteristics	Class 1--Arable	Class 2--Arable	Class 3--Arable
SOILS			
Surface texture	Sandy loams to friable silty clay loam	Sandy loams to stable friable clays	Loamy sands to friable clays
Profile characteristics	Sandy loams to friable clay loams: will hold a minimum of 6 inches of readily available moisture in the root zone	Loamy sands to friable clays: will hold a minimum of 4 inches of readily available moisture in the root zone	Loamy sands to firm clays: will hold a minimum of 3 inches of readily available moisture in the root zone
Structure type and density	Same for all classes, crumb, granular, blocky, or subangular blocky with weak or stable aggregates and densities less than 1.65. Overlapping of blocks allowable with densities less than 1.55. May be massive when textures are sandy loams or coarser.		
Depth to clean sand or gravel	48 inches to 6 inches dependent upon water holding capacities	36 inches to 48 inches dependent upon water holding capacities	18 inches to 36 inches dependent upon water holding capacities
Alkalinity in root zone	Less than 1 meq/100 g soil of exchangeable sodium	May contain up to 3 meq/100 g soil of exchangeable sodium when soils have relatively high lime or gypsum content and adequate subsurface drainage.	May contain over 3 meq/100 g soil of exchangeable sodium for soils high in lime and gypsum, with adequate subsurface drainage characteristics
Salinity in root zone	Salt content can be maintained at a level not to exceed 4 millimhos/cm	Salt content can be maintained at a level not to exceed 8 millimhos/cm	Salt content can be maintained at a level not to exceed 8 millimhos/cm

TOPOGRAPHY			
Total development costs	$72 per acre. With optimum productivity, development costs must not reduce payment capacity over $3.64, either individually or in combination	$145 per acre. With optimum productivity, development costs must not reduce payment capacity over $7.28 per acre, either individually or in combination	$215 per acre. With optimum productivity development costs must not reduce payment capacity over $10.92 per acre, either individually or in combination
Slope	Less than 2 percent in general gradient	Less than 4 percent in general gradient	Less than 6 percent in general gradient
Irrigation pattern --Length of run	Should not be less than minimum length of run required for soil type for the major crop in a given rotation	May be 25 percent shorter than the minimum length of run required for Class 1	May be 50 percent shorter than the minimum length of the run required for Class 1
Irrigation pattern --Size and shape of field	Should be of sufficient size and shape so that normal irrigation and tillage practices may be carried out unrestricted. Productivity will not be affected by irrigation efficiency.	Should be of sufficient size and shape so that normal irrigation and tillage practices will be only moderately restricted. Productivity will be reduced 5 to 10 percent by reduced irrigation efficiency.	Size and shape such that normal irrigation and tillage practices will be restricted, but still feasible for irrigation. Productivity will be reduced from 10 to 20 percent by reduced irrigation efficiency.
Surface leveling	Up to $72 per acre or approximately 360 cubic yards per acre	Up to $145 per acre or approximately 720 cubic yards per acre	Up to $215 per acre or approximately 1,100 cubic yards per acre
DRAINAGE			
Internal drainage (Natural)	Well aerated; no limit to moisture movement or root development; tillable over a wide range of moisture	Well to moderately well aerated; moisture movement and root development somewhat impeded; tillable over a moderately wide moisture range	Moderately well aerated; moisture movement and root development moderately restricted; tillable over a narrow moisture range
Surface drainage	Adequate protection from surface runoff and waste water can be obtained for $72 per acre or less.	Adequate protection from surface runoff and waste water can be obtained for $145 per acre or less.	Adequate protection from surface runoff and waste water can be obtained for $215 per acre or less.

Table 4A. U.S. Bureau of Reclamation-Sample land classification specifications, reconnaissance land classification. Southeast Asia

Classifying Characteristics*	For rice production (lowland type) Class 1R - Arable	Class 2R - Arable	For upland crop production Class 1 - Arable	Class 2 - Arable
Soils				
Texture				
Surface 0-12 in. (0-30 cm)	Fine sandy loam to clay loam	Loamy sand to clay	Fine sandy loam to clay loam	Loamy fine sand to permeable clay
Subsurface	Loamy sand to clay	Sand to clay	Sandy loam to permeable clay	Loamy sand to permeable clay
Cation exchange capacity of surface soil	>10 meq/100 g	>5 meq/100 g	>10 meq/100 g	>5 meq/100 g
Internal drainage characteristics	May be slow to very slow	May be slow to very slow	Good	Good
Depth				
To clean sand or gravel	Not applicable	Not applicable	36 in. (91 cm) or more	24 in. (61 cm) or more
To permeable armor	>18 in. (45 cm)	>18 in. (45 cm)	>60 in.(152 cm)	>36 in. (91 cm)
To impermeable zone	>12 in. (30 cm)	>12 in. (30 cm)	>96 in. (234 cm)	>96 in. (234 cm)
Acidity				
Surface soil pH,(1:1 water), 0-12 in. (0-30 cm)	>5.0	>4.0	>5.5	>4.5
Exchangeable aluminum, exchangeable manganese, and exchangeable iron toxicity*	None	Slight	None	Slight to none
Sodic factors**				
Salinity at equilibrium Electrical conductivity saturation extract	<4.0 mmhos/cm	<10 mmhos/cm	<4.0 mmhos/cm	<12 mmhos/cm

Table 4A. U.S. Bureau of Reclamation-Sample land classification specifications, reconnaissance land classification. Southeast Asia

Classifying Characteristics*	For rice production (lowland type)		For upland crop production	
	Class 1R - Arable	Class 2R - Arable	Class 1 - Arable	Class 2 - Arable
Available water Holding capacity in 4 ft. (122 cm) depth	Not applicable	Not applicable	6 in. (15 cm) or more with 1 in. in 0-12 in. depth (2.5 cm in 0-30 cm)	3 in. (8 cm) or more with 1 in. in 0-12 in. depth (2.5 cm in 0-30 cm)

*Specific limitations will be further developed when additional data are available. Class 6, nonarable lands, will include any lands within the classified areas which do not meet the minimal specifications. Dual classes may be mapped where soil factors and water table control will permit production of paddy rice or upland crops.

**Appraisal is dependent on type of clay and cropping pattern.

Table 4B. U. S. Bureau of Reclamation-Sample land classification specifications, reconnaissance land classification. Southeast Asia

Classifying Characteristics*	For rice production (lowland type) Class 1R - Arable	Class 2R - Arable	For upland crop production Class 1 - Arable	Class 2 - Arable
Erosiveness to water	Low	Medium to low	Medium to low	Medium to low
Gravel or cobble (permanent)	May contain small amounts of fine gravel	Same as Class 1R	May contain numerous cobble or gravel less than 3 in. (8 cm) diameter in surface horizon	May contain cobble or gravel up to 6 in. (15 cm) diameter in surface horizon
Position	Low position, but susceptible to surface drainage	Low position, may be subject to restricted surface drainage	Well-drained position	Well-drained to moderately well-drained
Topography				
Slope	Near flat	Near flat	<2 percent	<6 percent
Leveling requirements	Low	Medium to low	Low	Low to medium high
Stone removal needs	None	None	None	May contain a few surface stones up to 60 cm diameter
Tree or brush cover	May have occasional trees or some brush	May require some tree and brush removal for successful farming	May require light clearing of trees or brush	May require moderate clearing of trees or brush
Drainage*				
Flooding	May be subject to infrequent flooding	May be subject to fairly frequent flooding	No flooding	No flooding

Table 4B. U. S. Bureau of Reclamation-Sample land classification specifications, reconnaissance land classification. Southeast Asia (continued)

Classifying Characteristics*	For rice production (lowland type)		For upland crop production	
	Class 1R - Arable	Class 2R - Arable	Class 1 - Arable	Class 2 - Arable
Surface drainage to project outlet	Adequate	Fair to poor with correction possible at reasonable cost	Anticipated farm drainage requirements vary from none to moderate with reclamation by artificial means appearing feasible at reasonable cost	Anticipated farm drainage requirements by artificial means appearing expensive but feasible
Anticipated water table level with irrigation	High with control appearing feasible at reasonable cost	High with control appearing feasible at reasonable cost	>48 in. (122 cm) with control appearing feasible at reasonable cost	>36 in. (91cm) with control appearing feasible at reasonable cost

*Specific limitations will be further developed when additional data are available. Class 6, nonarable lands, will include any lands within the classified areas which do not meet the minimal specifications. Dual classes may be mapped where soil factors and water table control will permit production of paddy rice or upland crops.
**Appraisal is dependent on type of clay and cropping pattern.

Another consideration in quantitative evaluation of project specifications is that it is expensive. Traversing, even sample areas in a large project, takes time and money. This approach probably may only be adopted if the work is seriously in doubt. For these reasons, a qualitative approach is adopted in verification. Good progress reports, systematic compilation of records, and frequent correlation tours with staff of the client helps build confidence and reliability in the work.

Finally, the interpretations and recommendations of the project report require careful scrutiny. Problems sometimes occur when criteria originally developed elsewhere are blindly applied to a new project. As a result they might give a falsely unfavorable or favorable conclusion. If the United States Bureau of Reclamation criteria for salinity and sodicity had been applied in Sudan, vast areas of successfully irrigated land would have been rejected as unirrigable (Dudal, personal communication).

The client must also be wary of excessively favorable conclusions. The contractor of the soil survey may have special reasons for desiring a developmental project to take place. According to Dudal (personal communication), to prevent such errors and abuses, there is no substitute for the broadly experienced soil scientist to examine the survey report in depth, after some field checks.

CONCLUSION

The need for project specifications is obvious and as shown verification is not an easy procedure. Considerable savings can be made in time and money for both the contractor and the client, if the survey is continuously monitored by the client. The recommended soil correlation exercises, progress reports, etc., are very valuable towards this end.

ACKNOWLEDGEMENT

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I am uneasy about the cost figures of Table 1, which show a very much smaller increase in cost as map scale increases. As a very rough rule-of-thumb one might assume that costs increase 30-fold for each 10-fold increase in map scale.

ANSWERS:

The point is well-taken. The cost figures should be revised after more data has been collected.

Appendix I

Model of specifications for a soil survey project

A. Introduction

The Ministry of Rural Development of the government of Gondwanaland (hereafter termed the client) desires an Order 3 Soil Inventory with selected interpretations to support multiple resource management needs on approximately 300,000 acres in the Gondi district. The area to be investigated is outlined in the attached map.

B. Specifications

To provide the client an Order 3 Soil Inventory (as defined by USDA) at a scale of 1:25,000, with average-size delineations of about 10 acres for significant or unique contrasting areas. The soil mapping units will consist primarily of consociations or associations with some complexes based on phases of soil series. Some phases of families or miscellaneous areas may be mapped as soil characteristics or geomorphic conditions indicate. The contractor shall:

1. Be responsible for developing the soil mapping legend and soil mapping unit descriptions. These should, however, receive the approval of the Director of the Soil Research Institute (SRI).

2. Conduct, at a minimum, an initial, progress and final review for staff of the SRI.

3. Provide detailed soil data (typifying pedon descriptions and laboratory analysis) for soil correlation.

4. Provide a duplicate set of samples of all horizons of the typifying pedons to the SRI.

5. Provide 10 copies of a map showing location of traverses, location of typifying pedons and other pedons investigated.

6. Ink, match and measure the field sheets.

7. Provide 10 typed copies of the report with figures, maps, and photographs illustrating each of the major soils and the associated vegetation and landscape.

8. Note and bring to the attention of the Director, SRI, areas of cultural (historical or archeological) values, or unusual vegetational, geologic, or geomorphic features.

9. Develop soil interpretations for each soil taxonomic unit.

10. Collaborate with the SRI in the establishment of unnamed soil series.

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ANSWERS:

The point is well-taken. The cost figures should be revised after more data has been collected.

The above field inventory should meet the requirements set forth in the following publications: Soil Taxonomy, Soil Survey Manual. Any intended deviations from the above publications should be approved by the Director, SRI, in writing.

C. Reports

The contractor will submit a progress report (1 below) at least once a year and in addition after each of the field reviews stated in B, 2. It will be a technical report giving as much detail as possible.

A final report (2 below) shall be prepared in a professional manner and shall contain but not be limited to an extended summary, mainly designed for planning purposes.

1. Progress Report

a. Description, "General nature of the area," including climate, physiography, relief, and drainage.
b. Identification legend.
c. Map symbols.
d. Acreage and proportionate extent of the soils.
e. Soil mapping unit descriptions with the discussions of interpretations limited to range, engineering properties and chemical and physical limitations or potentials.
f. Description of typifying pedons from within the inventory area.
g. Soil interpretations for the following uses will be tabulated:
   (i)
   (ii)
   (iii)
h. General soil map and legend. (scale:specify).
i. Additional maps.
   (i) Name (scale:specify)
   (ii) " "
   (iii) " "
j. Key to the soils of the area.
k. Laboratory support data. (Must specify number of samples, types of analyses, etc.)
l. Glossary of terms.
m. Literature cited.

2. Final report.

a. General description of the area (mainly locational).
b. Nature of infrastructure, in terms of roads, paths, etc.
c. Soil description. Give brief descriptions highlighting limitations or potentials.
d. Maps. Provide maps for the following objectives (if stated) or evaluate area for alternative uses. (If objectives are stated, e.g. to grow rubber, classify soils into about 5 classes reflecting suitability of soils for the purpose. If these are competing uses, provide map for each use, and another map for discriminatory use.)

e. Indicate briefly alternative possibilities for use of the soil, giving guidelines for the planners to aid them to make decisions.

D. Time period

Deadlines for completion of each phase of project and time for submission of final report should be stipulated.

Appendix II

Information to Contractor

(to be attached to specifications)

A. Selection of Contractor

The award of the contract will be based on the proposal submitted which is most complete and most advantageous to the client. The client reserves the right to accept any or reject all proposals and retender the award if necessary. The contractor is requested to provide the following information and any other which might assist the client in their evaluation.

B. Points of evaluation of tender

1. Experience of firm

Provide details of firm, including examples of similar activities undertaken previously, with special reference to the following:

a) Soil mapping
b) Soil classification (specify)
c) Soil interpretations (specify aspects)

2. Experience of personnel

Provide biodata of all technical personnel who will be involved in the project. Include short-term consultants. Details of previous experience is very important.

3. Program

Provide a detailed work plan identifying the contribution of each of the personnel to each component of the statement of work. Details of logistics and the estimated man hours of work expended by personnel for each aspect of the project should be tabulated.

Provide estimates of costs involved in the project. Unrealistic estimates may render the tender invalid. If exceptionally high or low costs are anticipated in any aspect of the project, due perhaps to use of techniques other than those currently in use, give details and justifications.

Appendix III

Example of a contract for a small land use planning project

Objective:	Project to develop the land adjacent to town X.
Contracted by:	Office of the Mayor of town X. The secretary of the town council, Mr. Address: Tel. No.
Description of request:	Soil and land use survey to assess the present status of area (define) and to develop plans for the best economic use.
Base map:	Scale 1:10,000 (include other features or limitations of base map).
Area:	4,000 ha.
Maps to be made:	1. Soil map, scale 1:10,000. Hand colored. 2. Ground water regions map. Scale, 1:10,000. Hand colored. 3. Landscape map. Scale, 1:10,000. Hand colored.
Additional Maps:	4. Map showing observation points. Scale, 1:10,000. Black and white. 5. Present land use map. Scale, 1:10,000. Black and white. 6. Potential land use map. Scale, 1:10,000. Hand colored.
Soil Observations:	One auger observation per ha to a depth of 1.25 m. Due to anticipated variability of soils in the northeast part, more intense observations may be needed. At least five profile pits will be dug, described and samples taken for detailed characterization.
Groundwater:	An estimate of the maximum and minimum level of the water table will be made. The quality of the groundwater will also be evaluated.

Final report: Ten copies of the final report will be made (Stipulations on the contents of the report may be made here).

Cost of project: $5,000

Cost Analysis: To be elaborated.

Personnel (Technical)

	Name	Qualification	Man/days of work
1.	Senior Soil Surveyor		
2.	Asst. Soil Surveyor		
3.	Hydrologist		

Organization responsible for preparing final maps and report:

Name: Soil Survey Institute
Address

Director:

Dates: -	Beginning	End
Soil Survey:		
Map Preparation:		
Report:		

Final date for submission of reports:

Signed and dated:

Project coordinator	Director of Institute

SUMMARIES OF DISCUSSION SESSIONS

SESSION I

AN OVERVIEW OF PAST SRI ACTIVITIES

Chairman: H. Ikawa

Session I dealt with "An Overview of Past SRI Activities" and two presentations were made. One was by Dr. A. Van Wambeke on the "Summary of Cornell's 1977 SRI Workshop." Another was by Dr. R. W. Arnold on the "Introduction To Guidelines on Soil." Also during Session I, the workshop participants were given an opportunity to study posters showing methods of SRI evaluations.

The first workshop on SRI was held in April 1977, and that workshop analyzed seven major areas of concern: (1) orders of soil surveys, (2) evaluation of soil surveys and maps, (3) soil survey methodologies, (4) map characteristics evaluation, (5) soil properties important for given land uses, (6) soil data presentation, and (7) role of soil surveys.

The first workshop recommended more interactions between pedologists and planners by exchanging more relevant, more precise, and more quantitative information. The results of that workshop, including the proceedings of the workshop, also formed the basis of the present workshop in 1978.

Much has been gained from the past and present workshops and we would like to recommend that these kinds of workshops be continued in the future. The excellent work of the SRI group at Cornell University has concentrated mainly on concepts and methodologies. The next logical and necessary step is the field testing of these methodologies and we strongly recommend and urge that the SRI group pursue these in the near future.

SESSION II

SRI METHODOLOGY

Chairman: R. S. Murthy

Three papers were presented in this session. The first paper on "Planning Objectives" by Dr. Van Wambeke emphasized the fact that the adequacy of soil resource inventories for development planning could be appraised in a meaningful way only when the information given by the survey was matched against the requirements of specific planning objectives. While listing the areas of interest to planners, terms like _planning area_, _operational area_, _management area_, and _performance area_ referred to the units of land measurement such as hectares or square kilometers. While explaining the relationship between map scale and size of area of interest, reasons for reduction in scales of soil maps, adequacy of scales, etc., were clarified. The other points brought out in the paper included the information requirements with respect to diagnosis of land use, limiting factors, and map unit composition.

The second paper on "Evaluation of Soil Resource Inventories" by Dr. Hari Eswaran dealt with objective evaluation, i.e. the needs of the user. Attention was drawn to three aspects of evaluation, namely relevance, adequacy, and reliability to the stated objective relating to the technical part. Prior to making an evaluation, it was considered necessary to determine the objectives for which the SRI was made. Three major categories of objectives were considered in this process: master planning, project planning, and operational planning. The paper further presented details of various characteristics of SRI for evaluation pertaining to map unit composition, pattern analysis, legibility, legend and report analysis, soil analysis and interpretations, ground check, etc. The evaluation methodology was considered as effective guidelines for quality control in a national SRI program. The paper pointed to the essentiality of evaluation exercises particularly for developing countries which are in the process of setting up national survey organizations.

The third paper on "Soil Survey Report and Map Checklist" presented by Mr. T. R. Forbes helped to provide a concise summary of the report and map. The checklist was considered useful particularly to administrators who need a short summary. It could also be used as an instrument for soil resource inventory characterization. The various sections in the checklist related to the bibliographic and background material, the objectives of survey, categorization of soil survey according to map and legend characteristics, methodology of preparation of soil survey, results of field checking and finally, characterization or evaluation. Results of characterization of over two hundred soil resource inventories from around the world were also appended to the paper.

At the end of the session Dr. R. W. Arnold outlined the workshop procedures. In order to help the formulation of recommendations for future activities, he desired that the workshop groups may express their viewpoints. This would also help in expanding the cooperative efforts at the national, international, regional, and local levels.

Preparation of SRI methodology was the outcome of one of the recommendations made in the resources inventory workshop in 1977. It may be kept in mind that methodology forms only a part of soil resource inventory evaluation. It finds its application to situations where a special objective for utilizing the survey has been chosen and when the critical soil properties for a specific land use condition are available. The necessity of working out criteria for different objectives, keeping in view the limiting factors, hardly needs any emphasis.

SESSION III

USES AND ADEQUACY OF SRI INFORMATION

Chairman: J. Lizarraga
Report by R. Guerrero

Two papers were discussed in this session: 1) The Cost/Benefit Relationships of Soil Surveys by Dr. P. Beckett, and 2) Evaluating Rice

Lands of Mid-Country Sri Lanka by Drs. S. Somasiri and R. Tinsley. Following are the main conclusions of the discussion groups:

1) SRI agencies have as their responsibility the compilation of the information required for future planning and, as such, are in a position to call attention to the failures which occurred in the past, when planning was not based on soil resource information. To this purpose, it would be advisable to prepare soil survey reports with different sections of basic information for planners and the general public. At the same time, after finishing the soil inventory report the soil scientist should be actively involved in the planning and execution process. Also, the report should clearly express the objectives, include interpretative guidelines, indicate the variability in the reliability of the information presented and state to what extent the information is or is not available for specific purposes.

2) The benefits obtained from soil surveys and soil maps should not only be quantified in terms of direct monetary profits, since the information is also used by other institutions and/or other professionals. The recommendations might minimize the risk of losses and the conclusions could be valuable for technology transfer in different fields.

3) SRI for planning purposes should be carried out as an inter- or multi-disciplinary approach, as integrated teams. For agricultural purposes, the experience and cooperation of planners, extension agents, economists, farmers, and other professionals should be used.

4) The importance of establishing the cost/benefit ratios by using very simplified response curves was recognized.

Recommendation

It is believed necessary to systematically continue the present studies coordinated by Cornell University on the uses and adequacy of SRI information. In fact, soil survey methodology needs improvement to diminish the present gaps between soil scientists, planners, and the users of the soil survey. Therefore, it is recommended to strengthen the support for the Cornell Group working now on SRI.

SESSION IV

NATURE OF SRI INFORMATION NEEDED BY PLANNERS

Chairman: J. Schelling

Planners

We can distinguish many different kinds of planners with different needs. Some can have considerable knowledge of soils (soil scientists, agronomists, hydrologists). Others may want only interpretive data, geared to their uses (politicians, government administrators involved in regional or national planning, farmers).

Proposal. Set up a classification of planners, based on their needs.

Planning

Many disciplines are involved in planning. Integration of these disciplines is essential. Interdisciplinary communication is necessary at different stages of the introductory SRI productions, and during the planning process.

Proposal. Find explicit indications in the inventory effort concerning essential links with other disciplines, and give their two-way exchange a place in the planning process.

Planning can be subdivided into stages. For each stage a special kind of information is needed.

The use of our information will be more effective if the information is given in such a form that the planner does not need to extract it from a larger SRI set of information.

Proposal. Furnish the answer to each question of the user for the separate stages of a project as a separate product. This can lead to separate paragraphs in the report, and preferably separate interpretive maps. (Autoreduction could facilitate their process, but also cartography can be used for this purpose.)

Soil qualities are used in many SRI projects (FAO, ORSTOM, Netherlands Soil Survey, etc). They form an essential link in the interpretation process.

Proposal. Introduce the concepts of soil qualities into the guidelines, and update the relevant parts by their addition.

General Remarks

The guidelines have so far been developed in separate parts. The connection between these parts can at this stage be given more clearly.

Proposal. Integrate the separate parts of the guidelines into an integrated, logical, and consistent product.

SESSION V

PRESENTATION OF SRI INFORMATION TO PLANNERS

Chairman: S. Somasiri

The fifth session of the workshop was on the presentation of SRI information to planners. Five papers were presented and each paper dealt in detail with the individual subjects on which the authors made the presentation. The paper on psychological considerations in SRI information transfer stressed the need to reach the planners and decision makers at their own level of understanding and assimilation.

The second paper brought out the need for getting the planners and decision makers involved in defining the objectives of SRI. Then the planners and decision makers will be aware of the product coming from the SRI and they would be a part to it.

The third paper brought out the need to present the SRI information when it is needed by the planners. This is especially true when dealing with the information user at higher levels of planning. The second point brought out is that the scientists will have to devote some time to preaching what they believe the SRI does.

The third paper stressed the need for clear and factual presentation to the planners, but in a form that is easily understood, such as placing the soils in few ranks according to potential productivity. It is also important to indicate to the user how the soils in each rank respond to management in a positive manner. The last paper stressed the need for team approach in the decision making, the need to work as a team, with open channels of communication with the team members during the preparation of the SRI information. This would facilitate the soil scientist getting an impression of the real needs of the planners and preparing the needed information.

The specific comments that each author made on the presentation of SRI information to planners are summarized:

1. The SRI information should be presented in a form that is easily understood by the planner and decision maker concerned and it should be clear and well defined.

2. More often, what the planners would need is interpretation of the SRI to suit individual purposes. Therefore the soil scientist working on SRI must consider that it is part of his job to make as many interpretations as possible to meet the requirements.

3. In interpreting SRI, soil ratings designed to meet the needs of a local area seem better than ratings to fit into a national rating system. An effective rating system should include (i) the corrective measures required to overcome limitations, (ii) the level of performance after corrective measures are applied, and (iii) any continuing limitations.

4. Multidisciplinary approach in the site-specific planning investigations where the SRI scientists interact with the members of other disciplines, as it is done in USBR, is a good concept to work with.

In conclusion what I would like to stress is that we have some valuable information, a raw material. We have devoted much time and effort to mine it. We can derive much satisfaction if it is utilized for the betterment of mankind. So what do we do? Can we sell the raw material to the user? It is an emphatic no. We have to process it, that is, interpret it into as many finished products as possible and market it. In this process the soil scientist will be required to be a teacher, preacher, and a good salesman.

SESSION VI

QUALITY CONTROL

Chairman: J. Tinsley
Report by H. Eswaran

Quality relates to the excellence of the product and control of the mechanisms of monitoring the quality during the manufacture of the product. As beauty lies in the eyes of the beholder, the quality assessment is generally made by the user.

The first paper by Dr. Schelling dealt mainly with the stages in the inventory process and the places where attention must be paid to control the quality. The most critical stage is the initial one, which is the survey itself. Later comes the compilation of the data and finally the presentation of the product.

The second paper by Dr. Arnold focussed on the survey procedure itself. The basic theme was methods to enable the man in the field to improve the quality of his work. Dr. Arnold presented simple graphical means whereby the surveyor can check the quality of his work.

Many organizations have quality control built into the system. This, however, is not to the same extent in LDC's and the SRI group of Cornell has dwelled on this question. The Handbook produced by this group is indirectly addressed to this question also. The two speakers indicated that there was much more work to be done on this subject and that this could be one of the areas into which the SRI group at Cornell could venture.

Two additional and illuminating papers were also presented in this session. Dr. Flach discussed the response of soil survey organizations to government legislations. This was mainly based on SCS experience. Such organizations frequently have to play a two-way role. They not only have to assist in designing legislation but also respond to the legislation. Not all legislations are popular as considerations other than those of the activities of the soil survey organizations frequently determine the need of the legislations. The means by which the survey organizations respond are varied. In some cases, when the legislation calls for immediate action, survey activities have to be contracted out to meet the deadlines. [Editor's note: the final paper was unavailable for publishing with this proceedings.]

Solutions to the demands of the public and politicians on the one hand and the limited resources of the national SRI organization on the other, were presented in a case study of ONERN in Peru by Dr. Lizarraga. He gave an excellent and much appreciated account of the activities of this organization which can be considered as a model for many countries. Although he was very apologetic for being so enthusiastic of ONERN, I think that there was little doubt in the minds of the participants on the excellence of the work being done at ONERN.

In conclusion, the four papers presented different aspects of the subject of SRI and development planning. This illuminating session has presented many questions for thought and action.

SESSION VII

IMPROVING THE DIALOGUE BETWEEN PLANNERS AND TECHNICIANS

Chairman: L. Resler

There were four papers presented: "Value of SRI in National Research Planning" by Dr. M. Laker, "Value of SRI in Regional Research Planning" by Dr. R. S. Murthy, "Technology Transfer Programs of Land Use and Natural Resource Inventories and Information Systems" by Prof. A. Lieberman, and "Commissioning of Soil Surveys" by Dr. H. Eswaran.

The active discussion session following the presentations was an indication of how successful the speakers were. They were instrumental in fostering technical and philosophical exchange.

The National Research Planning papers summarized the need for soils information, but raised the question: Do we have pertinent parameters for appraisal in all cases? We should be concerned with efforts involved with obtaining the data. Soil scientists must know the positive and negative aspects of soil surveys and parameters appraisal and continually question and improve what is being done.

Dr. M. C. Laker's presentation in summary stated: A well-designed soil classification system in the lower categories, high quality soil resource inventories, and optional exploitation of these during the planning of soil-related research are essential prerequisites for the establishment of an efficient (i.e. reliable and wide in geographical scope) basis for the extrapolation of research data.

Dr. R. S. Murthy's presentation gave an account of the recognition and priority accorded for resource surveys, inventory, and land use planning in India. It also described the steps by which the data was gathered at the national, regional, and local levels. In order that the inventories, soil survey reports, and maps are properly and effectively utilized and cost of such surveys are justified, the report recommends evolving suitable machinery by which such valuable material is taken the fullest advantage of in the execution of various developmental projects.

It also recommends a dialogue between planners and resource survey and inventory personnel at different stages starting from planning up to the stage of completion and recommends suitable refresher training courses of short duration to various users to make them understand one's resources survey reports, maps, and interpretation.

Professor Lieberman's paper on technology transfer programs and land use and natural resource inventories and information systems was presented to encourage the creation of international training programs in this area.

It is believed such programs would enable individual countries to better inventory their resources, and to create and/or enhance information systems on land use and natural resources. To realize such training programs, the eventual creation of a few joint regional international centers is envisioned.

Disciplinary areas from which training program inputs would come, specific course elements, and research needs were identified. The need to relate such programs to the specific needs of individual countries and regions thereof was emphasized, and the determination of suitable educational approaches was given focus.

Planners, decision makers, and resource managers will be the primary recipients, with the ultimate users receiving attention through communications and extension education roles of the training programs.

In conclusion there seems to be no question that improving the dialogue between planners and technicians is required, if technical soils science is to increase its impact upon the planning process. The differences of opinion arise over how this is to be done.

SESSION VIII

STRATEGIES OF SRI OPERATION

Chairman: D. Slusher

Group A

1. How does the discipline of soil science or the soil scientist become involved with other people who are equally or more important in the planning process?

a) It is generally difficult to become involved, but one has to be aggressive. Soil scientists are inclined to sit in their own ivory towers and wait to be invited to help. This is the wrong attitude. One should go out and request help. It is better to say I like your help than to say I have something you need. This 'breaking of the ice' is necessary and with time leads to a two-way exchange.

It is not possible to legislate these things. However, if the organizational structure is present in the country, such cooperation may be coerced.

b) Just as the agronomist studies the soils and crops and develops a model combining the two, it is necessary to study the planner - classify him if necessary - and develop a model for cooperation.

c) Soil scientists must initiate multi- or inter-disciplinary approaches. However, success depends on the team leader, who must be highly motivated.

2. What are the stages in the planning process where the soil scientist can get involved?

a) Prior to answering this, it is necessary to emphasize that a commonality of language is necessary. Secondly, the soil scientist must be clearly aware of the goals and realize that he is just one cog in the wheel of success. It is his duty to see as much information as possible is made available to the planner.

b) It is necessary to evaluate the government structure, e.g.

NATIONAL PLANNING COMMISSION → SRI AGENCY

SRI AGENCY → PLANNING COMMITTEES

The soil scientist must participate actively in the planning committees.

c) Image. All soil scientists are considered as agriculturists and so are considered incapable of contributing to other disciplines. This is a big hurdle we have to overcome.

Training. Universities have to emphasize more the interdisciplinary approach.

Research. Soil scientists seldom publish in planning journals or cooperate in planning research. This must be rectified.

Involvement. Soil scientists must get involved in controversial issues. Through planning publications, publicize the successes and failures of projects. Get public involvement through news media to stress use of soils information.

Communication. Improve our communication skills. Adopt Madison Avenue approach.

Specifications. Participate in writing specifications of projects. Write reports for projects and not in the traditional manner.

3. What are the consequences of being involved?

People will start to question things that the soil scientists have taken for granted all their lives. This is generally uncomfortable but useful.

Recommendation. We recommend that there is a real need for organizing a multidisciplinary training program to train scientists in the planning process. We propose that Cornell University takes up the leadership in this and attempt to involve as many planners as possible. Cooperation with a planning institute is desirable.

Group B

The points that emerged from the discussions are:

1. User agencies need to be trained to use the Soil Resource Inventory data.

2. Resources survey/soil survey organizations need to set up suitable advertising, publicity, and training units.

3. In developing countries, farmers need to be provided with incentives to become convinced of the value of soil resource inventories.

4. Developing countries have problems of defining and selling the resource inventory data. There is need for specific projects.

5. Interaction between survey organizations and user agencies is essential to ensure the use of Resource Inventory Data.

Group C

1. Correlation of soil survey information is important. In every country translation of all soil classification information into one taxonomic system is essential.

2. Planners ask for the identification of homogeneous agricultural areas. They do not want the pure soils information; they want it interpreted.

3. It is important to consider who should act as the intermediary, who must do this interpretation: the soil scientist himself may have to do this job of translating basic data into an understandable language. The soil scientist needs some training in planning.

4. We have got good enough survey techniques. The biggest deficiency is the way in which reports are written.

5. The economist is the first one who demands information.

6. One west African country pushed crops research and extension to be done at a number of different localities. However, they are not taking soil characteristics into account in the development of these production "packages."

7. Netherlands experience: A group of horticulturalists, general agriculturalists, planning experts, etc. do research especially for interpretation. It is found that you must know some terminology from other fields also to communicate effectively. There is a long process of learning and improving through experience and interaction. They find that survey maps are too complicated. One must extract from them and give to the planner just what he needs at any specific point in time. You cannot make it simple enough.

8. Many users of soils information are too specialized to know what questions to ask from the soil scientist. Through short courses they must be taught some "soil language."

9. Training of soil science students at universities must be reassessed. They must not specialize too soon and must also get a good background in fields such as agronomy.

10. At what level should people be first exposed to soil science to create an awareness of the importance of soils? A good, simple and attractive introduction at high school level (perhaps as part of the general science course) seems to be a good starting place. The Soil Conservation Society of America is making good use of comic books for school children.

SESSION X

RECOMMENDATIONS

1) Thanks were given by A. Van Wambeke to participants for reviewing handbook.

2) Requests were made for more comments on handbook. (A. Van Wambeke).

3) Motion: similar workshops should be set up in developing countries. (second: H. Ikawa).

4) Motion: (A. Van Wambeke) Some agency in LDC's should be charged with organizing and setting up library of soil survey reports for general use (second: M. Laker) in a particular planning agency in each country.

5) Motion: (A. Van Wambeke) Mr. Sombroek from Inter. Soil Museum may have some interest in this and be commissioned to set this up (second: I. Sneddon). Agency should store bibliographic information only.

6) Motion: (M. Cline) Support on publication of bibliography of soils of the tropics has been cut off and should be reinstated (send to AID).

7) General motion: Participants upon reflection should send additional comments to SRI Group.

APPENDIX I

R. L. Tinsley - Special Considerations in Evaluating Soil Resource Information for Paddy Lands

SPECIAL CONSIDERATIONS IN EVALUATING SRI INFORMATION FOR PADDY LANDS

R. L. Tinsley[1]

During the course of the workshop it became apparent that normal SRI evaluations were not always appropriate when evaluating lands currently used for or to be developed for paddy rice or other flooded crops. Since several participants were associated with SRI programs where paddy was an important component of their efforts, a special voluntary discussion session was convened to allow those interested a chance to review how SRI information could be applied to paddy lands or what modifications were needed to evaluate paddy lands, what criteria were less important, and what criteria had to be reinterpreted.

This summary has been prepared from this extra session. Since it was an extra session for which the participants did not have an opportunity for careful preparation, or a ready supply of reference material, the ideas expressed should be evaluated as a stimulating beginning high-lighting problems and concerns, and not a final end product. The discussion was focused not on delineating the criteria needed to evaluate paddy lands but on contrasting the evaluation of paddy lands to the more common SRI evaluations which emphasize upland problems.

For the sake of orderly discussion seven questions were drafted as follows:

1. What land qualities need to be emphasized or de-emphasized in working with paddy lands?

2. What physical properties of the soil need to be emphasized or de-emphasized in working with paddy lands?

3. How should the different hydrological conditions, both natural and supplemental, be accounted for?

4. What chemical properties of the soil need to be emphasized or de-emphasized?

5. What operation problems must be considered in surveying rice lands?

6. What changes in diagnostic criteria would make Soil Taxonomy better suited for dealing with paddy?

7. What special methodologies are needed for presenting SRI information on paddy lands to planners and decision makers?

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[1] GSL/IRRI/USAID, Colombo, Sri Lanka

The above questions were distributed and recollected with the participants' comments. This summary was prepared from written remarks returned with the discussion questions and recollection of the oral comments made during the discussion. This review will treat each question in order.

LAND QUALITIES

Slope

Paddy lands tend to be more sensitive to slope demarkations, largely because of the terracing and leveling of each individual paddy. The slope controls the volume of soil material that needs to be moved and thus the size of individual paddies. The size of plots can influence the possibilities for mechanization, an extreme example being the very steep terraced mountain sides which must be worked exclusively by hand. Most good paddy lands have an overall slope of 1% or less. Paddies rarely are found on slopes exceeding about 8%. The mountain terrace systems represent a dramatic exception that really cover only a very small percentage of the world's total paddy lands.

Break in Slope and Contour

In terraced areas the concave vs convex slopes distinguish different degrees of moisture enrichment or depletion. Frequently the concave slopes will have artesian upwellings which cause an adverse elemental imbalance and de-compaction problems. Changes from convex to concave contour will also affect moisture enrichment or depletion, but not severely enough to induce nutrient disorders. The convex contours tend to have less available natural or local irrigation water making them more suited to upland rice cropping patterns instead of double rice.

Erosion

Generally erosion does not become an important consideration even in more sloping lands. The individual paddies act as sediment traps to retain the soil until it has settled out. Also, when there is ponded water, this will insulate the soil from direct impact or raindrops. However, there could easily be selective erosion of the fine particles. The fines come into suspension during dispersion and move to progressively lower paddies during intentional drainage. The lack of erosion in paddy areas may be illustrated by the frequent lack of levees on small streams, the catchments of which are entirely composed of paddy lands. An exception to the general diminished emphasis on erosion is the terraced mountains, when a breeched paddy can trigger chainbreeching all down the mountain side in a single massive erosion incident.

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[2] In this summary "ponded" water refers to water held within the bunds of the paddy and thus at least partially controlled. Flooding refers to water that exceeds the level of the bunds and thus cannot be controlled.

Drainage

The normal evaluation that poor drainage is detrimental to crops needs to be revised. Poor drainage is normally advantageous for paddies provided there remains a net downward movement of water. Upward water movement as occurs with artesian conditions can be detrimental to paddies. It is also better to have some control in the surface water movement, particularly during the early stages of growth.

PHYSICAL PROPERTIES

Hydromorphic Qualities

The general physical hydromorphic qualities of the soil become advantageous for paddy lands, when they would be detrimental to other land uses. Generally the higher degree of hydromorphism, the better suited for paddy.

Texture and Permeability

Generally texture needs to be emphasized with the more clayey and less permeable soils being more beneficial than the sandy coarse-textured soils, unless the latter are located with a high watertable.

Water Table

The depth of the water table becomes more important in paddy lands. The suction gradient between the true water table and the ponded surface water will affect the deep percolation of water and thus the rate of water loss through the soil profile. A water table close to the land surface is preferable to a deep water table a meter or more beneath the surface. However, artesian upwelling can be detrimental.

Compactability

Because the saturated surface condition cannot support movement, the soil immediately below must be sufficiently compacted to support all traffic on the paddy. This compaction could be the natural consolidation of the soil or the formation of an artificial traffic pan. The traffic pan would be a narrow horizon in which the soil was more compacted than the naturally compacted soil below it. This extra compaction may also contribute to reducing infiltration and deep percolation. Evaluating the problem may require a complete review of current parameters with possible development of additional parameters. Areas with upwelling water may require additional study in both classification and corrective methods. The upward water flow may tend to encourage a progressive decompaction of soil through the entire profile, even after the lower horizons have been completely consolidated during an abnormally dry period.

Aggregate Dispersion

Instead of evaluating aggregate stability, a measure of aggregate dispersion may be preferred. The wet cultivation attempts to disperse as much of the aggregates as possible in order to seal the soil and reduce deep percolation. Thus soils that disperse easily would have an advantage in paddy use. For intensive land use involving both paddy and upland crops an additional measure of re-aggregation may be desired. Techniques required for accurately and appropriately evaluating dispersion/re-aggregation problems of paddy lands may need to be developed.

Conversion Potential

When upland crops are grown in sequence with rice, the conversion from paddy use to upland use might require not only re-aggregation, but also considerable soil manipulation. This would involve rapidly forming the beds and drainage canals now needed to protect against excessive water. Even though the average climate may become dryer during the non-paddy period the land usually must be protected from even a single sudden high-intensity precipitation incident. Some measure may be needed to evaluate ease of soil manipulation.

Soil Depth

Under fully irrigated level land conditions the depth of the soil below the plow layer is considerably less important than in non-paddy use. Not only does the traffic pan provide a physical barrier for root penetration but also the ponded water provides adequate moisture, and increases availability of nutrients, so roots rarely need to penetrate below the top layer. Under rainfed paddy conditions soil depth can again become important but still less so than under upland conditions. However, when sloping land is going to be graded for paddy use requiring substantial amounts of soil movement, the soil depth becomes extremely important in the initial field layout and individual paddy construction.

HYDROLOGICAL CONDITIONS

Natural

Perhaps the most distinctive feature of paddy lands is the intentional retaining of water on the soil surface. This leads to a complete additional vector of land evaluation features that can be critical to paddy, but rightfully discarded in upland, evaluations. Unfortunately the hydrologic vector is "fluid" and can result in rapid changes in land qualities in both time and space. Without irrigation to stabilize the deficient side, the hydrologic values will vary grossly between wet and dry seasons of the year, then vary broadly with variation in rainfall between years (CV for wet months rainfall commonly approaches 50%) and finally vary narrowly with variation in incident rainfall between surges and lulls in storm frequencies. Once on the ground the water continues to flow over and through the landscape providing localized areas varying in moisture enrichment and depletion. The degree of these changes frequently is a function of the previously discussed variables in water supply, as well as intentionally manipulated intrapaddy overflow. Substantial changes in land qualities often occur within only a few cms difference in elevation. This provides a tremendous degree of highly mobile variation in land qualities that requires an evaluation of the overall dynamics of soil, land, and water interaction that may be difficult with more normal SRI methodology.

Within this dynamic framework several hydrological conditions can be identified that will account for a substantial amount of water movement across the land surface (overflow) and through the soil profile (interflow). These are:

Depleted. Areas with a net loss of water to surrounding area. Frequently these will be minor rises in the general landscape that can marginally be used for paddy and are often used as isolated upland cropping areas, surrounded by paddy.

Neutral. Areas of nearly level slope (1% or less) for which overflow either into or out of the paddies is slow and generally balanced. A subsurface water table occurs well below the ponded paddy water with an unsaturated horizon in between. This puts the ponded water under substantial moisture tension, increasing the rate of deep percolation.

Overflow enriched. Areas with a little more slope (from 1 to 8%) that allows rapid overflow enrichment from upper paddies to lower ones. The lowest paddies may also receive some interflow.

Groundwater enriched. Areas that generally have a shallow water table directly connected to the ponded surface water. This reduces deep percolation. Generally these areas are flat, similar to the neutral areas, so there is little potential for overflow enrichment.

Seepage enriched. These are generally small areas in which seepage water comes in from the sides, but not from the bottom. This is usually advantageous to the rice and prolongs the growing season. Frequently these areas will be minor depressions such as old streambeds. They occasionally become flooded over the bunds and thus may require tall varieties during mid-rainy season.

Upwelling enriched. Areas, generally quite local in extent with an artesian water flow coming up through the bottom of the soil. These areas are generally found on the bottom of steep valleys without incised streams, or in terraced areas where the slope changes from convex to concave.

Moderately flooded. Areas in which uncontrolled flooding regularly occurs to a sufficient height to restrict the use of short-statured rice varieties. The flood height would normally peak at between 40-100 cm and require tall erect varieties with some elongation potential but not the floating varieties.

Deeply flooded. Areas in which uncontrolled flooding regularly occurs to a sufficient height to require floating prostrate varieties. Water height would exceed 1 meter and could reach 5 meters.

Irrigation

To an increasing extent paddy lands receive some form of supplemental irrigation water. This can vary from very local seepage collection/re-distribution schemes, to non-storage stream diversions, to major projects involving large-scale storage and covering 500,000 to 1,000,000 ha. The vast majority of the paddy irrigation schemes are gravity-operated flooding systems. Rarely are pumps utilized except on small individual farm systems. The need for extra water to satisfy soil percolation demands make large pumping schemes economically questionable. The availability of irrigation constitutes major changes in land quality for paddies. This really needs to be an integral part of SRI studies, perhaps to a greater degree than when irrigating non-paddy areas. Because most paddy irrigation schemes are relatively new the effect of the extra irrigation water on diagnostic soil criteria may not have materialized. Fortunately much of the gross influence on land values can readily be interpreted from the design and operation of the specific irrigation scheme and basic land qualities. Again because of the desire for retaining surface water there are a couple special considerations that may need emphasis. They are:

Distance from source. In most large schemes there is an appreciable decrease both in volume and dependability of water as distance from the source increases. This is the result of hoarding in the upper portions of the scheme to the detriment of lower portions. Pond water allows each individual paddy to become a mini-reservoir, reinforcing this hoarding tendency and making it a more serious problem in paddy irrigation schemes than in corresponding upland irrigation systems. In upland systems the excess water would rapidly be detrimental to crops. This hoarding problem appears largely a managerial one, but an extremely complex and sensitive one. Most major paddy irrigation schemes in Asia involve small farms for which it is virtually impossible to accurately administrate a volume control on water to each farm. Without a volume control farmers are not motivated to minimize use and tend to hoard as much as possible (without regard for colleagues down the scheme whom they rarely meet). Land quality surveyors really need to put a function of this in their evaluation, and engineers need to consider designs that will assist in more equitable distributions.

Landscape inversions. When irrigation canals are placed along the top of the scheme so that water flows across the contours, the natural moisture enrichment as a function of relative position on a slope with the bottom land the most enriched will be reversed. Proximity to the canal will become more important, making the highest lands the most enriched and advantageous for paddy.

Induced upwelling. When irrigation schemes are put on more permeable soils and considerable water has to be applied to retain a ponded surface, the reappearance of the surplus water in lower parts of the catchment can occur as localized adverse upwellings. This can affect as much as 1/3 of the lower catchment of some schemes, and may have to be accommodated in post-scheme inventories of area. These upwellings would be difficult to accurately predict in scheme development-oriented SRI.

CHEMICAL PROPERTIES

Chemically evaluating soils for paddy use generally would require accounting for problems of reduction and dilutions of soil solution. This changes the emphasis of some regular chemical properties and may require additional criteria specific for paddy. Some of these are:

Oxidation/Reduction

A fundamental difference in chemical activity between paddy and upland soils is the reduction chemistry that occurs in paddy soils. This controls the availability of many ions and compounds which are either essential to the rice or toxic to it, the most important of which are the ions of P, Fe, and Zn and the toxin H_2S. The amount of reduction in a soil is controlled by duration of inundation, the amount of readily available organic matter that serves as a substrate for the reducing microbes, and the amount of reducible material. The extent of reduction in most soils is generally buffered prior to formation of serious toxin by reducible inorganic compounds such as Fe_2O_3 and MnO_n. This could be partially analogous to the way CEC buffers acidity in upland soils. Thus for good paddy land evaluation it might be desirable to develop a characterization measure of the reduction potential of a soil.

Soil Reaction

Under reducing conditions soil pH tends to move from either extreme towards neutrality in most, but not all, soil. Thus paddy lands do not need accurate pH analysis in the mid-pH range for soil, i.e. from 4.5 to 8.0. Outside of this range well-defined adversities occur and more careful consideration of pH would be necessary. Normally corrective measures such as liming for acidity are not required for rice and need not be part of paddy evaluations. Special consideration must be given to acid-sulfate soils when they are developed for rice.

Salinity

Salinity becomes important largely because rice is one of the best remedial crops on saline lands. If the water is available, the ponding will dilute the salts to a tolerable level or physically depress the salt accumulation to lower soil horizons and if continued long enough provide for permanent corrective leaching that will force the salts out of the system, while at the same time productively utilizing the land. There are now several good salt-tolerant rice varieties available.

Organic Matter

The importance of organic matter may require some refocusing. The organic matter is required as a substrata for reducing microbes. However, this would generally be the fresh organic matter, the content of which rapidly changes with season and cannot be a criteria for characterization analysis. The second role is as a clod cement that reduces the tendency of the super-saturated puddled horizon to crack upon drying. This would most likely be attributed to the more stable forms of organic matter, that can be a part of characterization analysis.

Fertility

As mentioned previously the oxidation/reduction chemistry of paddy soils affects the availability of many nutrient elements. This forces a reevaluation of both the indexes used to characterize fertility status and the levels obtained with fertility indexes. In most cases P and K become more available under paddy conditions, so their index level can be revised downward. However, Zn will become less available so its index needs more critical attention, depending on pH and inundation duration. Fe can be either toxic or deficient depending on reaction and hydrology, and needs critical attention on both ends.

Organic Soils

Organic soils would initially appear to be ideal for paddy rice because of the basic wet environment and adverse effect on the soil when drained due to dissolution and oxidation. However, organic soils have always presented a multitude of difficulties when used for paddy. Much of this appears related to the availability of various micronutrients such as Cu, Fe, Mo, etc. Also undrained organic soils have very limited compaction that severely hinders their physical management.

SURVEYING

The actual field investigation of paddy lands provides several unique considerations not generally encountered in upland surveys. These considerations can either hinder or assist the investigations. These include:

Time of Survey

Because the ponding of water and subsequent reduction will cause a temporary change in soil color, it is essential for accurate evaluation that sampling be done on either completely oxidized or completely reduced conditions. However, the oxidized condition is greatly preferred because it avoids the temporary gleying and is thus a more stable value. Unfortunately it frequently is not possible to have the entire area oxidized at once except during the middle of the dry season when much of the area will be too dry for easy augering. More often than not the higher part of the surveyed area will be dry while the lower ponded. This would necessitate multiple sampling dates.

Importance of Color

Hydromorphism is generally accurately conveyed by soil color. Thus when evaluating paddy lands the surveyor needs to concentrate extensively on relatively fine distinctions in soil color, much of which may require refinement in present techniques. Frequently differences in land qualities can be determined by relative changes in gray colors from various portions of a paddy. However, the absolute values may not extrapolate to other areas where parent material differences have caused basic differences in color matrix. This needs some more extensive study.

Terracing

The physical construction of paddies, involving leveling of each indicated paddy, can cause an appreciable difference in soil depth between the front and back edge of the paddy. This can be a serious problem in more sloping areas and lead to major differences in crop performance within a paddy. Also it leads to a technicality as to how to sample the paddy.

Flood Depth

In areas in which the flood water routinely exceeds the paddy bunds, there is a need to estimate the level of flooding. This is not generally reflected in pedological characteristics but can generally be obtained from interviews with residents and farmers.

Paddy Mosaic

The pattern that individual paddies form on the ground, and changes in that pattern, are frequently a good indication of changes in land qualities. In more level areas the paddies tend to be large and square while in more sloping areas they tend to be narrow, irregular, fitting into the contour. The shift from one configuration to another can frequently be used in delineating changes in land elements. The paddy mosaic generally shows up clearly on aerial photographs, allowing for considerable accuracy in making delineations.

General Discomfort

The wet muddy condition of paddies makes for a certain general discomfort in work, frequently requiring barefooted operations, that subject the worker to various health hazards not associated with upland activity.

SOIL TAXONOMY

Accurately evaluating paddy lands will eventually lead to several improvements in the taxonomic criteria used to classify soils. This would mostly concentrate in more sensitive subdivisions of the hydromorphic or aquic qualities. Some of these would include:

Anthraquic Horizons

This is a horizon described by Frank Moormann, in which a surface gleying or pseudo-gley is found above an ungleyed horizon. This is due to inducing hydromorphic conditions in better drained soils making the surface more reduced than the area below. This generally is a direct result of bunding and puddling the soil to encourage ponding of water in areas that if unaltered by man would not retain free water.

Flooding Regime

There will probably be a need to define various flooding regimes as part of different aquic suborders. These would designate different rice variety group limitations and might include:

less than 30 cm - suitable for short varieties
30 to 100 cm - require tall or elongating erect varieties
greater than 100 cm - require floating varieties.

Fe/Mn Accumulations

After prolonged use for paddy some soils develop a Fe/Mn accumulation horizon just below the traffic pan. When it occurs this is a readily identifiable diagnostic horizon, and a reasonable indicator of the length of time the land has been used for paddy.

PRESENTATION

The discussion session had to be adjourned prior to really discussing the last question. However, it was recognized that frequently the variability in paddy lands exceeded the details that normally could be mapped. In such case an alternative means of presentation may have to be developed to account for regular grouping of various distinct paddy land elements in one mapping unit.

CLOSING

This concludes the discussion on paddy lands. Again this summary is not intended as an all-inclusive description of the problem associated with SRI work involving paddy lands, but only those ideas presented at the extra discussion session. It is hoped that this will provide a stimulus for further thought and study by any individual requiring to adopt SRI investigations to paddy lands.

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