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CONSIDERATIONS FOR A COOPERATIVE SOIL SURVEY IN VENEZUELA

A Professional Paper
presented to the College of Agriculture and Life Sciences
at Cornell University,
in partial fulfillment of the requirements for
the degree of
Master of Professional Studies (Agriculture)

by

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BIOGRAPHICAL SKETCH

The author was born in Barquisimeto, Venezuela, on October 6, 1943, the son of M. Abreu Mendez and Ailie Anselmi de Abreu. He attended primary school and high school in his hometown. He started college education in Agronomy at the Central University of Venezuela in Maracay in 1960 and received an "Engenheiro Agronomo" degree from the Rural University of Brazil in October of 1964.

In January of 1965 he was employed by the Division of Edaphology of Directorate of Hydraulic Resources of the Venezuelan Government. He worked as a field agronomist at the Majaquas Irrigation Project in the State of Portuguesa for three years and then was moved to Guanare, in the same state, where he was in charge of the Regional Office of the Divison of Edaphology for the Western Llanos for two years. In 1967 he was transferred to the headquarters of the Division of Edaphology in Caracas, where he was in charge of the Soil Physics Department.

In September of 1970 he started graduate studies at Cornell University where he has majored in Soil Science.

He is a member of the American Society of Agronomy, the Soil Science Society of America and the Sociedad Venezolana de la Ciencia del Suelo.

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INTRODUCTION

Soil survey is, on one hand, the total operation of an overall program and on the other hand a specific survey project for a given location. The activities of a specific survey result in a soil survey report and map.

Soil surveys have been conducted by several institutions in Venezuela for about 30 years for purposes related with agricultural activities. Experiences in other countries indicate that the scope of soil survey can be extended to serve other needs related to planning and development of rural, urban, and regional interests in addition to the needs of agriculture.

As a human endeavor, soil survey has developed through a series of stages which reflect the state of cultural activity and man's perception of his environment at different periods and places. Soil scientists and people related with land use planning require a philosophy that enables them to define the role of soil information in a world of rapidly increasing pupulation.

A prime element in the philosophy of soil survey is a clear definition of objectives. These should be analyzed in terms of their nature, meaningfulness, and adaptation to specific conditions. The ultimate objective of soil surveys is to make predictions of soil behavior in meaningful terms to help people make wise decisions about the use of the soil resources. This, in turn, is related to our understanding of soil and the operations that are conducted in soil survey work.

Soil Survey in Venezuela

Soil surveys in Venezuela are conducted by several organizations. These include the Ministry of Agriculture and Livestock (NAC), the Ministry of Public Works (MOP), the Commission for the Water Plan (COPLANARH), the Agrarian Institute (IAN), and several Regional Corporations. Private agencies also conduct soil surveys by contract with the central government and regional corporations.

Soil survey activities in the Ministry of Agriculture started in 1937 under the responsibility of the Experiment Station of Agriculture and Animal Science. In the first years only a few soil surveys were made, at rather general levels. Important progress was achieved after 1942, when a Soil Conservation Mission from the United States visited the country and a number of soils were described. In 1945 the responsibility for soil survey at a national level was given to the Soils Department which was created for this purpose. Soil surveys of several areas in the country were made for general agricultural purposes. In 1970 the Soils Department expanded its activities to coordinate the National Soils Program, which includes studies in soil fertility, soil physics, soil chemistry, soil biology, soil mineralogy, and soil management. Soil survey is currently limited to a few selected areas.

At the Ministry of Public Works, the official interest in developing irrigated agriculture brought about the creation in 1942 of a small soil survey team within the Directorate of Hydraulic Works by recommendation of Dr. Wilbur Powers from Oregon State University. The increasing demand for soil information to aid in the process of planning and development of irrigated agriculture lead to the organization of the Division of Edaphology in 1965. At the present time, this Division is part of the Directorate of Basic Information of the General Directorate of Hydraulic Resources, and conducts soil survey work in a substantial part of the country for land reclamation. Attempts to project the applicability of soil survey beyond specific agricultural interest started a few years ago with a soil survey project for the area of the Tuy River Valley (Dumith, 1967) in which a satellite city to absorb the growth of Caracas was being planned. Soil survey reports with information for non-agricultural uses of soil are being demanded by government agencies involved in regional planning.

In 1968 the Commission for the Water Plan undertook the task of preparing a national land inventory which includes a soils map of the country at the scale 1:250,000. The work is being conducted by regions and is expected to be finished around 1985 for the area of the country north of the Orinoco River.

The Agrarian Institute is conducting soil survey projects to select areas for location, planning, and development of rural settlements within the Agrarian Reform Program enacted by law. Regional corporations such as CORPOANDES, FUDECO, and CVG, have also taken part in the evaluation of soil resources within their areas of influence.

Currently, extensive areas of the country are being surveyed by private companies under contract with the central government and regional corporation. It is estimated that soil survey work by contract is the largest effort in terms of area.

Detailed information of the progress of soil survey in Venezuela has been presented by Comerma (1968) and Dumith (1970).

Scope of this Paper

The intent of this paper is to present and analyze the conceptual framework that constitutes the current philosophy of soil survey in several parts of the world and apply this philosophy to Venezuela.

Concepts of soil are different for different disciplines and/or different cultural settings. Understanding of the character of soil is basic for its proper evaluation, use, and management. Some concepts of soil as ecological resources subject to planning, use, conservation, or misuse are discussed in the light of modern trends. Special emphasis, however, is given to other concepts of soil that are used in soil survey itself.

It has been found that the development of soil interpretations for use in the process of planning and development could not be successfully conducted without considering some changes in other soil survey operations in Venezuela. Soil classification, technical groupings, soil mapping, and soil correlation are discussed both in terms of their conceptual framework and their relationships with applied purposes.

In most cases, the discussion includes considerations related to the conditions and needs of Venezuela, both in the context of an overall soil survey program and of the different operations in specific soil survey projects. To build a philosophy, however, one has to avoid the dangers of provincialism as much as one has to avoid gross generalization. Wasteful resource use, soil exhaustion and depletion, and environmental pollution are recognized by modern thinkers as a world phenomena. Examination of national needs has to be made in terms of what recently has been called global thinking. In the last two years, for example, the world has experienced shortage of grains and meat. Despite the technological achievements, such as the so-called green revolution, international food demand is so great that many contend that the majority of new supplies must be generated within the hungry nations themselves. This means higher productivities on already arable areas and development of new lands for production. Nonagricultural soil use is also a global phenomena. For these reasons, experiences from other countries are necessary references. A discussion of their approaches to the acquisition and use of soil information is considered valuable for analysis of national needs without local prejudice.

A recurrent theme is that soil information is only one answer to the many questions in natural resource evaluation and land use planning for an expanding population. Soil survey reports are one of the most valuable tools to help decision-makers in their actions. Although soil surveys may contain information on climate, geomorphology, land use, and hydrology, it serves primarily as supplemental information for a given area. The main concern of soil surveys is to provide adequate soil information.

Venezuela has experienced, and will continue to experience, a great demand for soil information. There have been attempts to develop a conceptual framework for soil surveys, albeit limited by institutional constraints. It is evident that it is necessary to develop a model common to all agencies. The basis for that model can be found in the body of concepts and beliefs shared by the scientific community of international soil science. In addition to many citations for soil scientists of other countries, it should be noted that a number of concepts come from Marlin G. Cline, Richard W. Arnold, and Gerald W. Olson. The author's own work has been to try to apply their philosophy on soil surveys and soil survey interpretation to the conditions of Venezuela. He hopes that he has properly understood and correctly interpreted their views.

SOIL - A VITAL RESOURCE

Soil is a resource vital to the economic well being of any country and much of the history of civilizations reflects the significance or lack of it attached to the understanding and utilization of soil. In the modern world the activities related to obtaining and presenting field knowledge of soils is called soil survey.

In order to focus attention on the value of developing adequate objectives for a soil survey several aspects of soil will be discussed. These include man's dependence on soil, soil as a resource, soil as a part of the ecosystem, and some ideas about use, misuse, and conservation of soil.

Man's Dependence on Soil

Soil is an important resource primarily because mankind depends on it for subsistence and support (Olson, 1964a). The interest of people in soils started to change from food-gathering to food-growing about 9000 years ago (Simonson, 1968), consequently, the importance for soils for agriculture is ancient. The twentieth century has witnessed growth of population, advances in science and technology, and changes in agriculture that have caused important shifts in the usefulness of soil resources.

The relationships of soil to agriculture are, contrary to some opinions, increasingly important. Despite all advances of science and technology, the production of food is essentially sustained by soils. Waddington (1972) considers that though recent advances have made it "technically conceivable" that all our food could be synthesized without plants or animals, there has been no major effort made as yet. He also states that man will continue to use agriculturally derived food for at least the next hundred years. Mattson (1972) indicates that the production of exotic foods derived from sources other than agriculture is not likely to play an important role in alleviating mass starvation in the near future, even considering the alternative of increasing protein availability from fish culture. The obtaining of other goods like timber, fibers, and clays, even though they may have been supplemented by the technology of plastics in the advanced industrial countries, is still dependent on soils in most parts of the globe. Shelter for living and routes for transportation are placed on soil. The disposal of refuse of all kinds, such as septic tanks for human effluent and sanitary landfills for garbage, relies on soils; places for human relaxation like recreation sites, sport fields, playgrounds, depend in part on soil conditions; transmission lines, underground installations, and surface pipelines by which communications and electricity, oil, gas, and water conduction are possible, are but a few in an almost endless list of human needs that are contingent on soil to varying degrees.

This dependence of man on soils is heightened by the increase of population and the expansion of activities of civilization. Never before has the need to understand the qualities, variation, and extent of soils been more pressing.

Soils as a Natural Resource

Natural resources have been regarded by many people as biological or mineral systems or elements which are provided by nature with little possibility of control by man. Some take this erroneous concept to the extreme and confuse natural resource conservation with pure preservation. Others rely more on artificial resources and relegate nature's importance to the passive role of a physical, completely modifiable environment. Neither of these concepts is correct, and unfortunately, both approaches have been applied to soils. In the first case soil conservation concepts have been confined to general statements aiming to keep soil from use, a goal that just does not make any sense in today's world. In the other case, much more extended, only after an irreversible damage had occurred can people realize their error.

The concept of resource is eminently anthropic. Modern authors consider that the concept presupposes that a planning agent appraises the usefulness of his environment for the purpose of obtaining a certain end (Wantrup, 1968). Held and Clawson (1965) give the following definition: "A natural resource is any quality or characteristic of nature which man knows how to use economically to ends which he desires."

Man can make many changes in his environment, but the interactions are complex. Profound changes in natural systems have been caused by even primitive man with limited tools, as exemplified by the uninhabitable landscapes resulting from overgrazing in the Middle East and over-cultivation in the Thar desert of India (Bell and Tyrwhitt, 1972).

Soils in the Ecosystem

Ecosystem is a term to indicate the relationships among living things in nature. Odum (1972) considers an ecosystem to be "a unit of biological organization made up of all of the organisms in a given area (that is, 'community') interacting with the physical environment so that a flow of energy leads to characteristic trophic structure and material cycles within the system." The same author considers the development of ecosystems as ecological succession, which can be characterized in terms of the following parameters:

> "(1) It is an orderly process of community development that is reasonably directional, and therefore, predictable. (2) It results from modification of the physical environment by the community, that is, succession is community-controlled even though the physical environment determines the pattern, the rate

> of change and often sets limits as to how far development can go. (3) It culminates in a stabilized ecosystem in which maximum biomass (or high information content) and symbiotic function between organisms are maintained per unit of avilable energy flow."

He further adds that the "strategy" of succession is maximum protection, which often conflicts with man's goal of maximum production, and that recognition of the ecological basis for this conflict is "a first step in establishing land use policies."

Soils are part of the physical environment of the ecosystem. Past and present environmental conditions control processes and rates of processes that lead to soil formation and development. Understanding of soil genesis permits the prediction of further evolution. The direction of changes in soil properties is affected by human activity, particularly at this point in history when changes in technology, growth of population and its geographic expansion, and the liberalism in soil exploitation caused by food demand for international marketing are so intense. Soils are, therefore, ecological resources (Olson, 1971a, 1971b).

Use and Conservation

Natural resources are commonly classified as renewable and non renewable. Soils have often been considered renewable resources, and many societies have taken this for granted. Because of soils relationships with human activity, it is evident now that soil is only partially renewable.

For purposes of use and management several classifications of resources have been proposed. One scheme divides total resources into flow resources and fund resources. Flow resources have a stream of uses possible without loss of the resource, and may be nonstorable, like sunlight, or storable like water from natural precipitation. Fund resources can be exhausted by use, and may be renewable, like soil fertility, or non renewable like petroleum. Another scheme was proposed by Wantrup in 1963, which divides resources into stock and flow resources. Subdivision of stock resources is on the basis of absence or presence of natural deterioration, and for flow resources it is the inability or ability of human action to affect the resource. The important thing, however, is that resources are linked with use and, therefore, susceptible to planning.

Soil conservation, on the other hand, has meant different things to different people at different times. Frequently the term is used in the context of preservation or protection, though this is a meaning that belongs to the past. More recent, but still inadequate, definitions consider soil conservation as "static state of use" and "wise use." The modern approach to soil conservation is much more significant. The relevance of soil resources is related to natural and social sciences, and is dependent on planning and use at various times and places, and on relationships of soil with other resources. As indicated by Wantrup

(1968), conservation is concerned with the <u>when</u> of use and is subject to quantitative measure. In his own words

> "the economics of conservation serves, therefore, as a basis for formulating and implementing public policies that aim to protect or to change a given time distribution. Always, however, understanding for its own sake is worthwhile and is also a prerequisite to prediction and public action."

It is in this direction that soil surveys are related to soil conservation.

<u>Misuse of soil</u>.

The dependence of mankind on soils is aggravated by the fact that soils vary from one place to another; this variation exists because soils are a result of the interaction of climate and living organisms conditioned by relief, acting on some parent material through time. Processes of soil formation vary with these soil forming factors, resulting in different kinds of soils. Each kind of soil has some characteristics or set of characteristics that defines its behavior for specific uses, so that the characteristics that make one kind of soil suited to a given use may be present in limited degree, or may not exist at all, in other kinds of soils. Thus, soils are subject to misuse.

Soils are also segments of the landscape; they occupy area as well as depth. The extent of the area occupied by soils with a given set of characteristics is limited, and this means that for any single use the availability of suitable soil is also limited. As man occupies more and more land, this availability is reduced and may become a scarcity. The problem of a lack of adjustment between soil and use becomes in turn more relevant.

Man has experienced this lack of adjustment, or misuse of soils, in many instances. Probably one of the most documented examples is the erosion problem that developed in the American Great Plains in the mid-thirties. As the colonization of United States land proceeded to the west, people did not recognize that the new lands would require a management different than those in the east where the transfer of practices from the old world was possible because of the similarities of the soils (Kellogg, 1941). The consequences of this lack of adjustment or misuse of soil were tremendous and caused great concern about soil erosion in the United States. During the years 1933 to 1936, massive dust storms

> ". . . rose from previously plowed fields, extended for thousands of feet into the air, and for hundreds of miles on the ground, often so thick as to make breathing itself difficult."
> (Held and Clawson, 1965).

Those were in effect the years of the erosion boom; the problem was evident enough to give rise to several programs and to make this concern persistent for many years; the development of the Land Capability Classification was a result of this concern, as were many legislations and actions. In the USDA Yearbook of Agriculture for 1938, the emphasis was on erosion; whereas this emphasis has gradually shifted to land management (USDA's Yearbook of Agriculture - Soils, 1957) and land use planning in more recent years, the question of misuse has persisted for sometime. In 1941 Kellogg wrote:

> "There is a problem of maladjustment between the soil and people living on it in the United States. Its symptoms are rural poverty, poor health and unhappiness among many of the farm people and depleted productivity, and, in some places, erosion of the soil."

According to this author, estimates were made in 1938 of the extent of this maladjustment; on about 76 million acres being farmed, it was found, no known agricultural practice would return a satisfactory income for the labor required and maintain soil productivity; another 178 million acres were being used for crops by practices that either would not return a satisfactory labor income with the prices of that time, or would deplete further the productivity of the soil, or both.

These figures have been lowered considerably in the last three decades as a result of better knowledge of soils and more appropriate management practices. By the middle of the 1950's, only about 14 million acres in the Plains were used for crops on land that was subject to severe erosion (Held and Clawson, 1965). Further modification of the problem has been caused by change in the pattern of land use in the last decade. Some soils previously under agricultural use have been increasingly occupied by suburban development; some of those under forest have shifted to grassland and recreation, or even to agriculture. Although technology increasingly provides new means of overcoming some natural limitations of soils, the risk of misuse is always present. In Tikal, Guatemala, poorly drained soils caused problems for pedestrians 1,000 years ago in the same way that soils with similar limitations cause problems for vehicle traffic in New York State today (Olson and Puleston, 1970).

In many parts of the world, examples of misuse of soils are abundant. Large agricultural development projects for irrigation have undergone decline and abandonment because of salt accumulation caused by improper management. The settlement of structures and buildings that is evident in metropolitan areas is the result of imbalances between those structures and the ability of soil and subsoil to provide good foundation conditions. These conditions may occur in large areas, as in the case of Mexico City, or at specific sites.

In Venezuela, there are many evidences of this lack of adjustment. In the northern part of the country, the city of Coro is located on highly expansive clays. Many structures that have been built without proper consideration to soil conditions have been damaged by heaving. A newly constructed village in an irrigation project in the Llanos started cracking shortly after construction and had to be abandoned; the village was built on poorly drained soils that could not support the light structures. On a costly highway that connects Caracas with the interior of the country, landslides often interrupt the traffic; a segment of this highway has been under reconstruction for several years and still continues to erode by mass wasting.

Planning the use of soil

All of these problems of misuse can be avoided, or at least mitigated to a significant degree, with an adequate knowledge about the soil combined with the knowledge of other disciplines. The soils of a given area can be characterized in terms of their properties in such a way that predictions can be made about behavior under specific uses. By planning the use of soils a satisfactory adjustment can often be achieved. The availability of this information can prove its benefits in many ways--for example, by providing the location of soils suited to a given use. The USDA study that showed in 1938 a large acreage of soils under inappropriate use (Kellogg,1941) also showed that there were 51 million acres not being used that could be added to cropland. In other cases recognition of differences in soils to be placed under the same use might lead to different treatments. The application of adequate measures or the placement of soils under uses for which they are suitable involves an economic factor. Any agricultural enterprise is likely to be more profitable when the crop involved is produced on the appropriate soils. For uses where profit (in the sense of return of money) is not the prime consideration, the economic factor is also present because wise use of soils means a reduction in cost over the long period of time. There are many illustrations of construction works where extra costs could have been avoided by using soil information. Some often quoted examples are extra costs of a quarter million dollars for a high school building and $600,000 for a highway, that could have been avoided by moving the construction less than one mile as indicated by the soil map (Fairfax County, Virginia, 1964).

HISTORICAL DEVELOPMENT OF SOIL SURVEY OBJECTIVES

Needs for Objectives

One of the more important aspects in the development of an enterprise is to define its objectives. An objective is usually thought of as the end or desired result of an action. This is true whether the enterprise consists of placing an object in space, building a housing complex, or making a resource inventory. For these and many other tasks, the accomplishment of goals is subject to failure if the entire program is not supported by a definition of objectives sufficiently clear to guide all the steps of the job.

There are several reasons why soil survey as an enterprise must also be based on well defined objectives. In the first place, it is composed of several activities ranging from the description of soils to the publication of reports; each of these requires a process of reasoning and actions whose aim is to meet partial objectives within the overall system. The better defined the central objectives are, the lesser the possibilities of deviation in subsequent thinking. Secondly, a measure of performance of each part is possible mainly by checking how well the objectives are satisfied. Finally, and probably most important, is the fact that when the same activity is carried out by different organizations, separate efforts can only become a joint effort when they converge on common goals, that is, when there are clearly defined objectives and there is agreement with regard to them. Clearly defined objectives need to be (a) meaningful, in both absolute and relative terms, and (b) conceptually and operationally clear. There are many possible objectives for the undertaking of a single task, and the most appropriate one is usually selected by testing its relevance and relations with other objectives within a general context. An ill-defined objective, even if it is important, is a weakness in a program because its vagueness allows for deviations and also because there is no way of knowing exactly whether the goals are finally accomplished or not.

In a discussion about the problem of determining objectives, Churchman (1968) warns about the common fallacy in stating objectives by emphasizing the obvious; he gives the example of a medical laboratory. An obvious statement is to say that its objective is to make as accurate tests as possible. The final use of the laboratory analysis reveals, however, that the real objective is not accuracy, but what accuracy is good for: improving the doctor's diagnosis. The reasoning utilized in this example may be applied to soil survey; it illustrates the possibility of missing the real point in the statement of objectives and also emphasizes the fact that only when the real objective is recognized can the importance of the activity be evaluated and justified.

Changing Objectives in Soil Survey

Soil surveys were started in Russia and the United States in the last century and are now being conducted in most parts of the world. There have been substantial changes in concepts, operations, and applications of soil survey during this period. Objectives also changed and were adapted to new conditions in time and place. Frequently the main objectives of soil surveys has been stated "to study soils," a generalization that lacks the meaning and clarity necessary for official interest and successful work. A brief review of the past and modern trends may help in testing how these attributes have been considered in definitions of objectives for soil survey.

The early period

At the early times of soil surveys in Russia and the United States, a great need existed for a general evaluation of land resources; the goal of soil survey programs was to get a general knowledge of soils in the form of a simple inventory. In 1904, M. Whitney, then Head of Bureau of Soils in the United States, stated that soil surveys were made "To prepare maps that will indicate the extent, the distribution, and the location of the principal types of soil found in the United States"(Truog, 1949). This statement does not provide an idea of further use of that knowledge and therefore confines the importance of the objectives. The real objectives were not clear at that time because in part, many concepts regarding soil were not clear either. Soil science was just starting its development and the spread of its basic principles was quite slow. The original works of Dokuchaiev were not sufficiently known or recognized in the tsarist Russia because of the lack of official support (Tyurin, et al., 1959). Russian soil science developed more rapidly after the October revolution with the works of Dukochaiev's disciples and followers like Sibiertsev, Glinka, Viliams, and Prasolov (Gerasimov and Glazovskaya, 1960). Some of the works of the Russian soil scientists, including reports on soils of Russia by Dokuchaiev and papers on soil classification by Sibiertsev, appeared in the United States and the United Kingdom during the period from 1893 to 1908 but had little evident impact (Simonson, 1968). In Europe, only part of this continent benefited from the concepts of the Russian school by the publication of a book in German by Glinka in 1914. This work caught the attention of Marbut in the United States and he decided to translate it into English. The translation took six years and still had to wait seven more years until finding a publisher in 1927 (Moomaw,1942). The findings of the Russian school that became available to Marbut, and his own observations as he studied the soils of the United States, brought new insights into the nature of the objectives of soil surveys, as is shown by the following definition by Marbut in 1921:

> "What is a soil survey? It will be sufficient for our purpose to define a soil survey as an institution devoted to the study of the soil in its natural habitat. It is concerned primarily with the determination of soil characteristics as they have been developed by soil-making processes, including the work of man, the study of the significance of each, the isolation of the several groups of characteristics that should constitute a soil individual, the fixing of these groups by proper nomenclature, and the determination of the area and distribution of each soil unit."
> (Marbut, 1921).

This statement is a reflection of a philosophy in regard to soils that was not available at the time of the definition by Whitney. New concepts of soil as resulting from processes of genesis determined by given factors, the need for soil classification, and the definition of the soil individual included in Marbut's statement were products of the progress of soil science as a new model was being built from the growing knowledge about soils. However, as complete as it was from the conceptual standpoint, this statement does not say much about the ultimate purpose for which that information was being produced. The definition of Whitney was not conceptually clear and this led to the idea that soil surveys were inventories in their simplest form, a map with a list of briefly defined units without a mention of a further use. Surprisingly enough, this idea is common even in modern times. In the case of Marbut's statement, even being conceptually and perhaps operationally clear, there are no elements in it that indicated the meaningfulness of the objectives. Knowledge of the soils per se might be an important necessity by itself for soil scientists, but the real meaning depends on how important the concept stands in relation to other kinds of needs within the total context of the development of a country.

<u>Examples of modern trends</u>

Soil survey has been visualized thus far as a means to supply information about soils for rational use of this resource. The needs of information that all countries have in regard to its resources are essentially the same, however, the approaches vary among countries and within countries, and with time.

The availability of soil and the economic conditions influencing land use are expressed in the use of soil surveys and the character of the predictions. These relationships may be illustrated in countries where soil surveys are experiencing a great demand.

In the United States soil survey has been a cooperative effort of federal, state, and local governments, and numerous educational institutions. The program is called the National Cooperative Soil Survey. Soil surveys have been carried out for more than seventy years during which time the nature of the predictions made about soils has varied in order to adjust to the needs of the country. During the period 1935-1945 major emphasis was given to soil erosion control; in the following decade emphasis was shifted toward soil management and productivity in agriculture; and more recently predictions are made for a larger variety of uses. Within the single field of agricultural use, which continues to be the major application, the information has evolved from general statements to accurate yield predictions for several levels of management. Besides agriculture and forestry, engineers and planners are provided with valuable data and interpretations. Information applicable to regional planning, urban and community development, highway construction, recreation, and preparation for zoning ordinances is furnished by these data and by predictions about performance of soils under defined uses (Bartelli, et al., 1966). The kinds of predictions vary also according to the region. In the western states the development of irrigated agriculture is aided by interpretations for irrigation; in the northeast, soil surveys are designed to provide information for adequate use of soils in the resolution of conflicts of land use and environmental quality (Olson 1964a, 1964b). The degree of detail and accuracy of predictions vary in general with the specific objectives of the survey, but there is an increasing tendency to require predictions accurate enough for the individual farmer or landowner to be able to make the most rational use of even small tracts of land (Kellogg, 1966; Galloway, 1966).

In Russia, the situation of agriculture and land organization in the first two decades of this century demanded soil surveys as the basis for important projects, particularly large irrigation projects, and for expanding planting of industrial crops (Ewald, 1968). Later on, information for the economic organization of collective and state farms was provided by means of pedological studies that emphasized the application of chemistry for agriculture (Tyurin, et al., 1959). The need for adjusting soil surveys to new conditions has been recognized by soil scientists and the official programs attempt to update prior studies by including more specific soil information, such as permeability, compaction, abrasive properties, and specific resistance (Sotnikov, 1968). New requirements of the country call for changes in soil science scope and institutional organization (Gerasimov, 1972).

A final example, differing from the former two, is provided by the condition of soil survey in the Netherlands. This country has been taking monumental steps to gain land from the sea in order to satisfy the needs of the population. Agriculture is very intensive and at a high technologic level. High demands for land for housing, industries, and recreation with limited reserves of reclaimable land result in a decrease of acreage of cultivated land. Non-agricultural uses currently play a large part in soil surveys, yet the decrease in agricultural land results in a requirement for higher productivity of remaining farm lands. These needs of agricultural use are satisfied by very detailed predictions for individual crops, and by developing as many quantitative assessments of soils as is possible (Edelman, 1963; Haans and Westerveld, 1970).

Influence of official support

The examples just mentioned show that the objectives of soil surveys depend on the conditions of each country. Within a particular country they also vary with specific environments and with time in adjusting to new conditions. Progressive use of soil surveys has been possible in the countries selected as examples for two main reasons. One reason is the development of soil science. In all of these countries soil science has reached advanced stages. Each of them has been experiencing the growth of knowledge of soils, developing concepts, theories, and models of their own, and testing the achievements of others. The continuous effort of development and testing is both cause and effect of progress in soil surveys. The other reason for this progress, from which both soil science and society have benefitted, is the existence of a serious commitment of the government toward better utilization of soil resources. Without this attention on the part of the governmental administration, the achievement of progress in soil surveys and therefore of an adequate knowledge about the soils of a country, is not possible. This is demonstrated in the case of France. Soil science in France has also had a significant development. French soil scientists have developed their own system of soil classification and have provided significant contribution for other branches of soil science. But this development has resulted largely from the knowledge of the soils of the French colonies in Africa through the works of the ORSTOM, a French institution for overseas research. As a result of this lack of government commitment to the study of their own soils, the national program of soil survey is deficient and the knowledge of the soils of France is limited. Thus, the knowledge of the soils of a country is a responsibility shared by soil scientists and by the government. But unless the government makes provision for use of this knowledge, soil scientists cannot do much on their own and the country may be in trouble.

General comments

The development of soil science and of science in general, and the accumulation of information about soils in many parts of the world have contributed to the availability at the present time of much clearer concepts about the nature of the objectives of soil surveys. Simonson (1959) has stated that the objectives of soil surveys are both fundamental and applied. The applied objective is the prediction of soil behavior under defined use and management. These predictions may be implicit in the grouping of soils into capability classes for agricultural uses, or explicit by concrete statements about estimates of crop yields or performance of soils as engineering materials. The fundamental objective is to contribute to the growth of the knowledge of the soils of the country; this knowledge is gained by the investigation involved in soil survey and may be illustrated by the development of theories of soil genesis and its impact on the understanding of soils and in classification schemes. Those achievements have in turn resulted in more accurate mapping and in more efficient survey programs, so the applied objectives benefit from the progresses of the fundamental ones. These comments of Simonson referred to the approach to soil surveys in the United States, but they reflect also much of the modern philosophy of soil science throughout the world.

The study of soils which is made by soil surveys leads to a knowledge of soils that is intended to serve a higher purpose, the purpose of wise use of soil resources. The recognition of this purpose of soil surveys not only defines the meaningfulness of the objectives, but also provides the basis for a definition of objectives conceptually and operationally clear. Soil surveys serve the purpose of a wiser use of soils by providing for predictions about the performance of soils under specific uses. In order to make these predictions it is necessary to study soils in terms of their characteristics, their distribution in the landscape, their extent, and their genesis.

The adequacy of each of these domains in accomplishing the major objective implies that each domain has a more specific objective yet is integral and necessary to the overall objectives. When the central objective is fully understood, all of these parts are performed under a defined conceptual framework and by operations defined to better meet the objective. Soil classification and mapping, for example, are thus essential to the purpose (Kellogg, 1949a), but the criteria for both procedures depend upon the ultimate objective of the soil survey.

DEVELOPING OBJECTIVES FOR SOIL SURVEY IN VENEZUELA

Present Conditions

In the previous discussion it was apparent that the objectives of soil survey are dependent on the scientific and socio-economic conditions of a country. In developing the objectives of soil survey in Venezuela, it is necessary to consider them in relation to the background of this country.

In a general context, Venezuela is considered to be a country in the transitional phase--midway between pre-industrial and industrial societies--in which both a large portion of still unutilized resources and the spatial shifts involved as the economy changes from agrarian to industrial determine a great need for regional organization (Friedman, 1966; Urriola, 1971). According to the studies made by the Commission of the Water Plan (COPLANARH, 1970a, 1970b, 1970c), the desirable agriculture of the country for the year 2000 will be based on the production from 2.4 million hectares, assuming that current crop yields will be increased 2 to 4 times. With current average yields, 6.5 million hectares would be necessary. Land of high quality for agriculture has been estimated at 1.9 million hectares. Implicit in this prediction is the scarcity of land of high quality for agricultural production and its increasing occupation for more intensive uses in a short period of time.

As the best land is occupied, there will be the concomittent need for considerable increase in productivity, sound conservation measures and crop zoning.

On the other hand, the country is experiencing the phenomenon of a rapidly growing population typified by the migration of rural masses to the cities, with the consequent accelerated growth of the major urban areas and the tendency to form megalopolis. An annual growth rate of 3.1% projected toward 1990 means a total population of about 20.5 million, and 28.1 million for the year 2000. Relative to 1971, this means a doubling in the next 20 years and an increase of about 2.5 times in 30 years. The cities of more than 5000 inhabitants will hold 77% of this population, indicating the expected high degree of urban concentration with the environmental effects of pollution, floods, and additional stresses on the conflicts of land and water use.

Role of Soil Surveys

Let us consider now how these conditions affect soil survey in the country. For agriculture, the horizontal expansion that will occur in the next thirty years indicates that soil surveys should provide information about soil qualities and extent sufficiently complete to orient this expansion. This requires careful selection of areas and timing of programs, and interpretations of soils adequate for crop zoning. On the other hand, the need for higher productivity calls for increased amounts and accuracy of information, greater than that currently presented in the soil survey reports of the country. The general statements about potentiality for agricultural use must be replaced by statements, as precise as possible, about the kinds of crops that can be grown, the yields that may be expected under different levels of management, the properties of soils that limit other crops, and the inputs required to overcome these limitations for the desired production. These predictions should be made, whenever possible, in quantitative terms. Quantification constitutes a large departure from the current work, but it is as important for the country as an accurate mapping of soil units for which many statements can be made about use and management.

In regard to non-agricultural uses of soil, the conditions of Venezuela affect soil survey objectives both in the general scope and in the kinds of predictions that are required. Based on accumulated experiences of other countries, Urriola (1971) discussed this aspect for Venezuela. He stressed the need for including information and interpretations other than agricultural to make soil surveys useful to the planning and development activities of nearly thirty government agencies, and he also suggested some of the steps required for this accomplishment. Among these steps, some of the most important are the inclusion of the engineering characteristics of soils and the making of predictions related to the behavior of soils under selected non-agricultural uses. These engineering and non-agricultural interpretations of soils would also represent a significant addition to the current work in Venezuela.

The considerations mentioned indicate two major types of information that are especially needed for the general conditions of Venezuela: (a) accurate predictions for crops, and (b) engineering characteristics of soils. This information is needed in all soil survey areas or projects in the country, regardless of the degree of detail of the survey and of the agency involved in its realization. Within this general framework, each soil survey project may have, as specific objectives, other kinds of information as additions to the minimum standards. These specific objectives depend on the purpose of the particular soil survey and the specific conditions of the area.

Smith (1965) has stated that one reason for failure of soil surveys to be useful under changing conditions is the failure to maintain reasonable scientific standards. This is the experience in many countries, including Venezuela. Large parts of this country have been studied, but most of the soil surveys available are outdated and do not meet contemporary requirements. Other areas have been studied for only specific purposes, mostly for irrigation, and some kinds of other investigations are needed to give additional information. Thus, a significant part of the work already done needs to be re-evaluated. In regard to the definition of soil units, currently described soil series will require additional investigation in order to meet current standards, or for correct placement of the soils in a classification system. Soil correlation is an important task and while there has been an increasing interest in this work in recent years (Soc. Ven. de la Ciencia del Suelo, 1970; Mayorca, 1972; Arias, 1972), only a few significant steps to effectively implement correlation work have been taken (Schargel and Arnold, 1972). Mapping units need to be revised and defined with criteria of higher quality in regard to accuracy and reliability. The techniques for air photo interpretation, field procedures, and the laboratory work need to be done with strict adherence to specifications. If the delineations of soil areas on maps are to be interpreted with a relatively high degree of reliability, the soil survey must follow reasonable scientific standards.

Another consideration affecting objectives of a soil survey is the nature of soil surveys as resource inventories. Soil surveys are complex activities and are, in a sense, inventories of natural resources because they result in knowledge of the kinds, distribution and extent of the soils. There are two factors, however, that make them different from a simple inventory. One is the fact that they cannot be done remotely. Soils have depth besides area and the characteristics that determine their behavior under a given use are mostly below the surface. There is no remote sensor capable of recognizing and recording the set of characteristics observable in a soil profile. The usefulness of the soil survey is highly dependent on the field work and the care given to this field work. The other consideration is the fact that soil surveys provide bases for predictions about performance of soils and therein lies the scientific character of soil surveys, since the making of predictions is a fundamental purpose of science (Kellogg, 1941).

Responsibility of Soil Scientists

Soil surveys are not either purely scientific or purely utilitarian (Kellogg, 1949a;Simonson, 1959; Smith, 1965). Soil surveys are useful because they meet the needs of practical objectives but only through the understanding and application of scientific theory and methods. Soil scientists need to be aware of this. For one reason, modern soil surveys are more than ever before team works; better uses of soils do not result from pure pedology. The predictions that are made about soils are judgements that depend a great deal on the understanding and knowledge of soils. This realm of soil study is the responsibility of the soil scientist, whether he is employed by the government or by other institutions. But there are other elements that are necessary for these judgements which are the dominion of other scientists (Simonson, 1959). Predictions of behavior of soils for agriculture should be made jointly with agronomists, regional specialists, and others. For engineering interpretations a joint effort with engineers, highway specialists, and planners is necessary. In the United States this necessity for cooperation has been recognized for many years. In 1959, Simonson stated:

> "The findings in fields such as agronomy, farm management, and hydrology must be integrated with the identification, characterization, and classification of soils in order to predict soil behavior."

Soil scientists in the United States and in other countries are becoming increasingly aware of this interdisciplinary character of soil surveys, and this has resulted in soil surveys that are scientifically and practically sound and therefore are useful.

Proposed Objectives

In the preceding sections the importance of soil knowledge and its relationships to man's interest in using soil has been discussed. It was noted that objectives of soil surveys are both fundamental and applied, and that they may be specific within countries and regions. Soil surveys are made to be used. The possibilities and advantages of an adequate soil survey depend on the care that is given to the definition of objectives.

Soil surveys in Venezuela have been done with partial objectives mainly because of institutional constraints. The needs of the country are such that one can consider it to be a potential error to continue in this direction. Despite the necessary diversification in individual soil survey projects even within a single agency, it is believed necessary to achieve an agreement, at least, on the nature of the objectives that the soil survey should have in the next thirty years in the country.

The objectives of soil survey in Venezuela are (a) to provide soil information capable of helping those involved in making wise decisions and in implementing land use policies and programs, and (b) to contribute to the growth of the knowledge of the soils of the country in such a way that improved predictions of soil behavior can be made and used.

These objectives apply to all decision-makers. Soil information can help an individual landowner as much as it can help a planning group. Soil surveys can orient actions taken by a campesino, a farmer, or a home gardener in their property. Soil surveys also provide information that can be used by housing development agencies, industrial corporations, and government institutions involved in agricultural and land reclamation programs. Decisions about what land to clear, the size of farms, the location of communities, the placement of roads, the areas to irrigate, or the things to be done to be able to have a flower garden are all important each in its own domain. The accumulated experience of all disciplines need to be considered in developing more precise statements about behavior of soils under different uses. Soil surveys involve the study of soils and their environment for the understanding of their characteristics, genesis, and distribution on big and small places. Soils are described, classified, named, sampled and analyzed to achieve that understanding and contribute to the knowledge of the soils of the country.

Some Implications

The statement of purposes just presented carry some implications of change. These implications affect mainly the nature of soil survey operations, but also affect attitudes on the part of the government, soil scientists, and soil survey users.

Official interest in soil surveys is increasing in the country. Nevertheless, the pressures of development often lead to the implementation of programs without adequate basic information or to reduction of funds available for soil evaluation in favor of other more tangible works. Agricultural development and regional organization are so important in the country that they deserve a more determined attitude. As stated by Arnold (1972):

> "These governments which have recognized the value of soil survey and have truly supported such activities have recorded rather phenomenal success in the improvement of agriculture. The

transfer of knowledge and technology, both old and new, has been rapid and efficient. The progress of regional and national planning has also been increased."

Soil scientists and soil survey users may also need to change to fufill the objectives of soil survey. Soil scientists must be aware of the fact that the information that they are producing is to be used and consequently should make maximum effort to make that information most meaningful to users. They should also remember that they provide the basis for decisions and that their predictions are to be tested and relied upon by other people. This burden of responsibility calls for extreme care in the excellence of soil scientists in their work and for cooperation at all levels of operation. Soil survey users, on the other hand, need to express their needs for information and need to make an effort to understand the concepts and data which are displayed to them. Both scientists and users must remember that soil survey cannot provide all the answers for planning and development. The best they can do (and this must also be a soil survey goal) is to provide more and better soil information.

The nature of soil surveys in Venezuela must be adapted to the conditions of the changing times. It is necessary, at the present time, to make provision for the future. It has been considered here that a period of thirty years can be selected for a national soil survey program. Operations, procedures, and institutional organization may change substantially in this period. The conceptual bases of soil, soil surveys, and their relationships to applied purposes are more permanent and important to the lasting contributions which a soil survey may provide to any developing country.

SOME BASIC CONCEPTS IN PEDOLOGY

The understanding of basic concepts in soil survey is essential for the individual soil surveyor, for the communication between soil scientists, and for the effective exchange of knowledge with soil survey users from other disciplines.

All scientists deal with a "thing" which is the object or concern of their work. The role of the scientist is to make predictions about the thing he is concerned with, and the validity of such predictions depends on his knowledge about this thing. A soil surveyor needs first to prepare himself in the understanding of basic concepts about soil before he can recognize soils in the landscape and predict relationships that may be detected. Thus, the soil surveyor does not simply look for soils in the field, but recognizes something that corresponds to his model of soil. Concepts, mental images, structured ideas, and so forth, are all part of the reference framework that constitutes a model. The model is the bridge that connects the theoretical level to observational level (Haggett and Chroley, 1967).

For communication between soil scientists, one of the essential conditions is that all persons engaged in that science can communicate with and understand each other. In this line of thinking, soil scientists are able to transmit information and findings among themselves only when there is a series of concepts with meaning the same for everyone; thus, basic concepts allow scientists to talk about the same thing in understandable terms.

One of the interesting aspects of modern soil surveys is that they are prepared to be used by people other than soil scientists; although not all of the concepts involved in soil survey preparation have to be known by the users, some knowledge is necessary for the understanding of the information that is presented to them. For this, the necessity of a conceptual model before perception can be attained must be also stressed. The soil scientists often simplifies a complex natural system in the landscape in order to communicate to others the concept of the same system in a useful manner; even so, the user of a soil map needs a conceptual framework to perceive the pattern that is displayed to him.

Soil as a Population

Kellogg (1949b) has indicated that just as scientists deal with plants instead of vegetation as a whole, soil scientists deal with soils, instead of soil. This individuality of soils in nature results from unique combinations of effects of the soil forming processes which produce specific kinds of soils. Thus, soils can be studied as a collection of individuals in a natural landscape. This process can be illustrated by an analogy with animals. In a region, the determination of the animal population can be made by counting the number of individual animals, say, sheep, cows, horses, etcetera; within each group, further separations can be made for defined purposes, according to variability of characteristics. To characterize variability one may sample the population and use statistics. The same principles apply to soils. Soils individually considered have some common properties, but no two individuals are identical. To consider soils as a population one must deal with variability, and a limited amount of variability has to be specified.

Soils as Landscapes

It has been indicated that soils, like animals, can be treated as a population and studied by means of statistics. But, unlike animals, soils occupy area and are fixed in landscapes. Thus, soils have to be studied as parts of fixed landscapes and as definite fixed areas. The fact that soil exists as a continuum creates some difficulty in the definition of soils as three-dimensional individuals. A major difficulty arises from the fact that soils do not occur as discrete individuals exactly comparable to plants and animals (Simonson, 1968). Soils are segments of the landscape, but these segments in places merge gradually into one another instead of being distinct entities physically separate. Sharp boundaries do occur, however, when soils meet other bodies that are non-soil or sharply contrasting geologic, slope, or drainage conditions.

Soil surveys are based on the existence of soils as landscapes and most of its operations rely on the consideration of a soil individual. Intuitively an individual soil should be recognizable and be of large enough size for the intended use.

One aspect, not easily visualized, is the scale of individual soils in landscapes. Anyone can see the differences in soils from the viewpoint of quite different large areas. A person who travels from Caracas to the West perceives striking changes in the landscape. Without any training in pedology, he realizes that the flat, dark colored soils that support intensive agriculture in the Aragua valley are different than the light colored cactus covered soils of the semi-arid region around Barquisimeto. These are landscapes whose differences are striking and the laymen perceives this with no difficulty. Within each landscape, smaller variations are not so striking. A layman might notice some depressions and mounds, but major differences in soils are not readily apparent to him. Nevertheless, variability exists even at these smaller dimensions. For most people, it is relatively easy to understand differences between soils of desert areas and those of humid rainforests. These areas may be represented at scales of 1:100,000 or smaller; this is a scale of landscapes and soil individuals in landscapes are not apparent at this scale. Major kinds of soils are evident, however. This is so because of the "scale" of variation of the soil-forming factors. The following paragraphs may be helpful to visualize this.

Soils are a function of climate and biota, acting over parent materials as conditioned by relief over periods of time. These soil-forming factors have geographic distribution. Consequently, the overlap of one factor on another may produce differences in soils. Factors of climate and vegetation (biota) may be wide spread. They are, in a gross sense, related and relatively homogeneous over large areas, say hundreds of square kilometers. Time of soil formation is often relatively uniform, except for catastrophic events, over areas from tens of hectares to a few hundreds of square kilometers; however, time of soil formation may vary locally a lot. Parent materials are usually uniform over at least several hectares. Relief in a local area then becomes generally the major source of variation and commonly influences the effect of the other factors. It may be variable throughout a few areas, causing a complex microrelief, or uniform over tens of square kilometers. Thus, even within an area of uniform climate and vegetation, time of exposure of parent materials may contrast on local scenes and topography within an age-parent material may give rise to local differences in soils. In the Venezuelan llanos, for example, there are large areas with a wet-and-dry climatic regime and savanna vegetation. Erosion and deposition processes, however, have produced a landscape evolution such that recent alluvial deposits contrast with terraces of geologic tertiary age. Within this groundsurface, local differences in relief cause variation in soils over relatively small areas.

The effect of any of these factors depends on the combination of the others. The combinations possible have a limited variability in areas from a few hectares to a few tens of hectares. Soils in these areas have properties that may be correlated to recognizeable features of local landscapes. Mottling can often be related to position in the local landscape, for example, and natural drainage can be related to coarse materials deposited on higher positions and other features. Thus, areas of soils as homogeneous landscapes are generally small. They are observable at scales of 1:25,000 or larger. For most people differences in soils at this scale are not easily perceived. The soil scientist recognizes and predicts boundaries of such landscapes through models, which are based on the understanding of the geomorphology of the area.

The Soil Individual

One aspect that deserves consideration for defining the soil individual are the attributes of the individual itself. Cline (1949) stated that an individual is "the smallest natural body that can be defined as a thing complete in itself." In this definition, relative size and completeness are the attributes that provide the essence of the individual. To be "the smallest" means that it has to have limited variability. It was already mentioned that in soils such limited variability occupies only small areas. To be "complete" means to have the virtue of possessing all the attributes of the defined body. This, in turn, results in indivisibility and is related to size, thus implying the existence of physical boundaries.

Most natural bodies have distinct limits that one perceives instinctively, such as a person, a tree (Jansen, 1972). As previously noted, soils do not have this attribute but occupy parts of the landscape adjacent to and merging with one another.

The nature of soils is a condition of landscapes that cannot be easily modified by man. The situation of soil variability is similar to that faced by regional analysts who have to work with regions as basic units (Grigg, 1965; Folke, 1965; Juillard, 1962). Because of the complexities involved, the limits of basic units are fixed by definition and conventions. The individuals resulting from such definitions and conventions may be either artificial or arbitrary. The former is a human construct within a continuous universe (Knox, 1965), while the latter is conceived as a segment of the soil mantle that has fixed, conventional dimensions (Van Wambeke, 1966).

In the process of defining a basic unit in soil science, several requirements have to be met. Johnson (1963) indicated that a basic soil unit should satisfy the following requirements:

1. It should be a real object, observable and measurable in three dimensions, that should include the whole vertical thicknesses of the soil.
2. It should be independent of all taxonomic systems.
3. It should have clear, natural boundaries.
4. It should be of a size convenient for study, measurement and sampling.
5. It should be susceptible of reasonably precise definition, so it can be used consistently.

Some alternatives can be considered in selecting a basic unit. The primary particles of sand, silt, and clay could be considered as natural individuals, within the universe of soil particles (Knox, 1965). As a basic soil unit, they lack continuity characteristics of soil. They can be compared to cells in plants. Peds, which are aggregates of primary particles, are larger units, but they are not large enough to contain continuity, and do not show profile relationships. Knox (1965) has pointed out that hand specimens or soil samples for engineering determinations exhibit the characteristics used to differentiate the classes of engineering classifications, and therefore they are artificial individuals with respect to engineering soil classification systems. Soil horizons, or layers in the soil profile, are large enough to satisfy intrinsic relationships, but individually considered they reveal little about the whole profile

Soil profiles, a vertical cut showing all horizons, is mainly 2-dimensional. It can be compared to a picture. While it can show most aspects and relationships, it has no volume as a whole.

None of the discussed items meets requirements for the soil individual, because they lack the completeness required. The smallest natural body of soil that Cline (1949) considers an individual should have vertical limits from the surface to an underlying material one considers not soil--the thickness of the soil profile--and lateral dimensions large enough for observation and sampling.

The term pedon has been introduced as the smallest volume that can be called a soil (Soil Survey Staff, 1960). In essence, a pedon is a three-dimensional body of soil with area limits from 1 to 10 square meters; it extends downward to the lower limit of common rooting of the dominant native perennial plants, or the lower limit of the genetic horizons, whichever is deeper. Its maximum lateral dimensions are indicated in the definition by the Soil Survey Staff (1960) of about 3.5 meters which would correspond to one-half of the cycle of cyclic horizons that recur at linear intervals of 7 meters. Arnold (1964) suggested that for horizons that are cyclic at intervals from 1.3 to 4.3 meters, 80% of the cycle instead of the half-cycle should be included in the pedon to show at least 80% of the vertical variability.

The term pedon was proposed by Guy D. Smith (Johnson, 1963). According to Simonson (1968), the term is a collective noun for small basic soil entities, and thus parallels the word "tree" as a collective noun covering oaks, pines, elms, and other trees.

The pedon has some limitations. By definition, its extent is too small for potential mapping; in most cases the pedon is too small to show the configuration of the surface and cannot exhibit the range of characteristics allowed for the soil series. It does not define the relation with adjacent pedons, because location is not defined. The pedon does not fit the requirements of a soil individual mainly because it lacks geographical attributes. Another limitation is that its size is too small for use of a soil for applied objectives, like for farming, roads, and for foundations.

A larger body of soil is necessary for soil survey operations. The Soil Survey Staff (1960) defined such a body as the "soil individual." This term has been replaced by the term polypedon, proposed by Simonson (Johnson, 1963). The polypedon is defined as

> "one or more contiguous pedons, all falling within the defined range of a single soil series. It is a real, physical soil body, limited by 'not soil' or by pedons of unlike character in respect to criteria used to define soil series. Its minimum size is the same as the minimum size of a pedon, one square meter. Its boundaries with other polypedons are determined more or less exactly by definition." (Johnson, 1963).

The polypedon has geographical attributes; it can be recognized in nature by external features. Being a soil body larger than a pedon, it can be used to establish mapping legends. Its boundaries in nature reflect genetic factors. In this context, pedons become sampling units selected to characterize polypedons. According to Johnson (1963), polypedons are comparable to individual pine trees, individual fish, and individual men.*

Even though there seems to be increasing acceptance of the terms pedon and polypedon, there is no universal agreement on such terms. Changes of concepts and, of course, of terms, characterize the evolution of any science. Concepts are tested by use and application, and are further accepted or criticized and new proposals made. The polypedon is currently undergoing testing. Other basic soil units have been proposed by other authors and schools for soil survey and soil classificatin. These efforts reflect the importance of the definition of the soil individual.

To summarize, a basic soil unit or soil individual is an essential part of all operations in soil survey. It is the knowledge of such a unit that makes soil mapping possible; it permits bodies of soil to be related to classes in a taxonomic system and allows sampling for investigation. Currently, the polypedon seems to meet most requirements to

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*The term "individual," however, has certain problems. The statistician's individual, for example, is a pedon. A geographer's individual is a polypedon.

establish the classes of the lowest category (soil series) in a classification system. It also is the unit that can be combined into soil associations within landscapes to produce soil maps of smaller scales. Pedons are the sample units used to represent the larger geographic bodies.

SOIL CLASSIFICATION

The need of man to make the best use of his resources requires the knowledge and understanding of the objects that comprise his environment. Soil is an integral part of man's environment.

There seems to be a natural tendency, perhaps biologically driven (Rapoport, 1971), for most animals (including man) to explore objects seeking for comparisons with other objects that are already familiar to them. Philosophers and scientists have explored this phenomenon in great detail. In regard to the human understanding, Bridgeman (Cline, 1963) considers that the explanation is basically an act of recognition of familiar correlations among phenomena in nature. In the context of use of language for identifying the objects of our world, Kuhn (1971) elaborates on concepts of L. Wittgenstein. He suggested that in the confrontation with previously unobserved activities or objects, one applied a given term to something because what is being observed bears a close family resemblance to other things that one has previously learned to call by that name. Rapoport considers that "all understanding stems from perceived anologies-recognition that something is like something else."

The process of the human mind is reflected in its natural inclination to organize knowledge by grouping those objects on the basis of similarity. The process of sorting objects, ideas, or activities into groups and naming those groups is called classification. The product of such a process is referred to as a classification system (Simonson, 1971).

Being primarily a result of the human mind, some sort of classification is used continually by people. The process of classification is an exercise in logic, and every human being has some amount of natural logic--his common sense--that allows him to readily classify simple, everyday objects. Mort people without formal training in logic can set apart plants, animals, and minerals. But as stated by McCall (1952), one could not expect to readily deal with the complexities of his environment with common sense alone. It is in the realm of science and philosophy where man encounters the tools for classification of complex objects. The procedures of classification in science rely particularly on logical reasoning, the art of orderly thinking.

Thus, the role of classification is one of facilitating the mental handling of objects or ideas. It is a product of the human mind perfected as a procedure of the scientific method. To many people, particularly to those who have to deal with practical problems, classification as a scientific procedure seems a complication of little practical value. This is a mistaken assumption. Instead, classification is particularly directed to what Rapoport (1971) considers the most conspicuous feature of science: "a systematized search for simplicity, a method of making the world predictable."

Objectives of Soil Classification

Soils exist as unique kinds that are the result of specific combinations of the effects of the soil forming factors. The soil environment on which man depends in many ways is a complex one. To understand these unique kinds of soils, man has created the device of a soil classification systen.

In the development of soil classification a clear definition of objectives has been stated by Cline (1949):

> "The purpose of any classification is so to organize our knowledge that the properties of objects may be remembered and their relationships may be understood most easily for a specific objective."

Inherent to this definition are both immediate and ultimate objectives. While the immediate purpose is understanding, this is directed toward an ultimate, specific objective. Jevons, cited by Grigg (1965), stated: "There can be no use in placing an object in a class unless something more than the fact of being in the class is implied."

Thus, understanding is directed to other ultimate purposes: to gain some control of the environment and to enable inductive generalizations (predictions) to be made about the objects being classified. Rapoport (1971) considers that while understanding *per se* does not completely insure control, there is an undeniable connection between understanding and control. In soil science, practical applications of this are facts. It is the understanding of soil properties that has permitted the avoiding soil spoilation by erosion or oversalinization in soils susceptible to those processes in many parts of the world. In regard to the relationship between understanding and prediction, soil classification is the foundation for predictions of behavior when soils are used for various purposes. Thus, the following remark by Rapoport (1971) reflects the practical importance of soil classification: "The test of understanding of a portion of the world is a test of the ability to predict something on the basis of the alleged understanding."

One other objective of soil classification is to permit the successful transfer of knowledge about soils in one place to another (Simonson, 1971). This has been evident in the application of practices developed in some countries of advanced technology to countries that otherwise might be dealing with their soils by processes of trial and error.

By soil classification, scientists define kinds of soils which provides them with something they can talk about consistently. Classes provide some identity for soils with many properties that could not properly be referred to by other short descriptive terms. The recognition of those classes and their counterparts in nature allows a soil surveyor to make the delineations that result in a soil map.

Systems of Soil Classification

According to their purpose, soil classification systems can be of several kinds. Most authors (Cline, 1949; Simonson, 1971) distinguish the natural or scientific classification designed to group objects with many common attributes, from the technical groupings or interpretive classifications designed to group objects for specific limited objectives, generally in terms of their behavior or characteristics for a single specific use.

The foundations of natural classifications have their origin in the works of Aristotle, adopted and further elaborated by logicians through time. The principles of logic involved in the development of soil classification come mainly from the treatises of John Stuart Mill (1874) and P. W. Bridgeman(1927). Those principles have been discussed for soil classification by M. G. Cline (1949, 1962, 1963) and G. D. Smith (1963), among others.

The function of a natural classification is, as defined by Mill:

> "to provide that things shall be thought of in such groups, and those groups in such an order, as will best conduct to the remembrance and to the ascertainment of their laws."
> (Smith, 1965).

The objective of this kind of classification is, according to Cline (1949) "To show relationships in the greatest number and most important properties."

In this process, one groups soils "that belong together" (Cain, cited by Smith, 1963) on the basis of our current understanding of their properties and genesis. This is the kind of arrangement that pedologists have used in soil surveys.

Natural classifications of soils have been developed in nearly all countries where soil science has reached an advanced stage. Nearly all of those systems have been subject to revisions and modification with the expansion of knowledge about soils. Succession of classifications is a phenomenon common to nearly all disciplines (Buol et al., 1973). Cline (1949, 1961, 1963) and the Soil Survey Staff (1960) have emphasized that classifications are not truths by themselves, but merely contrivances of men to organize ideas in ways that appear useful. They are abstracts of the state of knowledge at the time.

Strict adherence to knowledge of the past would not only limit the acceptance of new facts as science progresses and thus "prejudice the future" (Cline, 1963), but would also imply a sense of completeness. As stated by Buntley (1962), a static classification presupposes a complete knowledge and understanding of the entities being classified and the classification itself will "serve no purpose other than perhaps as a headstone for a dead science."

Thus, particularly in the United States and the Soviet Union, classification systems have been under significant scrutiny. Other systems have also been developed in other places. In Europe, the better known systems are those developed in France, largely by Aubert; in Belgium, under the guidance of Tavernier; in addition, a system in the western Europe context has been developed by Kubiena, and another for the United Kingdom by Avery. In Germany the system of Kubiena has been modified by Muckenhausen. In other continents major efforts have been made in Australia and Canada. In Latin America, Brazil has been trying to develop its own system. Most of the other countries in Latin America use the U.S. system. Efforts to develop an international system have not been successful, and it does not seem feasible to achieve it in the near future. The World Soil Resources office of the Food and Agricultural Organization in a joint effort with the United National Educational Scientific and Cultural Organization is completing a soil map of the world through a series of maps with a common legend. Such maps have already been prepared for

Europe, Africa, and South America. Comprehensive discussion of the different classification systems will be beyond the scope of this paper. Discussions are available in several publications. Some of the more recent relevant summaries are the International Symposium on Soil Classification(1965),the FAO/UNESCO World Soil Resources Report 32(1968), and the book by Buol et al (1973). All these publications contain references to the original sources.

Because the United States system of classification has been used in Venezuela, a brief description of its evolution is presented here. The United States soil scientists have designed their systems to fit the needs of soil survey. Systems were developed by Whitney in 1909, Marbut in 1935, and Baldwing, Kellog, and Thorp in 1938. The latter was first published in the 1938 U.S.D.A. Yearbook of Agriculture --Soils and Men, and a supplement with other groups appeared in the Vol. 67, No. 2 (1949) issue of Soil Science. The work on soil classification was intensified in 1950, and a series of revisions, which were called "approximations," were prepared under the leadership of Guy D. Smith. Most of these revisions were internal documents within the National Cooperative Soil Survey until the publication of the "Soil Classification, A Comprehensive System, 7th Approximation." (Soil Survey Staff, 1960). This system, with some later supplements, have been widely used in the United States and many other countries, including

Venezuela. Further improvement of the system is currently under way. In 1970 appeared a publication of some unedited chapters of the Soil Taxonomy, (Soil Survey Staff, 1970) the approximate current designation of the system which will be published in complete form in 1974.

The following discussion will refer to the characteristics of this system and its foundations. Although soil taxonomy may be familiar to many soil scientists, an attempt will be made in this discussion to present those concepts which are believed to be most helpful for the understanding of the subject by many people, without special training in soil science. The discussion relies heavily on the works of M.G. Cline (1949, 1962, 1963) and the teachings of the same author and R. W. Arnold in courses at Cornell University.

Classes and Categories

"A class is a group of individuals, or of other classes, similar in selected properties and distinguished from all other classes of the same populations by differences in these properties" (Cline, 1949). The term taxon, plural taxa, is equivalent to class. A category is an aggregate of classes "formed by differentiation within a population on the basis of a single set of criteria" (Cline, 1949).

Some populations are so complex that one single set of classes does not give enough insight into the objects being classified and their relationships. In such cases, a classification system with a hierarchy of classes organized into categories is necessary. The scheme thus formed is called a multiple category system; the categories represent different levels of abstraction. The Soil Taxonomy is such a multiple category system and includes ten categories: order, sub-orders, great groups, subgroups, families, and series. The information that is displayed on soil maps to planners is given in some of those categories. As the level of abstraction decreases from orders to series, those who deal with planning at broad levels are likely to be more familiar with the higher categories, mainly with the great groups or subgroups. The series are more familiar to those who deal with projects.

Each of these categories is subdivided into several classes. The designers of the system considered information from 60 years of soil survey experience in the United States and from more than 8000 soil series. Yet, they considered that amount of information incomplete, and the system was designed to be "open-ended" and subject to additions of new classes and criteria as more information becomes available (Cline, 1962).

The forming of classes depends on the selection of a property that is possessed in some degree by all members of the population. Once a class is formed, one still has a group of individuals that are very much alike, but are not identical. As in statistics, soil classifiers use measures of central tendency to estimate the middle of the class. One individual thus typifies the central concept of the class. All the other members of the class may approximate or deviate from the central concept. In this context, the placement of an individual in a given class depends on its similarity to central concepts of different classes.

In a different context, classes may be differentiated on the basis of limits of properties chosen to define the limits of classes. This sets quantitative limits beyond which a definitive property may not vary within a class. This is the basis on which classes are differentiated in Soil Taxonomy.

A characteristic that is selected as the basis of grouping is called a differentiating characteristic. Among natural objects, many properties vary together with others; properties that change in this manner are said to display covariance and are called accessory characteristics. Its effect is to multiply the statements about the class and to increase the significance of the class. Thus, in the formation of classes, the best grouping is assured by selecting a differentiating characteristic that "(a) is itself important for the objective and (b) carries the greatest possible number of covarying accessory characteristics that are also important for the objective" (Cline, 1949).

In a multiple category system the properties of a class in a given category are the accumulated differentiating and accessory characteristics of that category and all others above it. Therefore, the number of statements that can be made increases as categories become lower in the hierarchy system.

The individuals in a population of natural objects seldom differ in one single property, instead, they vary in sets of properties. From the many properties that differentiate these objects, classifiers deliberately chose those that will best serve their purpose. One thinks of those properties as being diagnostic and definitive for the class.

The characteristics that have been chosen to differentiate classes in the Soil Taxonomy are soil properties that will likely determine the behavior of soils under different uses, and that are believed to be the marks of processes of soil genesis. This is so because the current understanding of soils rests on the principle that present morphological features are the result of past and current effects of soil forming factors. The use of genetic principles in the separation of classes is not only directed toward understanding soil genesis, but appears at present to be the most objective basis for the applied purposes of soil survey. Soils which are genetically similar will have similar properties and their responses to use will be the same.

Another reason for the genetic basis of classes and categories in the system is the necessity for the classes to have geographic counterparts in nature that can be delineated on soil maps. Thus, while the Soil Taxonomy has a genetic basis, it was developed " . . . to serve a program that has a practical objective" (Smith, 1963). This has been clearly explained by Cline (1963) as follows:

> "Genetic considerations governed the formation of classes, their character, and their organization in the system. From the perspective of one who applies the system to real things, the criteria that determine placement of a given soil individual in a specific class are soil properties."

Smith (1965) considers that

> "the most important single attribute of the system is that it subordinates both genesis and practical considerations to quantitative definition in terms of properties, which are fact within the limits of operational measurements."

This arises from the influence of Bridgeman logic and his concept of operational definition, according to which concepts are best fixed when they are described in terms of the operations used for measurement. If terms are related to the set of physical operations that are performed for its determination, then they will have operational meaning. These concepts were originally developed in physics but are now part of the modern philosophy of science. Franck (1957) states:

> "The procedure of modern science combines the methods of strict logical conclusions with the method of sense observation by confining the logical deductions within a formal system (axioms and theorems) and producing the object of sense observation by applying operational definitions to this formal system."

This is reflected by current trends in some sciences of interest to planners, like regional analysis and social sciences (Grigg, 1965). In the Soil Taxonomy, application of these concepts results in the selection of properties that may be observable and measured by specified procedures. Thus, for example, soil colors are referred to the Munsell notation, thicknesses of diagnostic horizons are specified, and values of measured properties are referred to specific methods. Civil engineers will find this quantification familiar to their handling of properties used in the classification of soil as a material, and of other properties of reference for construction works which are identified with the technique used for measurement. As stated by Lambe and Whitman (1969).

> "The direct approach to the solution of a soil engineering problem consists of first measuring the soil property needed, and then employing this measured value in some rational expression to determine the answer to the problem."

Anot r interesting feature of the system is the nomenclature. The system uses terms derived from the Latin and the Greek that intend to be mnemonic and connotative of the soil properties. They were selected also to be able to indicate the place of the taxon in the system, to be as short as possible, and avoiding existing terms (Smith, 1963). The name used for a class at the level of great group, for example, will be formed by three syllables, since it is in the third category of the system. One great group that should be familiar to planners in Venezuela are the Tropaquepts. Most soil survey users will get the first impression that such names are just complicated and even frightening. But the term becomes simple and useful when one sees that the last syllable <u>epts</u> refers to the order Inceptsols, meaning that it is a soil with incipient development; the middle syllable <u>aqu</u> refers to wetness, and the first syllable <u>trop</u> indicates a warm soil temperature regime. These are just the most conspicuous bits of information provided by the name in a very condensed form for illustration. From this information, and with a little bit more background, a planner would be able to know that he is dealing with a young soil, that will probably not have fertility problems but that has a drainage limitation that will likely affect agriculture, septic tank performance, among other things. This understanding should enable him to make wise decisions regarding the use and management of this soil. Thus, planners should be encouraged to become familiar with this nomenclature in order to derive benefit from its advantages.

Relationship of Taxa to Applies Objectives

Natural classifications are designed to reveal our concepts of order in nature by properly identifying the individuals with which we are concerned and organizing these individuals in such a way that we can see their relationships and make inductive generalizations about the objects studied. Cline (1949) stresses the point that no other grouping performs this important function and therefore this is the attribute that establishes its distinctiveness from all other groupings. Since the interest at this point is the use of taxa for practical purposes by planners, agriculturalists, and engineers, this part of the discussion concentrates on the aspect of inductive generalizations and their application to specific cases.

While the classes in the Soil Taxonomy provide information that can be useful for many applied purposes, they are not interpretive themselves for direct application to applied objectives. Cline (1963) states that

> "the practical role of the classes is to convey identity to otherwise unidentified real things in groups that can be interpreted. Interpretation of them requires at least one additional step of reasoning."

For applied objectives, the classes are the basic units that can be regrouped or subdivided on the basis of the characteristics of interest for each objective. This is the approach followed in the formation of technical groupings.

The use of the classes alone without further arrangement is more limited. Riecken (1963) has discussed in detail the application of soil classification in farming. Orvedal (1963) has dealt with the application in engineering. Both authors refer to the fact that the extent to which predictions can be made about the classes varies according to the categorical level, since the information for each class accumulates from the highest to the lowest category. This is a characteristic of multiple categoric systems (Orvedal and Edwards, 1941; Cline, 1949). In those studies it is shown that the usefulness of the higher categories is more indirect, as would be expected, and the practical importance of the soil series becomes evident. Being the lowest category, soil series are the units with the attributes of homogeneity required for many applied purposes. It is important to note the fact that the family category, the next above the series, has been reported as having a substantial anticipated utility for a variety of engineering applications (Orvedal, 1963). In the differentiating criteria of the families are included properties important to the soil-water-plant relationship; this category has also great potential for interpretations in agriculture. Its applicability to the soil survey programs in Venezuela should be thoroughly explored.

The limitations inherent to the use of a multiple category natural soil classification for applied objectives are thus related to the relative homogeneity of the classes in regard to some specified properties. Since no single set of properties would be equally significant to all objectives, it is necessary to have a device that will produce some partition of characteristics in favor of more homogeneity. Such a device is called a phase.

A phase is a subdivision of any taxon of any category based on properties significant for man's use, management or interpretation of the soil. As such, it is a pragmatic unit, external to the taxonomic system but related to it (Cline, 1962), that has no restriction regarding the categorical levels.

According to the purposes, many kinds of phases can be formed. The Soil Survey Manual (Soil Survey Staff, 1951) lists slope, erosion, stoniness, soil depth, physiographic position, and some other soil characteristics as phase criteria. In fact, one can use any property or criterion to create phases if these properties are significant for the objective. Phases are named by adjectives following the class name; thus, the term "Guanare, deep" identifies the deep phase of the Guanare soil series and the terms "Typic Hapludalf, stony, steep" identifies a phase as a subgroup. One of the characteristics commonly used to segregate phases is the texture of the surface horizon, formerly called soil type. In the past, the soil type was a taxonomic unit below the level of soil series. In the

Soil Taxonomy the soil type does not have status as a category. It still means the texture of the surface horizon, as one among many other kinds of phases.

The significance of the phase in adapting taxa to applied objectives comes from its flexibility, both in regard to the selection of criteria for differentiation and to the levels at which it can be applied. Its effect is to provide soil units that are homogeneous enough to be applied to specific soil use objectives.

Soil Classification in Venezuela

The soil survey in Venezuela has been carried out essentially with the criteria and technical procedures of the United States National Cooperative Soil Survey adapted to the conditions and needs of the country. The classification systems used are therefore those developed in the United States. Prior to 1960, the Soil Classification System of 1938 was utilized, and much of the information about soils described in the country is related to that scheme. Since 1960, nearly all agencies involved with soil survey have applied the Seventh Approximation (Soil Survey Staff, 1960) and the currently available chapters of the 1970 Soil Taxonomy.

The application of a system developed primarily for soils of other areas to local conditions in Venezuela involves most of the exigencies characteristic of any process of technology transfer. Because the Soil Taxonomy was especially designed to serve the Soil Survey of the

United States, its use in Venezuela has presented some of the problems associated with this process. The overall effect of its use, however, has been quite positive. Westin (1963) prepared a preliminary report of the distribution of soils in Venezuela at the great group level and found the system to be very useful for classifying soils in this country. The use of the system in the last decade in Venezuela provided a test for it, and the system has been a tool applicable to the soil survey program. In fact, every time a soil is placed in the classification system, the system is being tested. After this process it became evident that, although the system is appropriate for most of the soils studied, some important kinds of soils in Venezuela do not fit properly in the existent classes of the Soil Taxonomy system. Comerma (1971) has presented a study of the problem in detail. Several other works have dealt with this problem for specific cases (Soc. Ven. Ciencia del Suelo, 1972). The difficulties seem to be mainly associated with proper placement of soils of the country in taxa where the criteria of classification are not adjusted to the conditions of the country, as in the case of soil moisture regimes. This, incidentally, represents a potential object of research and improvement in many kinds of regions in the world. Olson (1972a) has summarized some application of probability calculations done by Dr. F. Newhall of the Soil Conservation Service to define moisture regimes in Iran for soil classification according to the Soil Taxonomy. Other problems are simply the lack of usefulness of some criteria for the interests of a particular country like Venezuela. The family category, for example, utilizes properties that are considered important for soil-water-plant relationships. In the United States, families are commonly separated on the basis of texture, mineralogy, and soil temperature regime. Texture and mineralogy are also important for Venezuela. The usefulness of the soil tempreature regime within Venezuela is practically nil, since most of the soils of lowlands will belong in one regime: the "isohyperthermic" (mean annual soil tempreature 22°C and difference between mean "winter" and "summer" temperatures less than 5°C). However, the use of soil temperature regime as family criteria is important to transfer knowledge from other places in Venezuela. In other cases there is no provision in the Soil Taxonomy to seggregate, at middle categories, soils which have variations in their properties worthy of separation. Dumith* has reported, for example, the problems associated with classification of Vertisols having high salt content and those that are non saline.

The experience obtained during this 13 year period of application of the system in Venezuela is considered

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*Deud Dumith, personal communication,July 1973.

extremely important and valuable and should help soil scientists in setting the patterns for the future. Comerma (1971) and others have suggested to continue the use of the system and deal with the problems of difficult placement of some soils in the existing classes by segregating these soils into proposed new classes. This suggestion has been carried already on an informal basis. In a recent visit to the U.S.D.A. SCS headquarters, Dr. R.W. Simonson, Director of Soil Classification and Correlation, informed a team of soil scientists from the Division of Edaphology of the Ministry of Public Works of Venezuela that there is no official mechanism to handle the proposals for new classes at the present moment. He recommended new classes should be proposed through fully documented presentation of the data in soil publications and periodicals of international circulation. This data publication would also contribute to exchanges of information and experiences with workers in other countries.

The most important question is that the adjustments or modification of criteria for the use of the soil classification system be conducted by complete agreement of all soil scientists in charge of soil surveys in Venezuela. Isolated arbitrary decisions in regard to setting up criteria of soil properties of classes would only contribute to confusion. Even though there is already some experience in the use of the system, there is still much to be done for an appropriate judgement about the goodness of the system for the conditions of the country. One good way to test any system is to use it, but additional investigations are necessary and these still have to be developed in Venezuela. Comerma* considers that some time span should be defined, maybe 30 years, for an appropriate evaluation of the taxonomic classification before a decision involving drastic changes can be taken. Soil classification everywhere, of course, is in a state of flux and change as more data about soils is collected and evaluated.

From the considerations in the preceding paragraphs, it is proposed here to formally support the suggestion of using the United States Soil Taxonomy for soil survey operations in Venezuela, handling the problem cases as proposed new classes and setting the next 30 years as the period for intensive investigations on soil classification in Venezuela. This means that while the interest in soil classification is considered of prime importance, efforts toward creation of a national system of classification in Venezuela other than in the context already expressed are not considered feasible or desirable at this time. To engage in such a task would require devotion of significant resources to a target that could not reasonably compete in

*Dr. J. Comerma, Coordinator of the National Soil Program at the Ministry of Agriculture, personal communication, July, 1973.

priority with other needs of soil evaluation. Soil survey in Venezuela will be facing a challenge of increasing efficiency for the next 30 years. The mechanism discussed has the advantage of allowing continuity and uniformity to soil survey operations while at the same time maintaining the scientific interest in the growth of knowledge about the soils of the country. In this line of thinking, the question of soil classification is placed in the perspective adequate to the conditions and needs of Venezuela.

To summarize, natural classification systems in soil survey programs are necessary to organize the existing knowledge about soils, and to provide for units with attributes of identity meaningful to the purposes of making inductive generalizations about soils and transferring soil information. From the various available schemes, which are the result of necessary succession of concepts, the soil survey agencies in Venezuela are using the new United States Soil Taxonomy. Conspicuous features of this system are its logical foundations, the subordination of genetic and practical considerations to measurable soil properties, its nomenclature, and its open-ended character. The classes of the system, while providing information relating to direct use of soils, are not necessarily interpretive themselves but can be rearranged for numerous practical purposes.

SOIL TECHNICAL GROUPINGS

Technical grouping of soils is their placement into classes showing similar behavior for practical purposes. This kind of arrangement has also been called special purpose, artifical, and interpretive classifications, in contrast with the natural classifications as discussed in the preceding section.

The distinction between technical and natural classifications is found in the objectives of each. The objective of natural classifications is to show relationships on the greatest number and most important properties (Cline, 1949). The objective of technical groupings is to show relationships in terms of potentialities for use, for which differences in one or just a few selected characteristics or conditions may be critical (Orvedal and Edwards, 1941). The primary units that are classified in taxonomic systems are polypedons. In technical groupings one classifies units of taxonomy or phases of them. A natural classification of soils is a basic need before technical groupings can be made.

General Principles

A prime requisite for technical groupings is a clear understanding of the objective for which the grouping is beind made. There are compelling reasons for this objective being emphasized. On the one hand, there are those needs of operational character that have been stressed throughout this paper in regard to the efficiency and usefulness of soil survey. Efficiency always involves the use of resources, and one must be aware of the significant waste of time, money and personnel that results from engaging in activities of ill-defined objectives. On the other hand, there are those considerations related to the rules of classification. Simonson (1971) has indicated that the same logical restrictions hold for the design of technical groupings as for natural systems. Other authors (Cline, 1949; Barnes, 1949) have pointed out the relationships of the grouping to the hierarchy of classes in regard to the number and accuracy of statements that can be made at each level. This aspect was thoroughly elaborated by Orvedal and Edwards (1941). The following discussion is based on their concepts.

The rearrangement of soils into larger and more inclusive groups results in more heterogeneity, that is, the character of the new groups formed becomes more general. When the original groups are classes at some categorical level in a taxonomic system that are gathered into groups of successively higher categories, we make a categorical generalization. Groups may therefore be categorically generalized at various degrees or levels. If soils are grouped at the degree of detail inherent to the lowest category of the Soil Taxonomy, that is, designated as series and phases, then they are considered to be categorically detailed. As the groups formed by categorical generalization become more general, the number and precision of the assertions possible about such groups is reduced. Thus, simple groupings made at high levels of generalization can serve very few objectives. This illustrates the practical importance of a clear definition of objectives for the grouping because it is the objective that governs the level of generalization. Incidentally, this very fact also illustrates the importance of detailed soil surveys; the units of the lowest category (soil series and phases) are the most homogeneous units and their interpretation will provide the most numerous and precise statements which are important for planners and engineers.

Grouping of soils into groups of the same category can be made only on the basis of differentiation. Otherwise one might place soils that are equally suitable for the purpose of the grouping into separate classes. This principle supports the remarks by Simonson (1971) about the logical restrictions of any grouping and the importance of clear objectives for the selection of the characteristic used as the basis of differentiation. Unclear objectives may result in violation of the basic principles of classification and will contribute to confusion. According to the purpose, technical groupings can be made for the following uses:

1. To feature selected properties - groups are made according to soil characteristics like slope, steepness, texture, etc.
2. To feature simple inferences such as those about factors

affecting soil behavior. If one needs to know how much land in an area will need artificial drainage, he can use the potential for runoff of each soil unit, and organize the units into groups, like very low, low, medium, and high runoff potential categories.

3. To feature complex inferences, such as those about soil quality. In this case several factors affecting quality can be rated, and soil units can be evaluated according to the rating for each factor. The judgement is made from the combined effects on quality. One of the widely used technical groupings of this kind is the so-called Land Capability Classification (Klingebiel and Montgomery, 1961), which groups soils into eight classes. An equivalent for the conditions of Venezuela has been recently developed by Comerma and Arias (1971).

Kinds of Technical Groupings

Technical groupings can be made in terms of soil limitations, management, and anticipated performance for the specific use of the soil selected.* The kind of technical grouping depends on the interest of the user and on the specific soil use being considered.

<u>Groupings by limitations</u>.

These are formed by selecting those characteristics that are believed to be, per se or by their effects on soil

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*From unpublished manuscript by M.G. Cline.

behavior, limiting for the purpose. The groupings thus formed will be mostly single category systems consisting of three or more classes that indicate the degree of limitations. Slight limitations would imply that soils in this group would have satisfactory performance and will need little or no modifications or special practices for the use being considered. Soils having moderate limitations have some limiting factors, but these can be either overcome for the intended use or controlled by proper management. The extra cost involved should not make the soil uncompetitive with other soils similarly-rated in regard to the same use. The soils classified as having severe limitations cannot be appropriately used for the intended purpose except at exceptionally high cost. Their degree of limitations is so high that use of the soil without highly expensive corrective measures might involve even considerable risk.

Limitation ratings can be made for many purposes, but they are usually valid only for their specific objective. Soils that have slight limitations for flooded rice, for example, would have severe limitations for septic tanks or for oil palm growth. Consequently, these kinds of interpretations are useful in planning stages that deal with specified uses of soils in project areas.

For agricultural purposes, this kind of grouping is particularly well suited to interpretations for individual crops. An example is a study conducted for grape production in several sizable areas of New York State (Arnold and Roach, 1971). For interpretations of potential for kinds of crops, like pastures, field crops, and woodlands, suitability groupings are preferred (Edelman, 1963).

For non agricultural uses, soils can be rated according to the degree of limitation for such uses as waste disposal, roads, underground services, or foundations for low buildings, among many other engineering purposes. These ratings are extremely useful for city and county planning, due to the availability of detailed soil maps that provide soil units such as series and phases surveys for areas of such extent. The interpretations based on groupings of limitations made from combined soil units like soil associations are more complicated and their precision depends on the information available for the individual components of the soil association. Because this is generally the soil information available for large areas, interpretations from soil limitations ratings should be carefully evaluated for the broad stages of regional planning.

Additional value is given to limitation ratings that give both the kind and degree of soil limitation. An interpretation of this kind for building sites for example will indicate "slight: 3 to 8% slope," or "severe, surface rockiness." This is being used in modern U.S. soil reports like the Broome County Soil Survey (Giddings, et al., 1971), and in soil interpretation reports prepared from soil surveys (Goodman, 1971).

<u>Groupings by management</u>.

These units are formed by grouping soils in classes that will require similar sets of practices, or similar alternatives of such management sets, for efficient use. The criteria followed in the grouping depends very much on the soil conditions of the area and the intensity of use. However, the categories depend primarily on the purpose of the grouping and the information provided about the soil features needed for the specified purpose.

In a modern soil survey, the management needs are described for each mapping unit in detail. Groupings by management are difficult to prepare from most soil surveys in Venezuela because the information generally provided in regard to use and management needs is too vague. In the U.S., this information has proven to be very useful. Individual farmers and extension agents need to translate soil yield data into operational practices. Agricultural planners can be given support in decision making by providing to them information on management of soils of large areas, as has been done in New York State (Feuer, 1965).

The capability units of the Land Classification System (KlingebielandMontgomery, 1961) are groupings of soils having similar management needs for certain kinds of farming. The capability units have been used with relative degree of success for planning purposes. In Genesee County, New York, those capability units were used as the building blocks for an overall appraisal of the agricultural potential of the county, together with other soil information (Genesee County Dept. of Planning, 1970). The system proposed by Comerma and Arias (1971) for Venezuela provides a means for grouping capability classes into management units. The designers of this system considered two broad management levels. One of the levels corresponds to a set of practices that are commonly applied in the current technology, without irrigation or drainage works. The other level, that of improved technology, would imply practices of irrigation or drainage and more intensive cultural practices.

Groupings by anticipated performance.

This is the kind of interpretation that rates kinds of soils according to their predicted output, such as crop yields, or in terms of suitability groupings for specific uses.

For agricultural uses, one of the most common of these interpretations is that which provides predicted yields. It is extensively used in soil surveys in the United States. The basis for these predictions are not only the soil properties but all other evidence available from farm experience and experimental stations on individual soils (Barnes and Harper, 1949). Their accuracy depends on the amount and reliability of the information on which the prediction is based. Though these yield predictions are not currently considered in soil survey reports in Venezuela, it is believed that a great potential exists for producing and using this kind of information. There are several important common crops, like sugar cane in the central west, rice in the llanos, and plantains in the Lake Maracaibo basin, that have been grown for many years in these areas and have been the object of research by the experimental stations. Considerable information may be obtained from experienced producers and crop specialists and related to the kinds of soils for yield predictions through specific procedures.

Suitability groupings of soils for agriculture are also common. These can be made for individual crops or for kinds of crops. There is already a considerable amount of information in this regard in the United States and Europe (Edelman, 1963; Haans and Westerveld, 1970). Several attempts at studying soil properties in relation to individual crops have been made in Venezuela (Strebin, 1947; 1965; Hernandez, 1956; Guilarte, et al., 1971).

Suitability groupings are also used for non-agricultural purposes. Soils can be rated according to their expected potential as sources of materials for construction when engineering requirements are simple and clearly defined. Soils can also be rated for houses, roads, or other uses on the basis of soil properties and engineering experience.

In most cases, suitability groupings are made from suitability ratings which imply not only soil limitations but also knowledge of the measures required and soil performance. Normally, a system of ratings which identifies classes as good, fair, or poor for a given use will be satisfactory for most uses. As in any kind of rating, the usefulness of such ratings is conditioned by the degree of accuracy and detail with which the classes are defined. The kind of criteria that should be considered depends, of course, on the specific use for which the rating is made.

The value of any grouping, whether it is made by limitations, performance, or suitability ratings, depends on the knowledge available for the interpretation. Much of this information has to come from fields other than soil science. This means that the soil scientists need to work with specialists of other disciplines in formulating criteria for the ratings.

The kind of interpretation depends on the objective and the interests of the expected users. Thus, some interpretations can best be made in terms of soil limitations and others in terms of suitability. Modern soil surveys normally present both kinds. Some authors (Haans and Westerveld, 1970) consider that the suitability evaluations on the basis of limitations will serve most objectives best. Reports made for planning purposes will usually have a combination of kinds of interpretation in tables and maps (Genesee Co. Dept. of Planning, 1970; Monroe Co. Planning Council, 1967, 1970; Rose, *et al.*, 1972; Wulforst, *et al.*, 1968).

The possibilities of technical groupings of soils for several uses in Venezuela are conditioned by the information that is available to the soil scientist. Substantial improvement can be made with some minor additions to existing procedures; for example expressing some soil properties in engineering terms can be achieved by determining Atterberg limits. Additional benefits can be obtained from other efforts, such as the use of information from farm experience and experimental data for yield predictions. Still, to provide the interpretations that are already standard in most advanced countries, it will be necessary to implement some changes in concepts and procedures that might involve drastic departures from the past. The consideration of non-agricultural uses, for example, requires some modification in the depth of the soil that was traditionally considered only for agricultural uses. The information needed and the ways in which this information is collected, manipulated, and best displayed, along with its interpretation, are requirements that go beyond the soil scientist's field of command and abilities in some cases. Technical groupings for some agricultural and engineering interpretations would also need some modification of current field and laboratory procedures in some cases.

SOIL MAPPING AND SOIL MAPS

Soils vary geographically according to effects of climate, biota, relief, parent material and time. The interaction of these factors produces unique kinds of soils over the landscape. The spatial distribution of these different bodies of soils constitute patterns that are not arbitrary but that have some kind of order. The variation in soil attributes is empirically related to external features which are perceivable at varying degrees in the landscape; that variation is subject to the complexity of natural systems. Perception of order in nature varies according to the complexity and to the conceptual model through which the landscape is observed (Jansen, 1972). Models used in soil mapping are mostly derived from concepts of geomorphology and pedology. It is, for example, from our concepts of fluvial geomorphology that one is able to recognize, in an aerial photograph, a river bank to predict what kind of soils can be found in the bank, and to separate these soils from other soils in adjacent areas. Lateral boundaries are determined by the geographic pattern inherent in our model. Knox (1965) observed that the most common boundary criterion is discontinuity, and by discontinuity he means simply the change of concentration or degree of expression of one or more properties, commonly observed as a maximum rate of change with distance or with time. He also states that sharp lateral discontinuity is present in soil landscapes but it is rare. When maxima in the lateral rate of change are correlated with surface features they provide a basis for efficient soil mapping. Cline (1963) observed that:

> "contrary to popular opinion, a soil mapper samples internal properties primarily to verify and refine predictions of kinds and boundaries of mappable soil bodies. The predictions are based on correlations between sets of internal soil properties and distinctive landscapes whose boundaries are not completely arbitrary."

He further considers that such correlations would be "explanations" in the sense discussed by Bridgeman in his Logic of Modern Physics (1927).

The work of soil mapping involved in the soil survey also has to be related to the objective. Jansen (1972) states that a soil scientist's task is to discover a useful pattern of orderliness in the spatial distribution of soil attributes and to communicate that pattern to others. He also considers that in doing so the mapper follows a process of ommission and selection. This is of paramount importance in modern soil survey since the objectives of the survey will govern what must be omitted and what must be selected for best serving the purpose. Thus, any area might be mapped differently for different objectives.

The Process of Soil Mapping

It is not the purpose of this section to discuss procedures for soil mapping. Such procedures vary and are discussed in detail in many publications. The purpose here is to describe in a very succinct way the general character of soil mapping in modern survey operations and the bearing of the objectives on the process.

Generally the first step is an airphoto interpretation of the area directed to landform recognition and to identification of landscape features from which soil attributes can be inferred. The airphoto interpretation is done with the aid of stereoscopes. The amount of literature in the field of airphoto interpretation for terrain analysis, landforms, and soils is indeed immense. Interested readers are directed toward some of the better known references including Belcher, 1945, 1948; Goosen, 1967; Soil Survey Staff, 1951, 1966; Am. Soc. of Photogramm, 1961; Tricart, et al., 1970; and Editions Technip, 1970.

Normally, black and white low altitude stereo pairs are used for aerial photointerpretation. Infared photography is less commonly used, but is finding increasing application. The use of color air photos for soil identification is in an incipient stage (Simakova, 1959; Kuhl, 1969). The development of air photo techniques and remote sensing has attained considerable status in the last decade so that there is little doubt that these will find increasing application in soil surveys in the future. Several authors have seen substantial advantage in the use of stereoscopic ortho photos for soil evaluation (Crosson and Protz, 1972, 1973; Protz and Crosson, 1972). The possibilities of remote sensing imagery have been discussed by various authors, including Belcher, et al., 1967; Finch, et al., 1973; Mathews, et al., 1973;and Elbersen, 1973. Most authors agree that the extent to which remote sensing (in addition to good panchromatic photography) can be used to advantage in soil surveys is yet to be fully determined (Orvedal, 1971). A recent experience indicates that small scale color infrared imagery has good potential in soil surveys, "but its effective use will require competent, innovative soil scientists that consider it as only one of many tools available" (Daniels, 1972).

In addition to air photo interpretation, soil surveyors analyze all the existing information about an area related to soils. previous soil maps, geologic data and maps, geomorphology, hydrology, climate, engineering, and other information is gathered and evaluated. With all this background a soil survey work plan is prepared and the first basis of the final soil map (called the mapping legend) is established.

The mapping legend includes all separations and symbols which are to appear on the map. The field work, which is the most important part of soil surveys, is done by traverses designed to cross as many boundaries as possible, but the intensity of soil examinations along traverses is adjusted to the particular objectives and kind of survey. The same principles of detail of examinations apply to the observations made by augering and digging. Grid work at predetermined points is not necessary unless a high intensity soil survey for site planning is being made. Field procedures for soil survey are presented in detail in several manuals (Soil Survey Staff, 1951; Jamagne, 1967; Maignien, 1969). An examination of soil survey methods in Latin America had recently been made by Van Wambeke (1973). The field work in most soil surveys in Venezuela is conducted according to the specifications of the Soil Survey Manual adapted to local conditions. A large part of the mapping is done by intensive field work in "sample areas." The application of photo-interpretation provides great advantages because many separations can be made by landscape relationships. Yet, soil maps that are prepared by airphoto interpretation alone do not compete in accuracy with those made with the field work commonly conducted in standard detailed soil surveys (Pomerening and Cline, 1953; Beckett and Webster, 1969).

In Venezuela, substantial improvement in soil mapping has been achieved by application of geomorphology, particularly in the study of alluvial landscapes. Soil areas are related to depositional systems, and segments of the landscape that have external features can be identified on air photos (Zinck, 1970). Soil samples for laboratory analysis are taken and determinations are made according to standard procedures (Soil Survey Staff, 1967).

A critical part of soil mapping is the decision of where to place the boundaries on the soil map. The delineations of kinds of soils are established for segments of landscapes that have recognizable boundaries, that have sets of soil properties which are consistently found for repeated landscapes, and that are significant for the objectives of the survey. The character of the mapping units which are finally defined for the soil map should be established in cooperation with people related to the survey, to fit the purpose of the survey and the nature of the soils of the area within established limits of detail and precision.

Soil Mapping Units

Aereal extent of soil properties are shown on soil maps. A delineation is a body of soil that is represented by a boundary on a map. A mapping unit is an aggregate of all delineations <u>of one kind</u>, collectively.*

Mapping units of soils are related to soil taxa. The basic unit for this relationship is the polypedon. As noted previously, a polypedon is a composite of many contiguous pedons, most of which belong to a single soil series. Since

*From unpublished manuscript by M.G. Cline.

it is not possible to map pure polypedons, a delineation always includes other bodies of soil that do not fall within the range of the named soil series. Thus, the polypedon is the link between physical entities in nature and our concepts for soil taxa. Mapping units then are not always pure, but generally have some proportion of unlike soils. These small spots of unlike soils are called inclusions. Such included soils may be of three kinds.

One kind, designated as similar soils, consists of soils with so little difference from the most extensive soils in the delineation that different recommendations for the use and management of the mapping unit could not be made. In general; similar soils share a common limit of differentiating properties at any taxonomic level, differ in no more than two or three properties, and share limits in all of them.

The other kinds are called dissimilar soils, and apply to soils that do not share a common limit with the named series, and differ in more than two or three properties. Dissimilar soils in one delineation are considered not limiting when inclusions will not limit predictions about behavior of the mapping unit, and limiting when the inclusions of the dissimilar soil will limit such predictions.

The maximum proportions of soils allowed as inclusions in a mapping unit vary according to their degree of similarity with the most extensive soil and with the kind of mapping unit. Current standards and specifications in soil mapping, however, are directed to keep inclusions to a minimum.

Kinds of Soil Mapping Units

The mapping units in soil surveys are named as phases of soil series, variants, complexes, associations, undifferentiated groups, and miscellaneous land types. A brief discussion of the character of these units follows, with emphasis on their use and interpretation.

Phases of a single soil series are units used when the inclusions are not abundant enough to affect predictions. Thus, even though the mapping unit contains inclusions, it is considered sufficiently homogeneous for most uses and the predictions are made for the areas as a whole with the inclusions. Phases of soil series are commonly used in soil maps at scales larger than 1:30,000. They are identified by the series and texture name separated by a comma from the phase designation. For example, Rodeo, 0-3% slope.

The soil"type" is actually one kind of phase, but it has been extensively used in the past and therefore is treated here separately. Most soil maps of detailed soil surveys in Venezuela have mapping units designated as series and types. As one kind of phase, it is used in conditions similar to those discussed above. Since soil types refer to the texture of the surface horizon, they are identified by the soil series name followed by the textural class of this horizon: Maracay clay, Maracay silty clay.

A variant is a mapping unit used for kinds of soils that are too extensive to be considered inclusions but their extention is not enough to establish a new series. Being outside the range of a defined series, they are named as the series they resemble most. Identification is made by the series name, plus a modifier indicating the deviation and the word variant. An example would be "Nogal, variante calcarea." Such units are treated as another series for mapping and interpretation. Interpretation should be handled as tentative or estimated since the kind of soil that they represent has not been completely characterized or its range of variation has not been established. Much of the expected behavior may be correlated with named soil series; however, the differences need to be indicated.

Soil complexes are mapping units for sets of soil bodies having patterns of mixture so intricate that the individual components cannot be separated adequately at scales of 1:20,000 or smaller. Soil complexes are identified by the names of the taxonomic units listed in order of dominance and separated by a dash, plus the word complex or a term that implies that the same designation applies to all the units involved. In some cases one component may be non-soil, such as rock outcrop. Phases such as slope or stoniness are usually applied to complexes. The definition of the mapping unit designated as a complex has three elements; the two or more taxonomic units, their proportions, and their pattern of mixture. The interpretation is made for the expected behavior of each soil individually, and an estimate of the effect of the mixture considering the area as a whole.

Soil associations are mapping units similar to complexes in some respects. They are also a mixture but differ from complexes because the individual components could be mapped separately at scales larger than 1:20,000. They are not mapped separately, either because the scale of the published map is not appropriate for the separation, or because the work necessary for separation is not justified. Soil associations are identified by the names of the individual components arranged in order of relative proportion, separated by a dash, and the word association. A mapping unit designated as "Asociacion Guanaguanare-Morita," is a soil association. The components of soil associations often are two or three soils named as series. They also may be named for higher categorial taxa. Thus, a Hapludalf-Ochraqualf Association is an association of soils named as great groups. On small scale maps of large areas, great groups, suborders, or orders are usual associations. The interpretation of soil associations, as in complexes, presents special problems. For highly contrasting soils each component must be rated individually. If the expected behavior is similar for each component due to similar limitations, the mapping unit may be interpreted as a whole. Then the effects of each component on use of the mixture as a whole must be predicted. The treatment that should be given to a soil association for interpretation purposes should be that, however, which best fits the purpose.

Undifferentiated groups are mapping units used when two potential detailed mapping units are not worth separating because of similar behavior. They are also used for mixtures of soil that do not have the repeating pattern characteristic of soil associations. Thus, an area designated on a map by an undifferentiated group can be one or the other of two components, or both. They are identified by the names of the two components joined by the conjunction "and." An example is "Nogal and Suapire soils." Because in this mapping unit different soils are put together due to similar behavior, interpretation is usually made for the unit as a whole but in some cases the components might need separate interpretation.

Soil Maps

A map is a graphic method of presenting data related to a place. Modern cartography reflects the explosion of knowledge in its diversity, since the map has found increasing application in fields ranging from geography to medicine. Maps that deal with a particular object or that are designed for a particular purpose are called thematic maps. A soil map is thus a thematic map. Soil maps are designed to show the distribution of soil mapping units in relation to other prominent physical and cultural features of the earth's surface.

In a discussion about cartography in relation to culture and civilization, Thrower (1970) states that

> "in the modern world the map performs a number of significant functions, among which are its use as: a necessary tool in the comprehension of spatial phenomena; a most efficient device for the storage of information, including three-dimensional data; and a fundamental research tool permitting an understanding of distributions and relationships not otherwise known or imperfectly understood."

These remarks are applicable to the functions of soil maps as they are conceived in the modern conceptual framework of soil surveys.

A soil survey always includes a report and a soil map. For interpretation purposes, many other maps showing selected soil properties or cartographic units representing classes of technical groupings may be prepared. In this document these kinds of maps will be referred to as interpretive maps. The phrase soil map is used to identify the basic soil map of the soil survey.

Soil maps have many attributes that are common to maps in general, in addition to those that are peculiar to soil information. Some of those deserve mention here because of its effect on the quality and usefulness of the soil map as a whole.

The scale is the ratio of a distance on the map to its corresponding distance on the ground. In soil maps, scales are usually represented as fractional or proportional which relates linear units on the map to distances measured in the same units onthe ground, e.g. 1:50,000. Scales of soil maps vary according to the kind of soil survey. The main impact of the scale on soil maps is on the size of the smallest area that can be shown on the map. The selection of the scale is thus related to the interests of the intended users of the map. Soil maps for regional planning, for example, may range in scale from 1:50,000 to 1:250,000, or smaller. For planning irrigation developments scales of 1:30,000 to 1:5,000 or larger may be required. Some kinds of land use, like experimental plots, campus sites, and building areas may require scales from 1:5,000 to 1:1,000.

Reference marks are base lines needed on any map, like latitude and longitude; natural features like streams, escarpments, lakes; cultural features like roads, houses, power lines; and individual features like fences, ponds, or wells. They are significant as reference points for the map user. Careful location of reference marks is an important part of the map preparation, since they allow the user to read accurately the kinds of soils in specific areas and individual fields.

The legend is an explanation of, or key to, the cartographic symbols used on the map. A soil map legend includes the standard conventions for reference marks and the soil legend. The soil legend consists of the symbols and the names of the mapping units. The kinds of mapping units employed in soil surveys were mentioned previously. They may or may not represent taxonomic units. Mapping units named as soil series or soil great groups, for example, represent classes of a taxonomic system. On the other hand, mapping units named as miscellaneous land types do not represent taxa. Other common mapping units are combinations or groupings of taxonomic units, such as soil associations.

An important attribute of soil legends is the degree of detail or generalization implied in the mapping units. The arrangement of kinds of soils into larger and more inclusive groups is called categorical generalization because it results in more heterogeneous units about which fewer statements can be made. Soil series, for example, are categorically detailed because they represent homogeneous concepts. Soil subgroups, as broader taxa, are categorically generalized because they represent heterogeneous concepts. If one applied the same idea to the cartographic units, and considers the degree of refinement of the delineation as a degree of cartographic detail or generalization, the process is referred to as cartographical generalization. It results in fewer boundaries and delineations with greater heterogeneity. A soil association, for example, is a unit categorically and cartographically generalized because of its attributes of heterogeneity.

Relationships between maps and legends

Orvedal and Edwards (1941) have stated that the possible reduction in the size of the map is related, generally and within certain limits, to the level of cartographic generalization. For example, if the soil series of a detailed soil map are grouped into soil associations, the number of boundaries is reduced and the resultant soil association map can be reduced in size and still be readable. This is important for planners that would need, at the same time, a soil map of a given area with enough detail of soil information for specific development proposals and some sort of general picture of the area as a whole for land use planning at higher levels. A detailed soil map will serve the first purpose. The second purpose can be served by a soil association map, generalized from the detailed map. These authors also emphasized that since cartographic generalization results in greater heterogeneity of the map units, the higher the level of cartographic generalization the less precise are the predictions that can be made about any specific area on the map. This is highly significant because of the limitations that it imposes for soil interpretation.

As a corollary to their conclusions, Orvedal and Edwards (1941) stressed that the level of both categorical and cartographic generalization must be governed by the objective. There is no other single factor more important in the many decisions that must be taken into account in soil survey operations, than the map's relationships to the purposes of the survey.

Orvedal and Edwards (1941) also presented four possible combinations of maps and legends which are briefly explained below:

1. Cartographically detailed and categorically detailed. These are maps that are detailed themselves and have detailed unit definitions. Examples of these are the soil maps of irrigation projects. Scales of such maps are generally 1:30,000 or bigger; common mapping units are phases of soil series. Areas delineated may range from a few tens to hundreds of hectares.

2. Cartographically detailed but categorically generalized. These maps are detailed themselves but have definitions of the mapping units which are generalized. Examples are maps in which units are grouped in interpretive groupings for specific purposes, or in higher taxa. Deleted boundaries are few; therefore, delineations are similar in size and number to those in the previous case.

3. Cartographically generalized but categorically detailed. These are, for example, soil maps where mapping units are soil associations, but such units are given detailed definition in terms of the individual components, the proportion of area occupied, and other data that provide detail to the definition of the units.

4. Cartographically generalized and categorically generalized. These are generalized maps with general definitions of units. A map of associations of great groups, even

if the associations are defined in terms of proportion of components, is a map of this kind. Numbers of boundaries are reduced and soil map units are broad.

Soil maps published

The results of the soil survey of a given area are presented finally in the soil survey report and maps. Soil survey maps are intended to present soil patterns in an area in such a way that they can be best perceived for practical applications. Since soil maps are perhaps more used by people that have no training in soil science, they are a communication media. As such, they are subject to the limitations and needs imposed by the users as well as those imposed by the soil pattern on the ground. The soil pattern is often more easily understood. Variability and complexity of natural phenomena are susceptible to manipulation only to a limited extent. In soil surveys, some efforts in this regard are possible, for example, by appropriate use of cartographic mixtures.

The consideration of the needs of the user is very important in the design of the soil map. Some of these user needs are related to the size of the map, the size of the mapping units, and the number of the mapping units. The size of the map (the area of the piece of paper where the map is presented) is important because the user should be able to see the area of his immediate interest at one time. He should also have the opportunity to use the soil map in conjunction with other maps of the same area. Planners are often discouraged to do this because the soil map is not at a scale compatible with other available maps.

The size of the delineations should be adapted according to the needs of the users; individual users would have different requirements than audiences at a public meeting, because of the kinds of areas in which they are interested and the physical distance between the observer and the map in each case. This principle also applies to the number of mapping units. About 12 units are commonly manageable on maps. Large numbers make it difficult to visualize differences of kind and location of mapping units and force the reader to go back frequently to the legend.

Special mention should be made about the presentation of the map. Thrower (1972) stresses that the modern map can be well designed and be even a thing of beauty and elegance. The Soil Survey Staff (1951) considers that soil mapping itself is an applied science or art. This concept is shared by Thrower (1972):

> "Cartography, like architecture, has attributes of both a scientific and an artistic pursuit, a dichotomy which is certainly not satisfactorily reconciled in all presentations. Some maps are successful in their display of material but are scientifically barren, while in others an important message may be obscured because of the poverty of representation."

This statement could be completely adapted to soil cartography.

Unfortunately, it is indeed a fact that soil maps in Venezuela are poorly presented in many cases. It is important that the soil maps be well presented if they are to be used by people. Soils are important enough that they deserve to be delineated on a map with aesthetic appeal. This is particularly true for countries like Venezuela where soil scientists are trying to convince planners to make more extensive use of soil maps.

There are many possibilities that can be explored for improvement of soil map presentation in Venezuela. A detailed analysis of them is beyond the scope of this document. For purposes of illustration some ideas are discussed briefly here. Currently, as is done in some other countries in Latin America (Olson, 1973), soil maps in Venezuela are presented on planimetric bases, generally in color. At least until very recently, coloring in Venezuela was made by hand on ozalid copies. Only a limited number of these copies were colored and available for use.

Modern methods of soil map presentation include use of topographic base and aerial photographic mosaics. Also, the same planimetric base with high quality design and cartography, printed in color, may be used. The topographic base has the inconvenience of too many contour lines in areas of complex or steep topography. Nevertheless, they have served the soil survey of the United States for many years. Maps of this kind for surveys of St. Lawrence County (Lounsbury, *et al.*, 1925) and Monroe County (Sweet, *et al.*, 1938), for example, were neatly presented and are good quality maps even by current reproduction standards. The soil survey maps in the United States are currently presented on aerial photomosaics on sheets of approximately 42 cm x 28 cm., which are folded and bound into the report to produce an atlas of 23 cm x 28 cm. Each atlas also contains a small scale colored soil association map of the entire area. A similar system is used by at least one country in South America (Hernandez, *et al.*, 1965). While the maps in this form may be quite expensive, this and other alternatives should be considered in a comprehensive study about the economics of map reproduction for the different kinds of soil maps for Venezuela.

SOIL INTERPRETATION

Soil interpretation is that phase of soil survey operations that deals with the manipulation of soil information for direct application. The process of interpretation, however, is not a mechanical organization of data that is done after the soil survey is completed; it starts with the definition of objectives for the soil survey and is interrelated with soil mapping and classification, as well as with other soil survey operations. The relationships between those operations and soil interpretation have been discussed in some of the preceding sections.

Soil survey interpretation is not a completely recent phenomena. Many early soil surveys were designed to be eminently practical. The conflict between utilitarian and scientific purposes has been a common one. In the U.S., for example, there was a period in the decade of the 1940's when soil survey was severely criticized by voices from both sides (Kellogg, 1949a). Similar confontations have taken place in many other parts of the world. Most of the previous work, however, was confined to soil interpretations for agricultural use. In modern times it has been recognized that the information obtained by soil surveys can be used to advantage for soil uses related also to engineering and sanitary works. Progress in procedures and techniques have also permitted more intensive application of soils information for agricultural uses. Thus, modern soil surveys are designed to supply information for many soil uses of interest to purposes of planning and development.

Soil interpretation for many uses has received increasing interest recently primarily because of more intensive soil use resulting from population growth, and from the need for land use planning that arises from geographic expansion and related infrastructure development (Olson, 1964a, 1964b). In this sense, soil interpretation is the response of soil survey to those needs. Increasing application of soil information has been possible, however, in great part because of progress in all aspects of soil science. Cline (1961) has discussed the developments in soil genesis and classification and the impact on our model of soil. He considers that the major impact has come through a change in attitude toward soil use and management: "This implies, for some of us, a model to which can be applied pertinent concepts of engineering, of economics, of crop production, and of that great variety of applied subjects that involve use and management of soil for the purposes to which man would put it." In this sense, soil interpretation is an effect of the accumulated knowledge that influences the modern model of soil.

Basic Principles

Soil survey interpretations are based on the knowledge and observations of soils obtained from research and genesis studies, and on data gained from experiences of soil behavior under different uses. Actual information on soil performance for soil units defined in a soil survey is not always available. Consequently, interpretations for many soils are made in great part by correlation with similar soils. Soil interpretations are often "predictions" or "estimates" of soil behavior under specific uses.* Steele (1967) stresses the fact that these predictions are not recommendations.

The purpose of soil interpretation is to anticipate performance of soil bodies of moderate size. Any kind of construction or soil use in specific sites of small size needs on-site investigation. Soil interpretation from soil surveys does not eliminate this need. Soil behavior under given uses is seldom related to individual properties. Evaluation of soils on the basis of single properties, or even by sets of properties, does not provide a good basis for prediction of performance if other conditions are not considered. Properties like depth to bedrock and slope, for instance, affect soil stability and mass wasting. Other soil properties, like allophane clay, may increase the

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*From unpublished mansucript by M.G. Cline, 1973.

hazards for landslides. . Still, local conditions such as rainfall intensity and distribution and vegetation cover can be more important for soil behavior under specific uses. Therefore, interpretations are made for named kinds of soils with some assumptions, because it is a set of properties in some conditions that produces a given behavior.

Soil survey interpretation is an interdisciplinary work. Predictions of soil performance for agricultural uses require knowledge of disciplines such as ecology, plant science, and agricultural engineering. Interpretations for engineering uses requires knowledge of soil mechanics. For regional planning purposes, at least some familiarity with these and other disciplines is necessary. Soil scientists alone do not have an adequate command of those disciplines.

The value of such predictions depends on many factors. Olson (1964a, 1946b) points out that limitations of soil survey interpretations are related to (a) soil variability, and (b) subsurface conditions. Limitations related to soil variability result from the relative purity of mapping units identified by a soil name. Soil bodies in mapping units defined as series or phases contain inclusions of other kinds of soils. Standards for those units allow 15 percent inclusions, but in actual practice inclusions may be present in larger proportions. Categoric and/or cartographic generalization of soil map units results in more heterogenity, and this in turn results in less numerous and less accurate estimates of behavior. Subsurface conditions can be predicted with different degress of certainty in different soils. Soil descriptions and data in soil surveys are mostly done from the surface down to 2 meters. Deeper sampling and testing is not possible for all places where observations of soil profiles are made, but only in selected places on the more important soils. Predictions of subsurface conditions are generally based on knowledge of geology, genorphology, and sedimentation.

Other factors affecting soil survey interpretations are the amount and reliability of the information on which the interpretation is based, and the specificity of the predictions themselves*. A given soil in its particular environment has a predictable response to management or to any kind of manipulation (Steele, 1967); however, the degree of accuracy of the predictions depends on the information available for the interpretation. On the other hand, interpretations that are made for one specific purpose will only rarely serve another purpose adequately. Soil interpretations do not provide the whole answer for land use planning. "Land" is an economic term for a geographic unit that has many attributes other than soil. Decisions in land use planning and further implementation of such decisions depend on many factors. The requirements of a modern society are

*From unpublished manuscript by M.G. Cline, 1973.

such that development plans and operations have to be directed toward meeting several goals that might be conflicting with regard to land use. An example of alternative considerations is a comprehensive plan of development to the year 2015 prepared for an area in the State of Illinois in the United States (Northeastern Illinois Planning Commission, 1972). The planners considered several goals including economic health, transportation, education and culture, aesthetics, recreation and others, that should be attained to provide an environment habitable for people. Efficient land use was only one of the goals. Eleven alternative designs were prepared and tested according to their level of goal fulfillment. On the basis of this test, four designs were further submitted to public scrutiny before a definite plan was finally recommended. This discussion and debate illustrates the relative weight of soil interpretation in the final decisions of land use planning.

Kinds of Soil Interpretation

Soil interpretations can be of various kinds. Contrary to popular opinion, interpretations do not necessarily involve classifications or groupings. Single soils can be interpreted according to their properties. Interpretation of single named soils is done for purposes of estimating soil behavior for a given use in areas identified in soil maps by that soil name. One might be interested, for example, in the location of a septic tank or a farm pond. The interpretation is made by listing the soil factors that affect the use and set the limits for which degrees of limitations or suitability are established. According to its properties, the soil unit is rated in one of these degrees. For agricultural uses, criteria of rating soils are dependent on specific requirements for individual crops, or for kinds of crops. Examples are interpretations for production of asparagus (Haans and Westerveld, 1970), and those made for horticultural crops in general (Edelman, 1963).

Interpretations for engineering uses are based on the specific requirements of each use, since structures would occupy mainly areas of small size. Differences in soil requirements are commonly significant between engineering and agricultural uses; interpretations are not always possible for generic "engineering purposes" as can be done with kinds of crops in farmers fields. Criteria for soil interpretation in engineering are provided by technical guides such as those prepared by the Soil Survey Staff (1971). This guide was developed for evaluating named kinds of soils, not sets of properties or properties alone.

Criteria for interpretation change as more knowledge and experience become available. Many soil properties may have similar effects in any conditions. For example, surface rockiness will impede the use of sleeping bags in camping sites everywhere. Still, criteria should be adjusted for the conditions of other places. Criteria and procedures for engineering interpretations of soils in developing countries have been outlined by Olson (1972b). He indicates that further development of such criteria and procedures are necessary.

Soil interpretations can also be made by organizing named kinds of soils into classes on the basis of similarities in properties of interest for defined uses. These groupings are made generally by limitations, expected performance, or suitability. Interpretations of this kind were discussed in the chapter of technical groupings.

A kind of soil interpretation that is often used is the judgement of soil properties that are important for land classification. This aspect of interpretation is commonly subject to confusion. Vink (1963) considers that soil survey interpretation is part of land classification. This statement is misleading because it might cause people to think that soil interpretation is confined to the land classification process, which is not true. Some authors have erroneously considered that soil survey interpretation always involves a classification (Soc. Ven. Ciencia del Suelo, 1970). It seems necessary, therefore, to emphasize the distinction between land classification and soil interpretation.*

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*Detailed discussion of this aspect is not possible in this document because of its complexity. Many concepts in regard to the term land are often subject to considerable argument. Distinctions are mentioned here only in regard to objectives of the soil survey. An interesting discussion on these distinctions has been presented by Badillo (1972).

Land classification is the act of assigning classes, categories, or values to areas of the earth's surface for practical objectives (Olson, 1972c). Soil interpretation deals with predictions of behavior of soil bodies for purposes of use, and may or may not involve organization of such soil bodies in groups. The so-called Land Capability Classification (Klingebiel and Montgomery, 1966) is a soil interpretative grouping. In this system soils are grouped into eight "capability classes" defined in terms of problems associated with agricultural uses. Other categories in the system are "subclasses" that identify the kinds of problems in general terms, and "capability units" which are groups of soils having similar management needs.

Interpretive groupings of this kind have been developed in several countries. Olson (1972c) has discussed some of the interpretive land classifications in English-speaking countries and some of their adaptations to local conditions. Similar developments have been done in countries with different cultural settings such as Portugal (Carvalho, 1968) and Peru (Zamora, 1971). Interpretations of soils in the context of land classification should be made according to the specific conditions and needs of each particular country. The Land Capability Classification was designed to meet the objectives of the Soil Conservation Service of the United States Department of Agriculture. When it was designed, erosion was a major problem and concern, so the classes are primarily erosion problem classes. The system, however, has been extensively used in many countries for purposes such as land taxation and/or evaluation of soil productivity. This misuse of classification systems should be avoided because it may result in serious errors. Technical groupings of one kind cannot necessarily be applied to advantage for purposes different than those for which they are designed. The appropriate approach might be illustrated with an example from East Pakistan (Olson, 1972c). The environmental conditions were such that crops could be grown throughout the year, soil erosion was not a major problem as was flooding, and wetland rice was the principal crop. The Land Capability Classification was not suited to those conditions and a different scheme was designed to fit local situations. The basic concepts of land classification, however, can be applied in contrasting environments if the system is adaptable.

Soil survey interpretations can be expressed in interpretive soil maps. These maps may present single factor soil interpretations, technical groupings for specific purposes, or soil interpretations for alternative uses. Interpretive soil maps based on single factors show geographic distribution of soil properties such as salt content or depth to bedrock. Generally, those maps delineate areas where such properties occur at selected intervals; for example, intervals of depth to water table of 0 to 1, 1 to 3, and more than 3 meters below the surface. Maps of technical groupings show geographic distribution of soils having similar degrees of limitations or suitability for specific uses. The groupings may be single category groupings in which suitability, for instance, is expressed as good, fair, and poor for given soil uses. Multiple category groupings, such as soil interpretations for land classification may be used. Interpretive soil maps for both of these kinds of groupings are widely used in land use planning (Wohletz, 1968) for highway projects (Smith, 1961), and for agricultural purposes (Fridland and Grigor'yev, 1967). An interesting form of interpretive soil maps is that designed to show alternative uses of soils. An example of this is presented by Rose et al. (1972). Some possible uses of soils are arranged in hierarchy, starting with the most demanding use, and the kinds of soils are rated for each use according to suitability or degree of limitation. The interpretive soil map prepared in this manner gives in one single map a general idea of the suitability of the soil conditions of the area for a variety of uses.

Soil Survey Interpretation in Venezuela

Soil interpretation in Venezuela has been confined to technical groupings for land classification. The most used systems are the Land Capability Classification of the Soil Conservation Service, U.S. Department of Agriculture, and the Land Classification system outlined in the Manual of the U.S. Bureau of Reclamation. The latter was translated into Spanish (MOP, 1963) and is intensively used in soil surveys of irrigation projects, with some modifications for the local conditions. The possibilities of soil interpretation and its application are currently immense. A document outlining soil interpretations for land use planning in the United States is presented by Bartelli _et al._ (1966). The variety of uses of soil survey information include agricultural, engineering, and planning purposes. Actually, soil information can be related to widely different purposes even in a single country. In New Zealand, for example, soil information is used for aspects as general as major land uses (Gibbs and Leamy, 1968) and as specific as dental health (Cadell, 1962; Ludwig et al., 1962). Detailed discussion of such a range in use of soil survey information is not feasible in this paper. One can visualize some of the soil interpretations that are likely to be of major importance in the next thirty years in Venezuela.

For regional planning, a review is presented by Urriola (1971). He discusses the uses of soil information, criteria of interpretation, and possibilities of soil survey for actual and potential users. The application of soil information for regional planning is related to a substantial degree to the scales of published soil maps. In the United States there are handbooks and guidelines for designing soil surveys with known requirements for planning (Kellogg, 1970). For example, for general planning small scale maps at about 1:60,000 to 1:100,000 are used; for operational planning scales from 1:60,000 to 1:15,000 are used. There is a need in Venezuela for more communication with planners in aspects such as this, particularly because regional planning techniques involve the use of many other maps. Topographic and geologic maps, for example, are commonly used in combination with soil maps (McComas et al., 1969; Bergstrom, 1970). There are procedures to carefully adjust scales and boundaries, but alterations in map scale may affect both the accuracy and legibility of the map. The problems of converting scales can sometimes be avoided by interagency agreements in regard to common scale, base, and boundaries (Hill and Thomas, 1972).

For agricultural land uses, soil interpretations that will be needed are yield predictions, soil suitability evaluations for crop production, management groupings, ratings for major agricultural and agribusiness* soil uses, and soil suitabilities for rural development projects. Yield predictions can be made in Venezuela for several crops. Suitability for crop production is an important interpretation to help decision-makers in crop zoning and for food industry planning and development. Management groupings are necessary for individual farmers, extension activities, and

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*Agribusiness is a term recently introduced to indicate agricultural related activities, such as products storage, transportation, and marketing. These activities involve soil use, too.

soil conservation programs. One aspect that would require considerable attention is investigation of soil properties that affect soil workability in farm mechanization. Land preparation and cultural practices are done in Venezuela with equipment developed in other countries. Efficiency of operations, quality of the work done, and effects on soil structure and physical properties are influenced by the effect of the equipment on kinds of soils. Soil properties such as kind of clay affect resistance to penetration and trafficability that are important for mechanized soil management.

Major agricultural and agribusiness related soil uses can be evaluated from a variety of soil interpretations. A system of grouping such as that developed by Comerma and Arias (1971) for evaluation of agricultural and livestock capability of soils in Venezuela can be used. Another scheme, particularly interesting for areas with flooding problems, has been presented by Stagno (1971). Both of these systems provide interpretation for several management alternatives, and have a good potential for soil interpretation in agriculture.

A very important need of soil interpretation in Venezuela is that related to rural development projects. The expansion of the Agrarian Reform Program will require a considerable amount of soil information in the next thirty years. Soil surveys can help in the planning stages by providing preliminary surveys with interpretations for selection of potential areas for rural settlements. Additional benefits can be obtained from soil interpretations for physical planning and development of such settlements, including determination of farm size and distribution and location of villages and roads.

An important intérpretation in agriculture, particularly for regional and national development, is the evaluation of soils for agriculture with some form of water management. Classification schemes such as that for irrigation of the U.S. Bureau of Reclamation, or other systems for drainage purposes, are too specific to be used at broad planning stages of large areas. It might be convenient to design an interpretive system for water controlled agriculture in small scale soil survey projects or large areas; this will provide a basis for selection of specific areas in which irrigation or drainage is necessary. Then soil interpretation for any of these purposes can be made from large scale soil surveys in the selected areas.

For engineering uses, soil interpretations should provide information about suitability of soils as source of construction materials (topsoil, gravel), limitations for septic tanks and sanitary landfills, and recreational uses. Other interpretations are possible, but these named are among the most important for the near future. Location of sources of construction materials is valuable information for several purposes. It can save money in exploration and transport and can serve as a basis for administration of management policies for public lands. Municipal ordinances can be prepared for use of those soil information sources and for policies of aesthetic improvement. This information is also important for economic considerations in land use. Areas of soil with gravel from 0 to 1 meters below the surface, for example, can be more profitable in some places as gravel mines than under farming. Interpretations of soils for septic tanks and sanitary landfills are likely to be necessary for urban and suburban uses. They can be prepared jointly with specialists (on the basis of soil properties affecting the use) according to the local sanitary regulations.

Interpretation for this purpose will require that some soil properties like permeability be determined by procedures such as percolation tests, and that these measurements be quantitatively expressed. Additional information can be obtained from water table and drainage studies (Sommers, 1971).

Another important type of interpretation is the evaluation of soils for recreational uses. The growth of populations and general development of Venezuela are demanding that more sites for recreation and human enjoyment be available. We need more parks, play areas, picnic sites, and rest areas along the roads and highways. Interpretation of soils for recreation is necessary and can be provided in any soil survey report regardless of considerations of area, soil complexity, or scale of publication.

SOIL CORRELATION

Needs for Soil Correlation

The preparation of a soil survey for one specific area, and the successful operation of a soil survey program for an entire country, require some kind of mechanism to ensure that both the individual survey and the national program are executed within certain more or less uniform standards. This mechanism, analogous in scope to those known in industry as operations research and quality control, is soil correlation.

The above definition could be illustrated if one applies some principles of system theory to soil surveys, since strict adherence to consistency is itself a form of systems approach (Churchman, 1968). A soil survey project of one area could be visualized as a whole (or a system) composed of many parts, (or subsystems). The purpose of the whole is defined. In order that the objectives of the soil survey of area X can best be attained, each of the component subsystems such as soil mapping and soil classification are designed to be consistent among themselves and with the whole. Simonson (1967) considers the process of soil correlation somewhat analogous to making parts of an automobile. If the different parts are not standardized, an automobile cannot be constructed. The same reasoning can be applied to a national program of soil survey. Because systems theory is flexible enough to allow one to do so, the national program can be visualized as one system, at a certain level, composed by many parts or subsystems, which are the individual soil surveys. These parts produce a large amount of soil information, through mapping and naming hundreds of soil units and classifying these units at some level of a taxonomic system. It is necessary then to have some sort of control to insure uniformity of this information, and correctness and accuracy in the naming and classification of soil units. In addition, soil units defined in each survey area are characterized in terms of expected behavior for many uses. Since previous experience or experimental data may not be available for many of the map units, the predictions in many cases have to be based on the information recorded for soils of other places. Similarities and differences among soils can be detected only if the soils compared have been defined, mapped, and classified by common criteria that provide a basis for comparison. Thus, the role of soil correlation in regard to a national program of soil survey is to provide for these common criteria so that every survey contributes to, and benefits from, the growth of the accumulated knowledge of the soils of the country.

The general effect of accurate soil correlation is to guarantee the reliability of the soil surveys. Its importance can be compared with that of tight quality control as used in industry. This effect, incidentally, is particularly critical in the current conditions of soil survey in Venezuela.

Objectives of Soil Correlation

Simonson (1963, 1967, 1970) has stated that soil correlation, in a narrow sense, is concerned with the definition, mapping, and classifying of kinds of soils in a given area. Broadly defined, correlation deals also with the improvement of standards and techniques for describing soils and with the application of soil classification. The Soil Survey Staff (1951) states that the immediate purpose of soil correlation is to assign names to mapping units that are consistent with the system of classification and nomenclature, so that units in new soil surveys can be identified with similar soils already established, new units can be designated by new names, and the results of experience and research can be related to specific kinds of soils by the use of such names.

The ultimate purpose of soil correlation, then, is "to ensure that kinds of soils are adequately defined, adequately mapped, and uniformly named in all soil surveys" (Simonson, 1963, 1970). Accomplishment of these objectives also permits the transfer of knowledge from other places.

Procedures and Problems

Most of the correlation procedures are conducted throughout the whole time of a soil survey. In the United States the process starts with the construction of the descriptive legend, continues during the mapping stages by means of field and progress reviews, and ends with the final correlation memoranda. Guidelines for these steps are provided by technical documents such as the soils memorandum 66 (USDA SCS 1967). The Soil Conservation Service has the responsibility of correlation at the national level by powers of law. Very briefly, the operations are conducted through the state soil correlator, at the state level, and through the principal soil correlator at the regional level. About 95 percent of the total work is done at these levels. Final correlation is made with personnel from the national staff of the Soil Survey. Detailed descriptions of those procedures are beyond the scope of this document. Only the main elements have been considered to give a general idea of the process. Even though specific operations vary widely among countries, their character is similar almost everywhere.

One of the major problems in soil correlation is the adequate definition of the soil units. The system of classification utilized is of prime importance because it sets up the elements of definition, and more important (Simonson, 1963), it "affects the outlook and approach of men in soil correlation." The process of creating soil series, for example, is dependent on the kind of information that is required for series description and definition in the classification system. There are some standards of a minimum number of soil descriptions and areal extent to define both the central concept of the soil series and its range of characteristics.

When these standards are not satisfied, soils have to be defined at other higher taxonomic levels or mapped as cartographic mixtures. Other problems may arise, for example, in regard to nomenclature. The next higher level of the Soil Taxonomy above soil series is the family category, which still provides the attributes of homogeneity that are necessary for many soil uses. The families are named according to some criteria, mainly according to texture, mineralogy, and soil temperature regime, in addition to the name of the higher categories, e.g., "Typic Chromusterts, fine, kaolinitic, isohyperthermic." Even though the soil unit may have to be classified at this level, the use of mapping units consisting of families would produce awkward legends.

Often the conflict arises whether the soil units should be correlated by morphology or by expected behavior. In other cases there is also a conflict of opinion in regard to the identification that will be given to soil units which may not have been adequately defined, or argument over whether they should be assigned numbers, local names, or symbols.

These are only examples of the many problems encountered in correlation. There are some ways to deal with these problems, but the important thing to be emphasized is that the solutions must be found and applied by agreement of those involved in soil survey in each particular country.

Soil Correlation in Venezuela

Soil correlation in Venezuela, as has been reported for other developing countries (Olson, 1972; Van Wambeke, 1973), has been conducted for sometime but still faces many problems and cannot be considered satisfactory. The first attempts at correlation were made in about 1959 (Comerma, 1968), and subsequent efforts have accomplished results only partially positive; there is still much to be done. The main problems and needs of correlation in Venezuela have been discussed in detail by several authors. Comerma (1968, 1969, 1970) has presented an evaluation of these aspects and suggested major guidelines for future action. Arias (1972) discussed observations made during the survey of around 18 million hectares conducted by the soils group of COPLANARH. He mentions problems such as definition of moisture regimes, minimum size of taxonomic units at the lower categories, relationships between taxonomy and interpretation, local and national correlation, and organizational and institutional problems. Mayorca (1972) has pointed out some of the needs arising from the use of the Soil Taxonomy at national levels. He stressed the need for the adoption of uniform methodology for laboratory determinations, according to the specifications required by the system in use.

These authors and others have concluded that the application of correlation is necessary for improvement above the current status of soil survey in the country. There is, besides, a great concern among national soil scientists in this respect. Unfortunately, this concern has not been shared by administrators in some cases, probably because the presentation of the problem has had the image of a scientific method of little practical interest. Since the scientific side of the problem is probably well known to most soil scientists, only some major points that have been indicated by those who have dealt with soil correlation in Venezuela will be stressed here. The intent is to give more awareness of the practical side of the process of correlation as currently needed in Venezuela.

Soil surveys can be useful to people only to the measure in which they are reliable. Decisions in regard to the use and management of soil bodies are only possible if the soil surveys provide information about soil bodies which have been well defined, well classified, and properly named, so that reliable predictions can be made about soil behavior when used for different purposes. Soil survey provides a mechanism by which administrators and others can give tools of utility about soil use to people; soil correlation is the mechanism that insures reliability of the surveys.

Soil correlation is particularly important for Venezuela at this moment because of the extensive areas in the country that are being surveyed by private contractors. The inspection of soil surveys made by contract is a very difficult matter. There is no way to inspect a photointerpretation, for example, other than repeating it at a substantial expense, or to supervise soil mapping in the field without frequent reviews. The government institutions, both at the national and regional levels, must realize that there is a potential for waste of funds and time in contract studies unless provision is made to ensure the usefulness of the surveys by standardization. The best way to assure this quality of standardization is through soil correlation.

There are good indications that soil correlation is progressing at a national level. The Division of Edaphology, which currently is doing a large part of the official soil surveys, recently set some guidelines for starting correlation work in its own studies (Schargel and Arnold, 1972). Comerma* reports that current efforts are directed toward the adoption of standard specifications for all agencies involved. Implementation of a national service of soil correlation is imperative <u>immediately</u>, even before establishment of a unique institution for soil surveys is considered.

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*Personal communication, July 1973.

The preceding comments have been directed mainly to administrators; they are the people who have in their hands the implementation of policies. The effectiveness of these policies are, however, ultimately dependent on working relationships with soil scientists. The major decisions of soil mapping, classification, and correlation are in the field. The bulk of the soils work is done by those who are in charge of the survey and their immediate supervisors. As stated by Comerma (1968):

> "the improvement of soil correlation in Venezuela depends upon the interest of all involved in improving their professional level and upon their commitment to produce a better organization of the soil surveys in the country."

SOIL SURVEYS AND OTHER SURVEYS

Kinds of Soil Surveys

The character of soil surveys vary according to several conditions. Among these, soil conditions, the objective of the survey, the cartographic material available, the methods of work, the precision of the units defined, and the intensity of observations are most important. The kinds of soil surveys produced vary essentially in the degree of categoric and cartographic detail, the scale of the published map, and the descriptions of the soil mapping units.

In Venezuela, standards for the different kinds of soil surveys are not completely uniform among all agencies involved. The Division of Edaphology of the Ministry of Public works has prepared specifications for four basic kinds of surveys: Great Vision, Preliminary, Semi-detailed, and Detailed (Gonzalez and Schargel, 1972).

Great Vision Soil Surveys are intended to produce the first information on soils of areas where little or no additional data are available, for a general evaluation of development possibilities. The level of study here would be applicable to the areas of Venezuela South of the Orinoco River.

Preliminary Soil Surveys present information about soils adequate for selection of specific areas with potential for development and alternative priorities for further decisions. These are applicable to early or mid stages of regional planning.

Semi-detailed Soil Surveys present information adequate for land use planning and location of specific development proposals such as land reclamation projects, rural settlements, or soil uses of areas of several tens of hectares that do not require intensive use and high unit investments.

Detailed Soil Surveys are made to produce soil information in enough detail to meet the requirements of planning and development of small areas for intensive soil use. This kind of survey is suited to farm planning and zoning proposals.

The specifications for each of these kinds of soil surveys are currently subject to test and adjustment. At the present time, there are efforts under way to develop uniform criteria among all agencies in Venezuela. Comerma* reports a tentative agreement in most specifications, summarized below:

Kind of Soil Survey	Publication Scale	Obs./Km^2	Mapping Units
Detailed	1:30,000	50-200	Series, Families, Undifferentiated Groups, Complexes, Phases.
Semi Detailed	1:50,000 to 1:100,000	5-10	Families, Sub Groups. Associations, Undifferentiated Groups, Phases.
Preliminary	1:250,000	1	Great Groups, Associations, Phases.
Great Vision	1:250,000	0.2-1	Orders, Sub Orders, Associations, Phases.

*Personal communication, July 1973.

In other countries definitions of levels and specifications vary widely, but in general three kinds of soil survey -detailed, preliminary reconnaissance, and schematic - are common (Soil Survey Staff, 1951; Commisao de Solos, 1960; Dev. and Res. Corp., 1967; van Wambeke, 1973; Olson, 1973). Some modification of the current scheme in Venezuela is possible in the future. On the one hand, it is expected that the soil inventory currently conducted by COPLANARH be concluded before 1990, probably by 1985. Since this inventory is at the level defined as preliminary reconnaissance there would be no reason to keep the level of Great Vision by that time. The area south of the Orinoco River should be surveyed at the Great Vision level, or even at mixed level with preliminary reconnaissance if possible, before that time, too. It is not possible to examine here the actual feasibility of the latter goal, but it should be considered at least desirable at high priority.

On the other hand, the increasing changes in land use from rural to suburban and urban will require more detailed soil information than that provided by the detailed soil surveys as currently defined. For these cases, it might be necessary to include one additional kind of soil survey similar to the ultra-detailed or high intensity surveys now in use in other areas (Olson and Marshall, 1967). Some areas that are presently being surveyed at preliminary or semidetailed level, like the central region of Venezuela, will require more detail in the near future because of competitive land use pressures.

A possible form of soil maps in the future is the idea of presenting maps of some region at a combination of scales. The agriculturally oriented soil surveys in the past have been mainly conducted in the valley areas, with almost no consideration at all of the adjacent mountainous or hilly areas. COPLANARH has indicated an increasing shift of agricultural activity toward the low plain areas. Due to the scarcity of good land for agricultural production, land use planning policies and zoning regulations should be designed to maintain these areas for farming. If this is done, suburban developments and urban growth might be forced to occupy hilly areas around present cities. The preparation of maps at two scales could provide valuable soil information for these areas before the conflicts arise, and permit some establishment of criteria for land use at the early stages of regional planning.

The process of development of Venezuela is occurring in a similar fashion to the kind of development described by Friedman (1966) for countries in a "transitional phase" (midway between the preindustrial and industrial phases). Countries in such a situation are experiencing industrial, political, agricultural, and other revolutions all at the same time. It is not surprising then that the operations of development, particularly those that result in land use changes, are proceeding at a rate faster than the operations of getting the information that is necessary for a planned development. Here and there, pressures of all kinds force the decision makers to implement development proposals with only limited information available. In this set of conditions, the tendency might be to widen the scope of soil surveys by including in them more information on aspects such as land evaluation, sociology, geology, and hydrology. For example, it was recently recommended that due to the successful experience obtained in soil surveys at the Division of Edaphology by the integration of geomorphology and edaphology, this good experience should be more extended to serve the purposes also for land and water conservation surveys. The orientation proposed included the preparation, during the operations of the soil survey, of a set of maps including lithologic map, vegetation map, structural-stability-of-soils map, and others (Tricart, 1972). This proposal was made in the context of surveys for basin conservation and planning, and for particular application to the area at the south end of the Maracaibo Lake; but the implication was to develop a methodology for general application in soil survyes for the whole country. There is little doubt that such an amount of information may be helpful for basin conservation purposes and that the purposes that motivated the author were of interest. But this kind of enlargement of soil surveys may have an opposite effect to what has been considered throughout this document the primary function of soil surveys, namely, to produce enough good information about soils in such a way that it can be used for many purposes. Evaluation of natural resources is a complex job that requires the cooperation of specialists from many sciences. Soils are only one of the many factors in land use, and even rational land use is only one of several goals in sound development planning. To play a significant role in the achievement of these goals, the best thing that soil survey can do is to produce the best possible soil information. Other kinds of information are the responsibility and dominion of disciplines other than soil science.

Other Surveys

To supply other information required for an orderly national development, other alternatives can be explored. At most, soil surveys can provide the basis for interpretation for several uses. But detailed information on aspects other than soils is neither possible nor necessarily desirable in soil surveys. The current needs of the country in this regard may be met by other approaches, like that followed for the development of the Guayas River basin of Equador (OAS, 1964). In order to provide the information necessary for the basin's development, an "Integrated Natural Resources Evaluation" was prepared by a team of technicians representing the disciplines of geology, forestry, soil science, irrigation engineering, demography, and geography. This work presented information on natural resources and their potentials that was reliable enough for setting development guidelines because the appraisal of each factor was made by authorized specialists in each field. This kind of work could be explored in Venezuela, either by cooperative efforts with international organizations or by appropriate national institutions, as is done in Peru. Soil surveys in Peru are conducted by the Ministry of Agriculture, mainly for irrigation purposes. To serve the needs of development planning in regard to basic information at a national level, the National Office of Natural Resources Evaluation (ONERN) was created in 1962. This agency is in charge of the inventory and integrated appraisal of the natural resources for development purposes. Zamora* has reported that the main executive branch of ONERN had already studied more than 15 million hectares of land with multidisciplinary teams that evaluate climate, soils, hydraulic resources, geology, mining, and forestry. The integrated studies of natural resources are published at a scale of 1:200,000. Other efforts in this context in Latin America are reported by Olson (1971b). It is interesting to note that the need for studies of this kind is common to many countries on other continents. In Canada, for example, the concept of integrated studies is being carried out in ecological inventories for regional planning by the General Directorate of Forests (Jurdant, et al.,

*Carlos Zamora, Director of Integrated Studies of ONERN, personal communication, March 1972.

1969). In Australia, the different requirements are met by a variety of kinds of special studies and maps, including terrain classification for engineering purposes (Grant, 1968), reports on geology, geomorphology and soils (Maud, 1972), groundsurfaces of specific areas (Beattie, 1972) and systematic surveys of natural resources (Christian and Stewart, 1952). In the United Kingdom, needs for planning of engineering construction and military operations are met by terrain evaluation studies by the Oxford-MEXE-Cambridge Group (MEXE, 1965; Brink, _et al_., 1966; Beckett and Webster, 1969; Crawford, _et al_., 1969). Similar works in South Africa and Nigeria are reported by Brink, _et al_., (1966). Nearly all the works in Australia and the United Kingdom, and the work by Jurdant, _et al_., (1969), in Canada that are cited here deal with landscape units called a variety of names like land unit, land facet, or land systems.*

These kinds of studies have some similarities with soil surveys; the mapping units are physiographically defined by air photo interpretation, and in many cases named by soil related terms like "lateritic ironstone caprock to surface" or "residual soil." Soil information, however, is reduced to

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*A class project work for the Course Agronomy 503, Soil Morphology, Genesis and Classification, at Cornell University presents definitions for many of the most common terms (Anonymous, 1969).

engineering characteristics of major soils in the terrain unit, except for the groundsurfaces that include a description of materials down to a certain depth that may resemble a brief soil profile description. Some of these studies (Jurdant, et al., 1969; Maud, 1972) may have soils information in appreciable detail. The objectives of most of these studies, and the objects studied, are different from those of a soil survey. They may be an interesting approach for general natural resources evaluation or other purposes, and the possibilities of similar studies for Venezuela should be explored. The discussion here attempts to show mainly that evaluation of natural resources at integrated levels is a matter of necessity for many countries, but that such evaluation is made through special studies that are different from soil surveys. Moreover, these integrated studies do not eliminate the need for soil surveys.

CONCLUDING REMARKS

The economic development of Venezuela from a transitional society to an industrial country is affecting the physical resources of the nation. Soil resources are being more intensively used and shifts in the spatial distribution of land use patterns are occurring on both developed and new areas. Planning and organization of soil resource use in these conditions require some improvement above the current status of soil information acquisition and use in Venezuela. Improvement is needed on both the general status of soil survey in the country as a national program and on specific soil survey projects for given areas.

There is a need for a national cooperative effort in soil survey in Venezuela. This effort can be accomplished either by formal agreement among all national agencies involved or by a single new soil survey institution. In either case, coordination and cooperation are necessary to provide for a general framework of work, common objectives, establishment of priorities, and short and long term programs. Specific soil survey projects for individual areas should be designed to fit specific objectives within a general framework to prevent unnecessary duplications in the changing conditions of the near future. Soil survey projects of specific areas can be done by operations, techniques, and procedures within common standards to contribute to the overall soil survey program. To maintain reasonable scientific standards in a program of this type, a national service of soil correlation is considered an imperative need. Improved definitions and descriptions of soils will assure quality and uniformity of the soil information produced by government and private institutions. It will also permit the transfer of knowledge from studied areas to new areas which is necessary to present and future actions on land use planning and implementation of plans and policies.

A cooperative soil survey also involves relationships with people from other areas of soil science, from other disciplines, and from teaching institutions. The soil survey reports are made to be used by people that are interested in many uses of soils, including agriculture, highways, buildings and regional development proposals. Evaluation of soil as a natural body for such a variety of purposes requires interdisciplinary work and the use of information available from research and experience from several disciplines. This requires, in turn, well prepared soil scientists. Universities play a major role in giving to soil scientists the potential and tools by which they can perform a useful and satisfying service. Cooperation with universities would also benefit soil survey through research in areas of soil science such as soil genesis, soil fertility, and soil management.

Research in the field of soil survey itself and further education and training are necessary in a soil survey program. There are substantial grounds for hope in this universities-soil survey relationship in Venezuela. A cooperative soil survey is then not only necessary but seems to be a feasible effort in Venezuela. Some major goals have been stated and some of the means to accomplish these goals were discussed in this document. The future of soil survey as a cooperative effort, however, depends on the commitment and effective actions of all interested people.

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