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LAND RESOURCE AND LAND USE CLASSIFICATION CONCEPTS AND METHODS

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ABSTRACT

This report documents the concepts and methods used by the Comprehensive Resource Inventory and Evaluation System (CRIES) Project to classify and evaluate land for national planning and policy analysis. The classification system uses two components -- soil and climate -- as the basis for delineating broad, relatively homogeneous geographic areas and to identify and tabulate major landscapes within these areas. The system is designed to provide geographic identity and soil detail suitable for national planning and analysis at minimum cost. After programs and priorities are established at the national level, the system hierarchical features allow detailed application at implementation levels.

Keywords: Agricultural planning, land classification, resource analysis, Soil Taxonomy, developing country.

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FOREWORD

This report is part of an effort by the Comprehensive Resource Inventory and Evaluation System (CRIES) Project to develop, adapt, and document general procedures for classifying, inventorying, and analyzing on a national basis the extent, current use, and agricultural development potential of land resources.[1/] The work is a joint effort of the U.S. Department of Agriculture (USDA) and Michigan State University (MSU) in cooperation with the U.S. Agency for International Development under PASA #AG/TAB 263-14-76. Participation of MSU is covered under Research Agreement #12-17-07-8-1955 between the USDA and MSU.

The CRIES project uses a multidisciplinary approach to assist developing countries in analyzing their agricultural production potential and to enhance their capabilities to conduct analyses for country-level policy evaluations. The CRIES staff collaborates with country representatives to design information acquisition and information management and analytical techniques tailored to the country's resource problems and needs. At the same time, CRIES retains a consistent approach to resource inventory procedures so that transfer of land resource information among countries may become feasible. Efforts are focused on the use of existing data, supplemented by primary data collection and informed judgment. The approach is designed to (a) use reconnaissance-grade data sets to establish a

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[1/] "Land" is broadly considered to include not only the soil surface and profile, but also naturally occurring vegetation, mineral deposits, and water resources as well as exposure to climatic features such as sunlight, temperature, precipitation, etc.

single, nationally consistent resource information base and to develop in-country capability for systematic collection and refinement, and (b) to undertake national-level assessments of agricultural production potential issues.

The report documents the concepts and procedures used to classify, describe, and interpret land capability and potential for national planning and analysis. The overall intent of the report is to illustrate the general concepts and procedures underlying the application of CRIES to many countries. Application of these procedures to individual countries is documented in country reports.

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INTRODUCTION

Land characteristics vary dramatically from continent to continent and within continents. Some variations are extreme while others are almost undetectable. Even where temperature, moisture, and soil conditions are sufficient to allow crops to mature during one or more seasons, differences in the character of land may still be sufficient to induce wide variations in the production of crop and animal products. Land characteristics may further be altered by man.

Major increases in the demand for agricultural products during the past several decades have caused rapid changes in land use patterns. Due to the need to maintain the natural resource base and sustain and increase agricultural production, numerous groups have developed procedures to classify physical and human activities for planning purposes (F.A.O., Beek, Clawson, TVA, etc.). Classification refers to the orderly and systematic grouping of objects together in mutually exclusive groups. A land classification then, rather than placing things into groups, is the orderly and systematic delineation of the earth's natural resources according to a predetermined plan. In these land classification studies, land is generally defined as the earth's surface and a continuum of its natural attributes. Land classification involves two basic approaches -- attribute classification and use classification. Both involve many of the same information elements but the methods of combining them and the form of the final output may be quite different. Each land segment has attributes that may or may not be unique to it. The interactions and weighting of the importance among attributes, their critical

ranges and appropriate zones of attributes may vary dramatically for a variety of uses.

Most physical attributes are quite stable with only marginal changes over time. As a result attributes such as climate, geology, soil and topography usually provide the base for most land classification projects. Breakdowns and groupings of these physical variables into homogeneous units on a reconnaissance level is normally based on soil, climate, and topography. Because of the high natural correlation among the many attributes these groups are not mutually exclusive.

Attribute classification recognizes the basic importance of soil, climate, geology, topography and vegetation in the study of land. Attribute classification defines groups by criteria relevant to the attribute and produces maps delimiting those groups. Topographic maps with boundaries displayed for particular elevation contours are examples of defining and mapping an attribute into particular groups for all uses.

Use classification requires nearly the same information but uses and presents the information quite differently. In use classification, attributes critical to the evaluation of that use, their interrelationships and relative weightings among groups, and the critical values and zones of groups are used to determine the boundaries of classification groups. Hence, the output of this approach produces a system dividing attributes at specific places relevant to a particular use. Range and forest surveys, erosion hazard maps, etc. are examples of these types of land classification.

In practice, few land classification systems fit clearly into either type. Traditional systems like that of the F.A.O. group and weight specific physical attributes into a form needed to answer particular agricultural questions. Narrowing the scope of the classification to agricultural uses allows the system to be evaluated in a particular way. Generally, a land classification system for

agricultural analysis must provide the basic knowledge necessary to assess the suitability of the land to support sustained plant and animal life for economic purposes. A land suitability classification is used to appraise and group specific areas of land by their suitability for a given use. The USDA Soil Taxonomy is an example of one of the major subsystems in an evaluation or suitability classification.

CRIES LAND CLASSIFICATION SYSTEM

Introduction

Agricultural planning and policy analysis requires integrated information sets for analyzing impacts of development and policy alternatives to achieve agricultural production potential. Key information sets are land resources, land use, human resources, and related agronomic and socioeconomic data. Land resource classification may provide the linkage among many of the parameters in these information sets.

The CRIES Land Classification System (LCS) uses two components -- soil and climate -- to group the many naturally occurring factors to estimate environmental impacts on the adaptability and vigor of economically important plants. The LCS is designed to stratify the wide array of natural resource - product choices into discrete ranges to provide an appropriate, level of detail for each stage of the agricultural development process -- policy, program and project. Land resource information must be developed at appropriate levels of detail for three levels of planning and policy analysis. These three levels are generally defined as:

1. Assessments to develop broad objectives, policies and priorities;
2. The selection and general siting of programs to meet objectives; and
3. The design and siting of projects to implement programs.

Broad policy objectives are formulated for large areas of land -- frequently at the country level. The nature of the land base varies greatly from area to area

but the broad areas used for national assessments need be characterized only by those features that are relevant to particular policy and program alternatives. Thus it is conceivable that identification and delineation of broad areas on the basis of a set of features critical to consideration of alternatives for a specific objective would be inappropriate and unusable for consideration of other objectives. Commonly, exploratory surveys identify the most important of these features and their relative extent; precise location is not considered essential.

From a consideration of the spectrum of alternative areas, those best suited for accomplishment of a stated objective are selected for further study. At this level of effort, additional attributes of the land resource base critical to specific programs are jointly assessed and the general siting of projects is accomplished. After selecting the project site, it's necessary to complete detailed project area surveys identifying additional critical land attributes designed in the project. Each succeeding survey to ascertain more accurate location of critical features and more precise definition of the physical environment are more comprehensive and more limited in scope. Thus, the general siting of a program and project in an optimum physical environment is assured.

This hierarchical approach can be used to allocate scarce funds and manpower according to policy priorities and planning stages. It provides the means for aggregate analyses of project-level data for programs and policies. The most compelling argument for this approach is cost. If one equates land investigation and mapping levels of reconnaissance, semi-detailed, and detailed to the planning stages above, the cost may vary as much as X, 20 to 50X, and 200 to 1000X, respectively.

The LCS is intended for analyses at the higher ranges of the three levels of the hierarchy. Map units, described below, are generally large, typically ranging in size from 20,000 hectares to several hundred thousand hectares although quite

small areas of unique, high-valued agricultural production may also be delineated. Frequently, the system is less rigorously applied to mountain ranges and vast arid areas with little or no agricultural potential.

Nomenclature

The LCS employs a two-level system of land classification -- a cartographic map unit for geographic location and estimates of more detailed physical components to provide analytical units with greater homogeneity. These two units of the system are defined as follows:

> Resource Planning Unit (RPU) -- an RPU is a geographically-delineated unit of land that is relatively uniform with respect to land forms, kinds and patterns of soil bodies, climate, water resources, and potential vegetation.
>
> Production Potential Area (PPA) -- a PPA is an unmapped estimate of the aggregate area and distribution of major soil bodies and, in some cases, associated micro-climates, within an RPU. It is sufficiently homogeneous with respect to plant adaptability, potential management requirements, and productivity to be reliably depicted by unique parameter estimates for national and regional analysis and planning.

RPUs serve several purposes. They provide an important overview of the physiographic regions of a country. RPUs may be composed of complex and contrasting soil components but this diversity is usually geographically associated in recognizable and definable patterns that occur in a repeating nature throughout the map unit. This natural pattern is distinct and unique to an individual RPU and distinguishes it from all other RPUs with different patterns of natural phenomena.

PPA estimates provide the homogeneity of soils, land form, and climate necessary to assess crop adaptability, productivity, management requirements, and development potential. However, the distribution, size, and associations of the individual PPAs and their patterns with respect to other PPAs must also be known. Program implementation is affected by the agronomic characteristics of the PPAs

and by the interrelationships, patterns, and size of the resource areas. Three patterns of PPA distributions and the planning and management constraints they impose are defined as follows:

Intricately Patterned PPAs. When two or more PPAs generally occur in complex patterns composed mostly of individual PPA bodies of less than five hectares, they will be described as intricately patterned. For national planning, such PPAs are considered as a single unit and represented by interpretations for the soil complex.

Finely Patterned. When two or more PPAs generally occur in patterns composed of individual PPA bodies usually larger than five hectares they will be described as finely patterned. For national planning, finely patterned PPAs are considered as individual units for most management options but carry size constraints for some program and project purposes.

Coarsely Patterned. When individual PPA bodies occur within an RPU in coarse patterns that are predominantly larger than 100 hectares, they are described as coarsely patterned. Such PPAs can generally be treated as separate units for national planning.

Information Sources

In order to create an RPU map, a working draft of a soil map must be prepared. Knowledge of the kind and distribution of the soils in a country is obtained in many ways. Manuscript soil maps at the scale of 1:1,000,000 are available from USDA files for most countries. Such maps summarize the knowledge about soils that was available to USDA in the 1950's and 1960's. Most countries also have newer published studies available -- ranging from very detailed site management studies for very small areas to highly generalized assessments. Additional information can sometimes be found in special studies for irrigation and drainage projects.

In almost every case, a surprising amount of information can be found. However, this information is usually fragmented and may represent several different systems of soil classification. Such information is of little aggregate

value for planning without conversion to a common system and an appropriate level of detail.

Information on climatic conditions is usually available from several sources. In-country weather station data are usually available in most countries. Data for a limited number of stations for most countries are available from the World Meterological Organization. In addition, published and unpublished data are often available on specific aspects of climatic conditions relevant to plant growth. Floristic maps and data, botanical plant lists by area, and vegetative maps are often available to supplement climatic data.

Methods

All available soils data, topographic information, and remote sensing information (aerial photography and Landsat imagery) are assembled by soil scientists. USDA file maps, generalized studies, and Landsat are the principal sources of the initial boundaries on the soil map derived by the CRIES project for a country. Landsat is an excellent source to locate major land forms, rivers, and other landmarks; it frequently shows significant locational errors in older base maps. From all such sources, a single soil map is compiled.

Soil map units commonly are "associations and consociations of subgroups" of the USDA Soil Taxonomy. Soil Taxonomy provides the means to reinterpret other systems of soil classification in terms of a single, internationally accepted standard. Detailed studies, descriptive materials, and counterpart knowledge are used to describe the map units. Where no soil studies are available, pedological data are supplemented with available data on geology, climate, vegetation, topography, and age to infer soil classification.

Climatic information is interpreted to obtain estimates of mean annual temperature, mean annual precipitation, number of wet seasons, duration of wet seasons, mean monthly temperature and precipitation during the wet season(s), and

the presence or absence of a killing frost for each map unit. Variations within an RPU may be described and, in some cases, may dictate the recognition of PPAs based on significant differences in climate.

An RPU map is developed from the soil map and available climatic data. Broad areas of the country are delimited on the basis of relative homogeneous landforms, soil characteristics, and climate. Where these features vary over relatively short distances, delineation of RPUs is based on the repetitive nature of one or several of them. These several distinctive landscapes are the production potential areas of the RPU. Where a single landscape and climate comprise the delineation, the RPU and PPA are synonymous.

Descriptive materials to accompany the RPU map are developed directly or interpretively from sources dealing with soils, climate, and agricultural practices. The kind of information included and the degree of detail are described and illustrated in Appendices A and B.

The first draft RPU map and descriptive material are reviewed in-country by field reconnaissance and in consultation with counterpart soil scientists and climatologists. The amount of time in-country and the quality of the product vary depending upon base materials and references available. (See Appendix A for sample descriptions and Appendix B for definitions of terms.)

Mapping

Regardless of the land resource classification system used, variables included in the classification criteria must be mappable to capture the desired attributes for a given location. Land resource classification maps are graphic representations of the classification system's categories. Generally, the level of map detail is a function of two factors -- map scale and the classification used. Map units delineate unique kinds of land according to certain systems. Map scale limits cartographic detail that can be legibly shown. Hence, map scale is generally an

indication of the level of map detail. Map scales may be increased for legibility. Reconnaissance maps usually have scales of 1:250,000 or smaller, semi-detailed maps range from 1:65,000 to 1:130,000, and detailed maps are 1:65,000 or larger.

Classification systems prescribe hierarchical taxa that correspond to these general map scales. Map units on large scale maps may be described in greater taxonomic detail. As map scales decreases, the area included in the map units increases. It would be convenient if the taxonomic detail could be aggregated in the same manner as map units. This is, unfortunately, not the case. Taxonomic detail is aggregated by relaxing differentiating criteria to produce larger groups with fewer common characteristics. Map units may be aggregated to larger groups by combining them with contiguous units. Hence, as map units become physically larger (and map scales smaller), map units should become more heterogeneous.

Soil Taxonomy

Soil Taxonomy is a system of soil classification designed to group individual soil series and other pedons to emphasize the greatest number of natural relationships and important properties without reference to a specific practical purpose. The system is hierarchical in nature and conceptualized on the basis of availability of a great amount of data about a great many recognized soil series in the U.S. and the world. Hence, the system is especially well suited to aggregate detailed knowledge about land and soils into higher order groups based on natural relationships that enhance predictions of soil behavior under stated conditions for stated purposes.

The six categories of the Soil Taxonomy system in order of ascending rank and decreasing number of differentia are series, family, subgroup, great group, suborder, and order. There are 10 orders, 47 suborders, 200 great groups, 1000 subgroups, and approximately 4,500 families identified in Soil Taxonomy.

Although Soil Taxonomy essentially groups a great many soils into succeedingly larger groups (each category has fewer, larger groups with fewer common characteristics), it is better explained as a differentiating system from the most aggregate to the least aggregate. Soil orders group all of the soils in the world into 10 classes on the basis of the presence or absence of diagnostic layers (horizons) and unique chemical, physical, or mineralogical properties (Table 1).

Within each order, only the nature and properties of the specific soils in that order need to be considered for further differentiation. Hence, differentiating characteristics are not applied uniformly throughout the system, but are selected as those most appropriate to the particular type of soil being differentiated to characterize the diverse and complex population into successively more homogeneous taxa.

Generally, suborders subdivide orders on the basis of properties that influence soil genesis and are important to plant growth, or reflect the most important variables within the orders. Great group differentiations are based upon kinds, arrangement, and degree of expression of diagnostic horizons and different genesis. Subgroups subdivide great groups by the central concept of the great group intergrades into other orders, suborders, or great groups, and extragrades that have properties not representative of the great group, but are not transitional to other kinds of soil. Families, the lowest class of the systematic portion of Soil Taxonomy, differentiate soils within subgroups on the basis of physical and chemical properties and other characteristics that affect management, such as particle size distribution, mineralogy, soil temperature, soil depth and content of sulfides.

A phase can be used at any level of taxa to denote subdivisions on the basis of some important feature such as slope, surface texture, erosion, stoniness, and/or soluble salt content.

Table 1.
Derivation of soil order names

NAME	Formative Element: Element	Formative Element: Derivation	Major Characteristics of Order
Alfisol	alf	meaningless symbol	High base status forest soils; subsurface layer of accumulation of translocated clays.
Aridisol	arid	Latin aridus, dry	Soils of arid regions.
Entisol	ent	meaningless symbol	Recently formed soils.
Histosol	hist	Greek histos, tissue	Organic soils of swamp and marshes.
Inceptisol	cept	Latin inceptum, beginning	Young soils with few or faint diagnostic features or layers.
Mollisol	oll	Latin mollis, soft	Grassland soils of steppes and plains with thick dark surfaces high in humus.
Oxisol	ox	F. oxide, oxide	Sesquioxide-rich, highly weathered soils of the intertropical regions.
Spodosol	od	Greek spodos, wood ash	Mineral soils with subsoil accumulations of sesquioxide and humus.
Ultisol	ult	Latin ultimus, last	Low base status forest soils; subsurface layer of accumulation of translocated clays.
Vertisols	vert	Latin verto, turn	Shrinking and swelling dark clay (30%) soils.

The nomenclature of Soil Taxonomy is coined largely from Greek and Latin roots that indicate the place of the taxon in the system and connote some of its most important properties. The formative elements in the soil name are carried through to the subgroup level so that the name will connote certain soil properties and indicate each higher taxon to which it belongs. The subgroup Arenic Argiaquoll is an example.

ORDER	M OLL ISOL	(OLL - soft, high in humus)
SUBORDER	AQU OLL	(AQU - aquic moisture regime)
GREAT GROUP	ARGI AQU OLL	(ARGI - an argillic horizon)
SUBGROUP	ARENIC ARGI AQU OLL	(ARENIC - sandy surface)

Family names are formed by adding specific descriptive elements such as:

Loamy, Calcareous, Arenic Argiaquolls

Interpretations

Agronomic interpretations are made at the production potential area (PPA) level. The description of the PPAs provides the relative homogeneity of land form, soil, and climate to estimate plant adaptability and productivity, and general management requirements for national-level planning. Depending on the amount of background information available, two levels of interpretation may be made directly from PPA descriptions: a general assessment of plant adaptability and productivity, broad management requirements, and development potential for national-level planning; and, second, more detailed recommendations by crop group.

The general interpretations provide indications of the potential of the physical environment for supporting agricultural endeavors. Economic evaluations of the relative practicality of various management practices and kinds of land use are not considered in the identification and description of PPAs; such evaluations would require additional information on the capital outlay requirements for the

variety of alternative resource treatments, the operating costs associated with various cultural practices, the value of yield improvements achieved through such treatments and practices, and so on.

One general interpretation relates to soil potential. Soil potential is an expression of the expected performance of a soil for crop production under a particular type of management. Ratings of soil potential are used for planning purposes and are not intended as specific recommendations for soil use. Interpretations of soil performance for crop production are expressed by one of three ratings. These are:

> A good rating implies high production potential at low long-term risk to the soil and for the expected crop. Soil limitation and limitations of climate are minor or nonexistent. If necessary, soil limitations are easily correctable by manipulation of the surface soil.
>
> A fair rating implies average production potential and some risk to the soil resource. Soil limitations present some difficulty in use of equipment and require special management practices to attain the same level of productivity as that expected in a PPA rated good. Examples of limitations would be moderate wetness, low available water capacity, erodability, slope, subsoil restrictions, salinity, and poor physical conditions for tilth. In those areas where soil limitations are minor or nonexistent but a climatic factor such as seasonal dryness is important, a fair rating is also used.
>
> A poor rating implies low yields or unacceptable production potential and/or high risk to the long-term productivity of the soil resource. This rating results due to the presence of either severe climate or severe soil limitations. Such limitations include slopes (greater than 30 percent), extreme droughtiness, drainage condition (poorly or very poorly drained, or excessively well drained), long periods of flooding, high salinity, and shallow rooting depth (less than 50 cm).

Another general interpretation concerns limiting factors affecting land use. Limitations and restrictive features of the physical environment, principally those related to soil and climate, affect either directly or indirectly the use of land and the production of economic plants. Those attributes of the soil and climate which to some degree, either singly or in concert, adversely affect the soil potential ratings are:

Soil features: shallowness to bedrock; depth to restricting layer; wetness; susceptibility to flooding; steepness of slope; texture--sand; clay; stoniness; extreme acidity; extreme sodicity; extreme salinity; and erodibility.

Climate features: duration of dry season; length of growing season; and distribution of rainfall.

The more detailed interpretations made from PPA descriptions are crop recommendations. Crop recommendations denote where major crops or major crop groups are adaptable and provide some indication of yield potential under alternative management levels.[1/] Ratings are qualitatively expressed as high, medium, and low:

High: When a crop or crop group is rated high conditions in the PPA are compatible with the known requirements of the crop or crop group. It may be inferred that a high rating implies a possibility of yield comparable to the upper values reported in the agronomic literature for a given level of management.

Medium: When a crop or crop group is rated medium, one or more of the known crop or crop group requirements will not be fulfilled due to conditions that prevail within the PPA. A medium rating implies that crop yields will be less than the upper values reported in the agronomic literature for a given level of management.

Low: When a crop or crop group is rated low, conditions in the PPA are incompatible with several of the known requirements of a crop or crop group. Yields of crops under such a rating can be expected to be highly variable from year to year. Additionally the low rating is used to acknowledge that crops with highly variable yields are traditionally cultivated within the PPA (under circumstances that the matching of crop requirements with PPA conditions would with such cultivation not to be advisable).

It should be noted that these crop recommendations are generalizations most suited for initial screenings for national-level planning purposes. In the case of single crops these qualitative rankings generalize requirements as though all varieties were similar. In the case of crop groups, the rating applies across all species included in the group.

[1/] Crops taken to be major crops are a matter of judgement.

Two sample RPUs, one from CRIES work in Honduras and one from Syria are presented in Appendix A. Note the difference in descriptive and analytical content due to availability of information in the two countries.

LAND USE/COVER CLASSIFICATION

Somewhat less than 3 billion acres of the earth's 33 billion acres of land actually produce crops in any given year. An additional portion of the land base contributes to agricultural production through the support of livestock. Historically agricultural production has been expanded by bringing new lands into production. However, since the early 1950s, additions to cultivated area have contributed less than 20 percent of the world's total increase in agricultural production. The major portion of the agricultural production increase during recent periods is attributed to yield improvement.

Several methods are used by the CRIES project to develop land use information. The choice of method is a function of the availability and reliability of alternative data sets and cost. The major purpose is to derive information on major land cover/use (cropland, rangeland, forest, urban, etc.) and crop distribution patterns within the major land use category of "cropland" by RPU (and inferentially by PPA when such areas are coarsely patterned). Some developing countries have census land use data sets on major land use and crop distribution patterns reported at five or ten year intervals. Less frequently countries collect census-type land use information on an annual basis through an ongoing agricultural statistics program. All such census-type information is generally collected by internal administrative boundaries. Allocation systems are required to distribute the census-type land cover/use data to the mapped RPUs. Occasionally auxiliary sources of mapped land use data are available from a commodity group (e.g., a national cotton control board) or another activity. Often the census-type and the auxiliary data are found to be limited in usefulness because the data do not fully

exhaust the land resource base, i.e., only land use for the agricultural sector was delineated, or the data are out-of-date and not representative of current land use.

In the absence of other land use data, visual interpretation of Landsat imagery may be used to develop maps of major land cover/use. Visual interpretation of Landsat provides a cost effective method for delineating major land uses. Land cover/use classifications may be selected to be closely compatible with the land use categories for which statistics are periodically collected by the participating government.

Land cover/use maps are completed in three stages. In the first stage a preliminary evaluation of Landsat imagery is undertaken to establish test areas that are representative of land cover/use patterns in the participating country. The test areas selected are visually interpreted and are used for verification purposes during initial ground truth activity. The second stage involves comprehensive mapping of land cover/use for the participating country from Landsat imagery aided by the field data acquired during the initial ground truth activity and other available supplemental data. The final stage involves a final field check of persistent problem areas that are encountered during the interpretation, a re-interpretation of these areas through consideration of the additional field information, and preparation of final map products.

A final classification scheme for a visuallydelineated land cover/use map takes into consideration the data sources available for interpretation, the use patterns identified during the interpretation, and the use(s) to which the information on land cover/use will be directed. It is generally necessary to assure mutually exclusive classification categories to allow for cross-referencing with RPUs or comparison with the published tabular statistics information on current land cover/use patterns. Typical country classification categories are:

- Urban and Built-Up
- Agriculture
    - Intensive Agriculture
    - Extensive Agriculture
    - Pasture
- Rangeland
- Forest
- Wetlands
- Barren/Open
- Water
- Cloud Cover

The sum of the categories should totally exhaust the land area. This mutually exclusive nature of categories allows most of the agricultural area to be isolated from the nonagricultural area. Agricultural categories are delineated and described to reflect as much as possible the type of farming that is occurring within the category.

APPENDIX A

Two Sample RPU Descriptions

This sample RPU is found in Honduras. The descriptions of the RPU and PPAs are based on information available in that country.

RPU 4

GENERAL DESCRIPTION

RPU 4, an 87,000 hectare area, consists of a low, mainly wet area in the lower Aguan River Valley and associated coastal plain. Soils were formed in deep alluvial and marine deposits. Elevation descends from about 50 meters to near sea level. Temperatures are generally warm. Rainfall is generally adequate for agriculture but there are marked dry periods near March and September. Four PPAs are distinguished by differences in soils.

PRODUCTION POTENTIAL AREAS

PPA 4-1, about two-thirds of this RPU, consists of Tropic Fluvaquents. These poorly drained, clayey soils of slow permeability are inundated annually for long periods. They would be suitable for row crop production if they could be drained and protected from flooding. Without drainage, possibilities for agricultural use are very limited.

PPA 4-2, about 10 percent of this RPU, consists of the better drained alluvial soils of this lower floodplain. Although inherently more suitable for crop production than the wetter soils of PPA 4-1 they are also limited by annual flooding and would be benefitted by flood protection.

PPA 4-3, also about 15 percent, consists of the coastal beaches, dunes, and associated inclusions of wet, sandy flats and some marshy depressions. Principal soils are the very droughty, mainly incoherent sands, Typic Tropopsamments, and the wet sands, Typic Psammaquents. The wet depressions include some organic soils, Histosols. Because of extreme droughtiness in some parts of the PPA and extreme wetness in others, the PPA is not suited to agriculture but should be reserved for forest, wildlife, or recreation uses.

PPA 4-4, about 10 percent of this RPU, includes areas in the eastern part of the unit that range from gently sloping to rolling. Typic Tropohumults are the dominant soils. These well drained soils with adequate rooting depth and workable texture are suited to row crops on gently sloping areas. However, they would require erosion prevention measures on the more strongly sloping lands if close grown crops were cultivated.

PPA PROPERTIES	4-1	4-2	4-3	4-4
GENERAL				
elevation	15 m	15 m	0-10 m	0-50 m
dominant slope	3%	3%	0-15%	3-15%
portion of RPU	65%	10%	15%	10%
CLIMATE				
- Annual				
wet seasons (no.)	1			
average precipitation	1950 - 2350 mm.			
average temperature	27°C			
- Wet Seasons				
average monthly precipitation	450 mm.			
average monthly temperature	25°C			
months	Oct. through Jan.			
- Dry Seasons				
average monthly precipitation	79 mm.			
months	February through September			
SOILS				
principal components	Tropic Fluvaquents	Typic Tropofluvents	Typic Tropopsamments . Typic Psammaquents	Typic Tropohumults
depth to bedrock	200 cm.	200 cm.	200 cm.	100 cm.
texture	mod. fine/fine	med./fine	coarse	med./mod. fine
coarse fragments	non-stony	non-stony	non-stony	non-stony
permeability	mod./mod. slow	moderate	very rapid	moderate
available moisture capacity	high	moderate	very low	moderate
drainage class	poorly drained	mod. well drained	excessively to poorly drained	well drained
flooding	common - long	common - long	common - brief	none
INTERPRETATIONS FOR AGRICULTURE				
soil potential for cropland	Management Type* I II III IV	Management Type* I II III IV	Management Type* I II III IV	Management Type* I II III IV
	poor poor poor poor	fair fair fair fair	poor poor poor poor	good fair fair good
factors limiting land use	wetness; flooding	flooding	coarse texture; droughtiness; low available moisture	slope; erodibility

*Management types are: I - no use of inputs and no land preparation; II - some input use and use of animal power; III - high input use and mechanical power for land preparation and cultural practices; IV - tree crops.

This sample RPU is found in Syria. The descriptions of the RPU and PPAs are based on information available in that country.

RPU 27

GENERAL DESCRIPTION:

RPU 27 is a gently sloping basalt plain with shallow, stony soils. It is relatively inextensive, covering an area of approximately 25,400 hectares. Elevation is 400-500 m. The mean annual temperature range is 16° to 18°C. Annual precipitation ranges from 500 mm to 1,000 mm.

RPU 27 is divided into four coarsely patterned PPAs on the basis of depth of soils and precipitation.

PRODUCTION POTENTIAL AREAS:

In PPA 27-1, the soils are Lithic Xerorthents, vertic phase. These are dark reddish, fine textured soils that are shallow to the underlying basalt. Stoniness is common. They are slowly permeable and have low available moisture capacity. Because of shallowness and stoniness, the PPA is best suited for use as pastureland. Because the agricultural potential is very low, this PPA has not been subdivided although the climate is somewhat variable within it. The annual precipitation ranges from 500-1000 mm. During the wet season (Nov. through April) the average monthly precipitation ranges from less than 60 mm to greater than 90 mm east of Arida.

In PPA 27-2, the soils are deeper than in PPA 27-1. They are Typic Chromoxererts. These are distributed in depressions and more gently sloping areas, and are most extensive in the southeast part of the RPU. Properties are generally like those of the soils in PPA 27-1 except that these are deeper. The PPA is suited for use as cropland but the clay soils require careful management and irrigation would be necessary for optimum yields. Annual precipitation ranges from 500-1,000 mm. During the wet season (Nov. through April) the average monthly precipitation that is less than 60 mm.

PPA 27-3 is located primarily in the eastern part of the RPU. The soils are like those in PPA 27-2. Precipitation ranges from 600-1,000 mm annually. During the wet season (Nov. through April) the precipitation averages more than 60 mm.

PPA 27-4 is generally located in the central part of RPU 27. The soils are also like those in PPA 27-2. The annual precipitation average is 800-1,000 mm. During the wet season (Nov. through April) the average monthly precipitation exceeds 90 mm.

REPORTED OR OBSERVED CROPS:

Irrigated cotton, sugar beets, fruit trees, corn, and wheat have been reported or seen in the RPU.

WATER RESOURCES AND USES:

Most of the area is suited only for pasture land, but about a third is suitable for irrigated crops as well as rainfed crops. No reservoirs or government test wells are in the area. One fairly large spring - annual flow of 850 l/sec - is in the RPU.

CROP RECOMMENDATIONS:

PPA 27-1 is generally unsuited for production of conventional major crops with or without irrigation. PPAs 27-2 and 27-3 share the same soil but differ in the intensity of the wet season. Yields may be expected to differ somewhat, but the general suitability for most crops is adjudged similar for the two: with irrigation, the PPAs have medium potential for small grains, cotton, nonrosaceous fruit trees, pulses, olive, grape, and oil crops. Small grains have low yield potential under rainfed production in these two PPAs. PPA 27-4 has the same kind of soil as the two preceding PPAs, but has a wetter climate. With irrigation, the potential for production of major crops is the same as for PPAs 27-2 and 27-3 above. Without irrigation, PPA 27-4 has medium potential for small grains, cotton, some vegetables, and pulses.

PPA PROPERTIES	27-1	27-2	27-3	27-4
GENERAL				
elevation	400-500 m	400-500 m	400-500 m	400-500 m
dominant range of slope	3-8%	0-3%	0-3%	0-3%
portion of RPU	80%	7%	7%	6%
CLIMATE				
- Annual Characteristics				
average precipitation	500-1,000 mm	500-1,000 mm	600-1,000 mm	800-1,000 mm
average temperature	16-18^{o}C	16-18^{o}C	16-18^{o}C	16-18^{o}C
- Wet Season Characteristics				
average monthly precipitation	60 to 90 mm	60 mm	60 mm	90 mm
average monthly temperature	11-12^{o}C	11-12^{o}C	11-12^{o}C	11-12^{o}C
period of wet season	November through April	November through April	November through April	November through April
SOILS				
principal components	Lithic Xerorthents, vertic phase	Typic Chromoxererts	Typic Chromoxererts	Typic Chromoxererts
depth to bedrock	less than 50 cm	greater than 50 cm	greater than 50 cm	greater than 50 cm
texture	fine	fine	fine	fine
coarse fragments	stony	stony	stony	stony
permeability	slow	slow	slow	slow
reaction	alkaline	alkaline	alkaline	alkaline
salinity	-	-	-	-
available water capacity	low	low to moderate	low to moderate	low to moderate
drainage class	well drained	well drained	well drained	well drained

APPENDIX B

Sample Criteria for Technical Terms in RPU-PPA Descriptions

Criteria for
Technical Terms in
RPU/PPA Descriptions[a]

Slope:

class	percent
level	3
undulating	3-8
rolling	9-15
hilly	16-30
steep	30

Depth to bedrock: < 50 cm (lithic); > 50 cm (non-lithic, i.e. word lithic does not appear in the soil name)

Texture: very coarse (more than 25% gravel)
coarse (sands, loamy sands);
moderately coarse (sandy loam, fine sandy loam);
medium (very fine sandy loam, silt loam, silt);
moderately fine (clay loam, sandy clay loam, silty clay loam);
fine (sandy clay, silty clay, clay).

Coarse fragments:

class	soil surface covered
non-stony	0.01%
stony	0.01-0.1%
very stony	0.1-15%
extremely stony	15-50%
rubbly	50-90%
very rubbly	90%

Permeability of the soil profile:

class	inches/hour
very slow	0.06
slow	0.06-0.2
moderately slow	0.2-0.6
moderate	0.6-2.0
moderately rapid	2.0-6.0
rapid	6.0-20.0
very rapid	> 20.0

Salinity

class	pH
strongly acid	> 5.5

[a] These criteria were developed for CRIES work in Honduras.

moderately acid	5.6-6.5
neutral	6.6-7.3
moderately alkaline	7.4-8.4
strongly alkaline	< 8.4

Available moisture capacity: Estimated available moisture capacity for a soil profile to a depth of 140 cm or to a layer restricting root growth:

class	range in cm
very low	0-8
low	8-15
moderate	15-23
high	23+

Flooding:

class	description
none	does not occur
rare	unlikely but possible under usual weather conditions
common	likely to occur annually under usual weather conditions

Duration of flooding:	description
very brief	2 days
brief	2-7 days
long	7 days - 1 month
very long	>1 month

Soil drainage class:

class	description
excessively drained	Water is removed from the soil very rapidly in relation to supply (very coarse textured, rocky, or shallow soils; also some steep soils).
somewhat excessively drained	Water is removed from the soil rapidly in relation to supply (coarse textured soils, and some shallow and some steep soils).
well drained	Water is removed from the soil readily but not rapidly (commonly medium textured, although not excessively).

moderately well drained	Water is removed from the soil somewhat slowly in relation to supply during some periods (commonly, with a slowly pervious layer within or immediately beneath the soil, relatively high rainfall for some periods, or a combination of these).
somewhat poorly drained	Water is removed from the soil slowly enough in relation to supply to keep the soil wet for significant periods during the growing season (commonly with a slowly pervious layer, a high water table, additions of water by seepage, nearly continuous rainfall, or a combination of these).
poorly drained	Water is removed so slowly in relation to supply that the soil is saturated periodically during the growing season or remains wet for long periods (high water table, slowly pervious layer, seepage, nearly continuous rainfall, or a combination of these).
very poorly drained	Water is removed from the soil so slowly in relation to supply that free water remains at or on the surface during most of the growing season (commonly level or depressed sites, or in high or continuous rainfall areas on moderate and high slope gradients, hill peats and climatic moors).

SUGGESTED REFERENCES

Beek, K.J. Land Evaluation for Agricultural Development. The Netherlands: International Institute for Land Reclamation and Improvement/ILRI, 1978.

This publication reviews and explores land-use systems analysis with particular reference to Latin America.

Clawson, Marion and Stewart, Charles L. Land Use Information. Baltimore, MD: The John Hopkins Press, 1964.

This publication explores and recommends necessary requirements of a good land use information system.

Craven, C.W. Sr.; Olson, R.J.; Reichale, D.E.; Schuller, C.R. and Voelker, A.H. Reflections on Regional Environmental Systems Analysis. Oak Ridge, TN: Oak Ridge National Laboratory, 1977.

This publication deals with the research strategy to develop and validate a hierarchy of computer models to assist in the analysis of relevant economic, physical, ecological and social processes in a 16-county region of East Tennessee.

Food and Agriculture Organization of the United Nations. A Framework for Land Evaluation. Rome, Italy: FAO, 1976.

This publication outlines and describes current FAO procedures for land evaluation and suitability classification.

______________________________. Land Evaluation in Europe. Rome, Italy: FAO, 1975.

This publication outlines the development of land evaluation methodology to be used by FAO/UNESCO Soil Map of the World with a view to making a global evaluation of the land resources available for agricultural development.

International Bank for Reconstruction and Development. Land Reform. Washington, D.C.: World Bank, 1975.

This publication identifies land reform with the changing institutional structure governing man's relationships with the land.

Jacks, G.V. Land Classification for Land-Use Planning. Harpenden, England: Imperial Bureau of Soil Science, 1946.

This publication related land classification to grouping of lands according to their suitability for producing plants of economic importance.

Land Classification Seminar. Proceedings of Land Study Bureau. Honolulu, Hawaii; 1969.

The Land Study Bureau's land classification study provides the kind of basic data required for land management and land planning problem analyses and land use determinations.

Lund, Gyde H.; LaBau, Vernon J.; Folliott, Peter F. and Robinson, David W. Integrated Inventories of Renewable Natural Resources. Proceedings of the Workshop, Tucson, Arizona; January 8-12, 1978. Tucson: Rocky Mountain Forest and Range Experiment Station, 1978.

This publication reviews various land and vegetation classification schemes, remote sensing opportunities, statistical considerations in integrating inventories and the available data processing packages and systems.

U.S.D.A. Soil Conservation Service. Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys. Washington, D.C.: U.S. Government Printing Office, 1975.

This publication describes the technical definitions of categories and classes, gives data and descriptions for selected soils, and explains meanings of soil class names used in the "Soil Series of the United States, Puerto Rico, and the Virgin Islands' Their Taxonomic Classification."

U.S.D.A. and Michigan State University. Honduras Land Base Report. 1405 S. Harrison Road, East Lansing, MI., 1980.

____________________________. Land Resource Base Report prepared for the Syrian Agricultural Sector Assessment Project. 1405 S. Harrison Road, East Lansing, MI., 1979.