BIBLIOGRAPHIC DATA SHEET

1. CONTROL NUMBER	2. SUBJECT CLASSIFICATION (695)
PN-AAJ-818	AP00-0000-0000

3. TITLE AND SUBTITLE (240)

The relationship between the area-frame and CRIES projects

4. PERSONAL AUTHORS (100)

Johnson, J. B.; Schultink, Ger; Putman, J. W.

5. CORPORATE AUTHORS (101)

USDA/ERS. Natural Resource Economics Division.

6. DOCUMENT DATE (110)	7. NUMBER OF PAGES (120)	8. ARC NUMBER (170)
1981	48p.	333.7613.J67

9. REFERENCE ORGANIZATION (130)

USDA/ERS

10. SUPPLEMENTARY NOTES (500)

11. ABSTRACT (950)

12. DESCRIPTORS (920)

Natural resources	Statistics
Agricultural planning	Land use
Agricultural development	Sampling
Statistical analysis	Policies
Statistical samples	Resources

13. PROJECT NUMBER (150)

14. CONTRACT NO.(140)

PA/AG/TAB-263-14-76

15. CONTRACT TYPE (140)

16. TYPE OF DOCUMENT (160)

AID 590-7 (10-79)

333.7613
J67

THE RELATIONSHIPS BETWEEN THE AREA-FRAME AND CRIES PROJECTS

Staff Report No. AGESS810720

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July 1981

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THE RELATIONSHIPS BETWEEN THE AREA-FRAME AND CRIES PROJECTS. By James B. Johnson, John W. Putman, and Scott Witter, Natural Resource Economics Division, Economics Research Service, U.S. Department of Agriculture, Staff Report No. AGESS810720, July 1981.

ABSTRACT

Agricultural policy analysis required integrated information sets, information management, and analytical capabilities. The intent of the area-frame project is to provide a method of obtaining statistical information at the national or subnational levels on current performance and economic characteristics of the agricultural sector. The CRIES project obtains information to identify the quality, quantity, use, and adaptability of natural resources and the development of management and analytical capabilities to analyze options for resource use. The basic concepts used by each project are reviewed to provide a basis for making recommendations for coordination in countries requesting technical assistance.

Keywords: area sampling frame, agricultural statistics, agricultural resource planning, land use stratification, resource inventory, enumeration methods

* *
* This paper was prepared for limited distribution to the *
* research community outside the U.S. Department of *
* Agriculture. *
* *

ACKNOWLEDGEMENTS

The recommendations put forth in this report are the result of a series of informal discussions held on prior occassions by staff members of the Economic Research Service and the Statistical Reporting Service, U.S. Department of Agriculture, and staff members from the Department of Resource Development, Michigan State University. The concepts and procedures of the CRIES project discussed in this report were developed by the project staff in its provision of technical assistance to developing countries. The project is funded under PASA #AG/TAB 263-14-76 between the U.S. Agency for International Development (AID) and the U.S. Department of Agriculture (USDA). Participation of Michigan State University (MSU) is covered under Research Agreement #12-17-07-8-1955 between USDA. Agency support was furnished by the Economic Research Service and the Department of Resource Development, MSU, for the authors, James B. Johnson and John W. Putman (ERS), and Ger Schultink (MSU). Much of the summary of area-frame concepts and procedures included in this report was taken from published sources on the subject.

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I. SUMMARY AND RECOMMENDATIONS

A. Introduction

Agricultural planning and policy analyses require integrated information sets, information management, and analytical capabilities to evaluate the impacts of development alternatives and agricultural policy options directed towards achieving agricultural production potential. Key information sets needed are current and/or historic performance of the agricultural sector including crop areas, yield, and production; livestock inventories and production; socio-economic information including commodity and input prices, production practices, and costs; and natural resource characteristics, resource use, and resource suitability and development potential.

The purpose of the CRIES project is to develop integrated information sets on the quantity, quality, current use, and agricultural suitability and development potential of natural resources and the information management and analytical capabilities to use such information sets in evaluating policy options for realizing agricultural production potential.

The purpose of the area frame project activity is to provide a cost effective method of obtaining statistically reliable information at the national or subnational levels on selected current performance characteristics of the agricultural sector. The area frame project offers flexibility in the estimation of a variety of types of statistics on agricultural production and socio-economic variables.

Historically, the two projects have not combined their technical assistance activities in developing countries. The two projects developed a joint working arrangement in one country. Neither project is designed to fulfill all the information needs for agricultural planning and policy analysis. After each project is initiated in a country, it has usually been called upon to make modifications to

provide for previously unforseen information needs. Because there exists a tendency on the part of information managers in developing countries to identify additional information needs subsequent to the initiation of each project's basic data acquisition activity, both projects must maintain the flexibility to fulfill these additional requests.

The two projects should be reevaluated with the goal of providing more of the information needs of each developing country. Closer coordination of the two projects could result in integrated information sets developed through compatible concepts and procedures that would fulfill more of the information needs for policy analysis and planning purposes of each country.

B. Differences in Procedures

In an area-frame project the land area is stratified (usually according to current land use), frame units delineated within strata, and segments delineated within frame units. Under methods of frame construction auxiliary data on soils, resource conditions, irrigation, etc., are sometimes used when readily available to achieve a high level of homogeneity within strata.[1/] The stratification process is two dimensional (geographic and land use). There are usually compromises between the levels of homogeneity possible in strata and frame unit delineation and maintaining the integrity of recognizable man-made or natural boundaries for the frame units. Frame units, usually 30 to 50 square kilometers in size, are divided into segments which are delineated on large scale maps or photographic products so that boundaries are recognizable to enumerators conducting sample surveys.

When a randomly-selected segment is surveyed, the usual result is a total enumeration of the variables of concern within the segment. The sample totals obtained from interviews and observation of the segments, are expanded to obtain

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1/ There have been some recent experiences with optimum stratification techniques where such types of information have been more explicitly employed in the stratification process. However, these approaches are most applicable where detailed information is available on costs and variations and an explicit need has been established for this improved stratification.

estimates for the stratum total. In the simplest case, when segment size can be controlled for equal probability sampling, expansion factors are the inverses of the sampling ratios, i.e. $\frac{N}{n}$. Estimates are presented at the state, region, and/or national levels with accompanying statements of the statistical reliability of each level. Estimates have traditionally not been reported at the frame unit or strata level.

In the CRIES project activities, the national land area is inventoried to delineate homogeneous resource planning units (RPUs). The units are defined to be relatively homogeneous with respect to soil and climatic conditions associated with suitability for agricultural uses. Interpretations for potential agricultural uses can be made directly from the land resource inventory; such interpretations range from the general to the specific. General interpretations relate to soil suitability and limiting factors affecting land use for crop production. Specific interpretations are made for crop adaptability and productivity. To establish a base from which to evaluate policy alternatives, baseline information on current major land uses, including agricultural uses, and performance variables of the agricultural sector (yields, area planted, livestock production, prices of inputs and outputs, production costs, etc.) are associated with each RPU. If estimates of such variables are unavailable at the national or subnational level from an on-going area-frame project, baseline information is derived from other secondary data sources. National or regional estimates of particular land use or performance variables, available from secondary sources, have to be disaggregated through the use of allocative procedures to the RPUs. If suitable secondary sources are unavailable, the CRIES project employs primary data collection methods especially for establishing major land use by RPU. Major land cover/use is mapped through the visual interpretation of Landsat imagery. The Geographic Information System is used to cross reference major land cover/use with the RPUs. The overall intent

is to establish a baseline, composed of integrated information sets onto the current conditions in each RPU, suitable for the analysis of comparative advantages in resource use to evaluate alternative agricultural policy options directed towards increasing agricultural production.

To summarize, the area-frame project uses enumerated data from randomly selected segments (small land areas with recognizable boundaries) to expand to national or subnational levels with a measured statistical reliability for agricultural sector performance variables. The CRIES project stratifies the national land resource base into RPUs and relates information on land use and agricultural performance to these units to provide a baseline for analyzing agricultural policy alternatives.

C. Commonality in Use of Base Materials

Land use information is used by both projects. Unless sources are already available, both projects rely on land cover/use information that can be interpreted from aerial photography or Landsat imagery. Those constructing area frames use land use maps derived from such sources for stratification, and if the map or base materials are of adequate scale, to delineate frame units within strata. The CRIES project uses such land use maps to associate current land use with the land resource base to provide a baseline for the analyses of policy options.

Those constructing area frames usually have developed strata by a ratio definition where a specified percentage or more of the existing land use within a stratum must be in the dominant use indicated by the stratum's name, i.e., a cultivated crops stratum definition might require 75 percent or more of its total land area to be in cultivated crops. Greater homogeneity for strata could often be achieved; however, doing so might compromise the delineation of recognizable boundaries for frame units. The CRIES classification categories have varied from those similar to the strata definitions employed for area-frame construction to

general type of farming definitions. An example of the latter would be an intensive agriculture land cover/use category that would include areas of major irrigation development with evidence of multiple cropping. Nominal adjustments in the classification category (strata) definitions and the cartographic detail (minimum map unit size) could fulfill the needs of both projects.

Both projects generally use medium-scale topographic maps to register their land use interpretations. In addition, the CRIES project registers its RPU delineations to such a base. Both projects often have a need to have the political subdivisions of the country delineated on the topographic base. Area frame activities use political subdivisions (administrative boundaries) in the frame unit delineation unit process and often use administrative boundaries in the allocation of enumerator assignments. The CRIES project uses the administrative boundaries to cross-reference the results of policy analyses conducted by RPU with regions, states, provinces or other political boundary configurations used for policy implementation.

The CRIES project uses soil maps, maps of climatic characteristics, and vegetative cover and/or zone maps in the resource inventory to delineate the RPUs. Other associated maps of hydrologic zones, irrigated areas, etc., surface and groundwater characteristics are also incorporated into the resource inventory. The area-frame projects have traditionally used such types of information as auxiliary information to verify the land use patterns that are used as the primary basis for stratification.

Area-frame projects conducted in developing countries use physical map overlay procedures to associate auxiliary information available on mapped bases with land use maps used as the basis for stratification. For certain purposes area frame projects also capture the mapped data so that the information can be

computer managed.[2/] Activities of the CRIES project often uses physical overlay procedures (topographic map, soils maps, maps of climatic characteristics) in the delineation of the RPUs. The Geographic Information System is used to record the mapped data, through manual or computer-aided digitization procedures, and to cross-reference the various information sets on land use, etc., with the RPUs.

The area-frame project usually provides or assists in providing the computer routines for editing, summarizing, and expanding sample observations and totals to obtain national or subnational estimates. Likewise, the CRIES project usually provides an Agroeconomic Information System (AIS) in those countries where there exists an ongoing agricultural statistics program with a sufficiently large information base to warrant a computerized information management system for efficient information management. The configuration of AIS depends on the structure of the particular country's information base.

D. Recommendations for Integration of the Projects

In developing countries where both the CRIES and area frame projects are scheduled for concurrent implementation, the following sequence could be tested for appropriateness.

1. The two projects would work jointly with developing country officials to determine the information needs of the agricultural sector.

2. Both projects would determine the participating country's existing primary data acquisition and information management capabilities. This would include identification of:

   a. Primary data acquisition capabilities using remote sensing materials and enumerative surveys.
   b. Computer-based information management capabilities.
   c. Computer-based analytical systems capabilities; i.e. - standard statistical routines; economic modelling capabilities, etc.

3. The two projects would select a topographic base of sufficient scale for delineation of area frame strata and RPUs. If possible, this map or an auxiliary map of similar scale, should reflect the national and internal political boundaries of the participating country.

[2/] 1981. AgRISTARS, Domestic Crops and Land Cover Project, No. T-11-81, Temporary Directive, Economics and Statistics Service, USDA, p.4.

4. The CRIES project would conduct the natural resource inventory and evaluation. Copies of all individual resource maps (soils, climate, vegetation, hydrology, etc.) used in the delineation of the RPUs would be provided to those constructing the area-frame so that they could be referenced in the stratification process.

5. The two projects would mutually select one geographic-referenced information management system.

6. One project would capture the mapped data from the topographic/political boundary map for inclusion in the geographic information management system. These data would provide control totals for national and subnational political areas.

7. The two projects would mutually specify the classification criteria for a major land use map. One project would proceed with the interpretation of major land use categories from aerial photography and/or other remote-sensing materials to provide the land cover/use map.

8. Concurrent with the proceeding step the CRIES project would digitize the RPU map for inclusion in the geographic information system. Additionally, any of the individual resource maps that would add information beyond that included in the resource planning unit map to the area-frame construction process would be digitized and added to the geographic information management system.

9. The area-frame project would proceed with frame construction, including delineation of frame units and segments to accommodate the enumeration of agricultural performance data on a periodic basis.

10. The CRIES project would proceed to develop its baseline integrated information sets from secondary data or primary data collection activities. When primary data collection activities are required, statisticians from the area frame project would participate in sample design and expansion procedure specifications.

11. The CRIES project would provide training in resource inventory and evaluation procedures and other techniques required to update and refine the integrated information sets needed for the analysis of policy alternatives directed towards increasing agricultural production.

12. The area-frame project would proceed with the training needed to assure participating country management of the enumeration, editing, summarization, and reporting activities of a complete agricultural statistics program. Training would also be provided on techniques for area frame maintenance, updating and segment rotation (and personnel needs, etc.).

13. The CRIES project would provide training on the use of analytical procedures to provide a basis for the evaluation of agricultural policy options. Collaboration would be needed from those involved in the area-frame project to provide training on the use of statistically reliable data on agricultural sector performance variables once the agricultural statistics program is operational. Also, those involved in

the development of the agricultural statistics program would provide training in the use of disaggregated performance variable national totals for assignment to the RPUs or other sub-national delineations used in policy analyses and evaluations.

II. PURPOSES OF PROJECTS

A number of developing country governments have been provided or requested technical assistance to pursue area-frame sampling for the purpose of developing statistics useful in evaluating the performance of their agricultural sectors. Likewise, a number of developing countries are now using concepts put in place through collaboration with the Comprehensive Resource Inventory and Evaluation System (CRIES) project to inventory and evaluate natural resources, the agricultural uses of natural resources, and the agronomic and socio-economic factors associated with agricultural production as a basis for assessing agricultural production potential.

Some of the concepts, procedures, and base materials employed in developing area frames and in conducting natural resource inventories and evaluations are similar or complementary. Subsequent sections of this report present discussions of the concepts, procedures, and materials employed by each of these two activities.

A. Purpose of the Area-Frame Sampling Project

Area-frame sampling can provide accurate and timely information based on small samples. The use of sample survey data will allow accuracy to be evaluated in terms of sampling error (precision) and procedures can be implemented to evaluate the level of nonsampling error (bias). Nonsampling errors can generally be minimized through modifications in concepts used, and through quality control procedures for data collection and summarization. Sampling errors can be reduced by improving the survey design and/or increasing sample size. Sampling error and cost data can be periodically reviewed in order to optimize the creation of relevant information in a timely fashion for use by decision makers.

Many developing nations gather their only statistical information of the agricultural sector by total enumeration such as a complete nationwide census conducted at ten year intervals. A census-approach to acquiring statistical information for the agricultural sector is used because it is traditional, the conceptual basis for such is easily understood, and policy-level officials are generally familiar and/or have had prior experiences with the method. There are disadvantages of the census (total enumeration) method of acquiring statistical information. The overriding disadvantage is the cost of conducting a total enumeration. Another disadvantage is the difficult task of tabulating and analyzing the information so that it can be reported to users in a useable published form within a reasonable time period. Probability sampling is a more efficient means of acquiring statistics on the agricultural sector.

Considering factors of data reliability and cost, area-frame sampling is usually a more effective and efficient means of obtaining agricultural statistics than total enumeration.

B. Purposes of the Comprehensive Resource Inventory and Evaluation Project

The agricultural production process encompasses a wide array of natural resource-product combinations. This array is managed under a variety of technological, institutional, and market conditions. For national-level planning there is a need to use a systematic framework to stratify the array of natural resource-product combinations into discrete intervals that facilitates the consideration of alternative technological, institutional, and marketing arrangements for policy analysis.

Through the application of appropriate taxonomic concepts the natural resource base is classified into discrete units that provide the foundation for the coordination of a computer-aided information and evaluation system. To facilitate the analyses of programs and policies directed towards achieving agricultural

production potential, information sets generally associated with the natural resource inventory are land use, agronomic, and socio-economic information. A variety of evaluations can be conducted through integration of these information sets. The current use levels (with respect to areas used and intensity of use) of the agricultural land resource base can be calculated. Preliminary indications of the avenues for increasing agricultural production can be specified; that is, if the land resource base suitable for agricultural uses has apparently been fully exhausted, it becomes readily apparent that agricultural production increases will have to be achieved through yield improvements (considering more suitable varieties, the increased use of purchased inputs, etc.), through the appropriate location of the production so that each crop is produced on that resource base for which it has the highest comparative advantage or least comparative advantage, and through the introduction of capital improvements into the agricultural sector to fulfill treatment needs of the land resource base. As the number of policy and development options become more numerous, analytical procedures are needed to adequately trace the interactions among the resource base, possible uses, and economic factors.

III. CRIES LAND RESOURCE CLASSIFICATION AND EVALUATION CONCEPTS AND PROCEDURES

Agricultural production requires the presence of naturally-occurring factors such as soil, temperature, water, and sunlight in the general proportions needed by plants. These interrelated factors are generally grouped into two components -- soil and climate -- to simplify the problem of estimating the impacts of the environment on the adaptability and vigor of economically important plants. Categorization of these two main factors underlies the resource evaluation concepts and classification procedures employed.

A. Purpose of Land Resource Evaluation

To provide for analyses of comparative advantage in the use of agricultural resources - it is necessary that the land resources be inventoried into areas (land resource units) that are relatively homogeneous for which reasonable estimates about current land use, plant adaptations, plant productivity, management practices, and development options can be made. The classification of the land resource into resource units with known soil and climatic factors will facilitate agrotechnology transfer from other resource units with similar soil and climatic conditions.

B. Definitions

The CRIES project employs a two-level system of land resource classification to accommodate information management and analytical needs. The homogeneous resource area that fulfills the analytical need is called the production potential area (PPA). The unit that is geographically and cartographically identified to facilitate information management is called the resource planning unit (RPU).

RPUs and PPAs are specifically defined as follows:

> Resource Planning Unit — an RPU is a geographically-defined 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 — 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 divide the landscape into natural, physiographic planning units, serve as reference points for field technicians, and provide the reference for the Geographic Information System to merge, cross-classify, and aggregate mapped, natural resource data from various sources.

RPUs are generally composed of a variety of similar and often contrasting soil bodies (and sometimes microclimates) which may occur in intricate and complex spatial patterns. Such complexities, however, are generally regular and repeating in nature and are uniquely different from the spatial patterns and complexities of other RPUs.

The interpretation of RPUs for crop adaptability, productivity, and management requirements must take soils and microclimates into account in greater detail. Hence, the individual, major soil bodies and associated microclimates composing an RPU become production potential areas (PPAs) suitable for the analysis of agricultural production alternatives.

PPAs are taxonomically defineable with respect to their soil properties; microclimate conditions, if variable within a particular RPU, are associated with the aggregate of soil bodies that comprise a PPA. PPA estimates provide the homogeneity of soils, land form, and climate necessary to assess crop adaptability, productivity, management requirements, and development potential for national and regional planning. 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 resources 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 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 a single-valued input coefficient (productive factors) and an output (yield) coefficient.
>
> 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.

Map units of RPUs and tabular estimates of the area, distribution, and agronomic capability of PPAs within RPUs provide the essential geographic location and resource interpretations for determining national policy and priorities at a reasonable cost. This allows the time consuming and more costly detailed mapping and investigations to be deferred until program and project priorities are identified and for the level of detail to be determined by program and project needs.

C. Procedures

RPUs are sufficiently extensive that they can be shown on maps of intermediate or small scale; PPAs are portions of the mapped RPUs. Although individual PPAs are usually not extensive enough to be mapped on maps of intermediate or small scale, they could be depicted cartographically on maps of large scale for purposes of subregional or project planning.

The creation of RPUs and PPAs involves the study of the resource patterns of a country. Knowledge about the kinds of soils, climate, and natural vegetation and their distribution, as portrayed in the soil and climate studies, are combined to create broad segments of the national or regional land resource base that are relatively uniform with respect to the physical environment within which a specific kind or kinds of agricultural endeavor can be carried out with expected results.

A key step in the process of creating RPUs generally involves superimposing transparent copies of working drafts of soil maps derived according to taxonomic criteria over topographic reference maps and refining these delineations through field surveys. In order to work with the concepts of the RPU, knowledge of the

kind and distribution of soils is essential. This knowledge commonly is derived in several ways. It can most easily be acquired from published maps and reports dealing directly with the subject. These may range from very detailed studies in which soils are mapped and described with precision suitable for site management to those highly generalized for regional planning procedures. This knowledge can also be derived from published and unpublished data dealing with subjects related to soils and soil genesis, e.g., geology, vegetation, climate, etc.

Information about the kinds and distribution of soils is sometimes available from generalized studies dealing with the country as a whole. Some additional detailed information is sometimes found in special studies such as those prepared for irrigation and drainage projects. The more detailed studies of the relatively small project areas are consulted for the purpose of characterizing units in the generalized studies. To supplement these documented data, project soil scientists consult with the developing country counterpart soil scientists to obtain additional data based on their knowledge and experience.

Usually several systems of soils classification have been used in published soil studies available in a participating country. By using available descriptive materials, the soils are reclassified in terms of a common system, Soil Taxonomy. For those areas for which no pedological classification is available, classification can often be inferred from other data on geology, climate, vegetation, topography, and geologic age.

Resource units are characterized in terms of elevation, ranges of slope and nature of the underlying materials. Elevation and slope are usually estimated from topographic maps. The nature of the underlying materials can usually be obtained from published or unpublished sources dealing with geology and/or information contained in legends of available soil maps.

Information on climatic conditions is usually available from several sources. Weather station data can often be obtained from climatological files in the participating country or for a more limited set of stations from the World Metereological Organization. In addition, sometimes published or unpublished data aspects of climatic conditions can be obtained that are relevant to plant growth. Other sources such as floristic data, botanical plant lists by areas within the country, and vegetation maps provide information that can be used to obtain information on climatic conditions through inferential procedures.

Climatic information is interpreted to obtain estimates of several variables important to plant adaptability and plant productivity at the RPU level. Among those variables for which estimates are sought are mean annual temperature, mean annual precipitation, number and duration of wet season(s), mean monthly temperature and precipitation in the wet season, duration of the growing season, and the presence or absence of killing frosts. Variations within an RPU for a particular climatic variable, where particularly significant, are incorporated as microclimatic conditions in the delineation of the PPAs of an RPU.

The criteria for establishing PPAs are perhaps best described by example. Consider a geographic area consisting of steeply sloping limestone ridges with shallow stony soils separated by level or nearly level ground with deep non-stony soils of nearly equal extent. Climate is considered uniform throughout the geographic area. Neither the steeply sloping limestone ridges nor the areas of level, non-stony soil are sufficiently extensive to be considered an RPU, so they are considered together for planning purposes. The steep ridges comprise one PPA and the intervening level ground comprises the other PPA. Each PPA has unique potential for agricultural use.

A corresponding illustration is one in which soil is uniform and microclimatic conditions differ within an RPU. Consider a mountainous area with steep slopes

and predominantly shallow soils extending to elevations of several hundred meters. Microclimatic conditions, especially temperatures, vary significantly with changes in altitude. In this instance, potential for economic use differs at low, mid, and upper ranges of elevation. Each range of elevation can be identified as a PPA within the mountain RPU.

In some situations, PPAs can be identified on the basis of differences in physical characteristics within an RPU but the potential for agricultural use might not be significantly different, or a single overriding factor may severely limit the potential for economic use. In these situations RPUs would be identified but would not normally be divided into PPAs.

The proportion of an RPU that is represented by a PPA is estimated on the basis of the resource scientists' accumulated knowledge about the RPU. In some instances the figure can be based on field observations, in other cases by use of reference maps, and in yet other situations by use of judgement and previous experience. Rarely would precise measurement of the extent of PPAs be feasible.

D. Interpretations

RPUs generally range in size from 50,000 hectares to 300,000 hectares in most agricultural areas but may be as small as 5,000 hectares in intensive agricultural areas and as large as 1 million or more hectares in mountainous or arid expanses with limited agricultural potential. The number of PPAs delineated in an RPU ranges from one (a totally homogeneous RPU with respect to soil and climate) to four or five.

Agronomic interpretations are made at the PPA level. The PPAs provide the homogeneity of land form, soil, and climate to reliably assess plant adaptability and productivity, management requirements, and development potential for national-level planning. Two levels of interpretation can be made directly from the PPA descriptions. The first is a general interpretation for agricultural land

use. The second, more detailed interpretations are the crop or crop group recommendations. (An example RPU/PPA descriptions are included as Appendix A).

1. General Interpretations:

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 PPA descriptions; such evaluations 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.

The first 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.

The types of cropland management might be defined as follows:

I. Very limited use of inputs and no land preparation.

II. Some input use and use of animal power.

III. A high level of input use and use of mechanical power for land preparation and cultural practices.

IV. Tree crops.

Ratings of soil potential, expressed as a function of management types and soils, are used for planning purposes and are not intended as specific recommendations for soil use. Interpretations of soil performance for crop production could be assigned one of three ratings as follows:

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 produce above average yields naturally occurring in a PPA rated good. These limitations include 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 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. Severe climate or soil limitations such as very steep slopes, extreme droughtiness, drainage conditions, long periods of flooding, high salinity, and shallow rooting depth are present.

The second 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. Attributes 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.

2. Crop and Crop Group Interpretations:

The more detailed interpretations made from the production potential area descriptions are crop recommendations. Crop recommendations denote where major crops or crop groups are adaptable and provide some indication of yield potential under alternative management levels.[3/] Ratings are qualitatively expressed as "high", "medium", and "low". Explanations of these ratings are provided:

[3/] Crops taken to be major crops are a matter of judgement. Food or fiber crops of minor economic importance may be suited for specific PPAs.

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 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.

IV. CRIES LAND USE/COVER CLASSIFICATION CONCEPTS AND PROCEDURES

Each developing country faces a series of important questions relative to how it might expand agricultural production. Among these are: (1) What portion of its land base suitable for cultivated agriculture is currently in such uses?; (2) What are the resource limitations and associated treatment needs of currently uncultivated lands suitable for development as cultivated lands?; (3) What sources of capital exist or could be developed to bring additional areas into cultivation?; (4) What varietal improvements in crops, and changes in the application of ferlitizers or other purchased inputs, and changes in cultural practices can be achieved to

intensify production on the land base currently in cultivation?; and (5) What are the socio-economic limitations such as fragmented land holdings that might limit increases in agricultural production? All such questions focus on land, limited in supply, as a major input into agricultural production. Therefore, the ability to identify the current uses of land is extremely important in addressing these questions.

Several methods have been 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). The association of major land use with the land resource delineations allows assessments to be made of the proportions of the land resource base suitable for agriculture that are currently under cultivation and/or used for range. Those areas of the land resource base suitable for agriculture but not currently used for agricultural purposes can be isolated and evaluated to determine treatment needs and associated capital outlays required to bring them into agricultural production. Current use patterns by RPU provide background information necessary to conduct more detailed physical assessments and economic evaluations on possible means of production intensification and/or rearrangement of production patterns to realize comparative advantage in the location of agricultural production.

As previously stated, the means of associating land use with the land resource base for these stated purposes of assessment and analyses depends upon the types of data available. Some developing countries have census land use data sets on major land use and crop distribution patterns reported at five or ten year intervals. A few countries collect census-type land use information on an annual basis

through an ongoing agricultural statistics program. Such census-type information is generally collected by internal administrative (political) boundaries. Allocation systems are required to distribute the census-type land cover/use data to the mapped RPUs. Auxiliary sources of mapped land use data are occasionally available from a commodity group (i.e., national cotton control board, etc.) or another project 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 reliable data on land use, visual interpretation of Landsat imagery has been used to develop maps of major land use and/or cover types. Visual interpretation of Landsat is a cost effective method for delineating major land uses. Land cover/use classifications are selected to be as compatible as possible with the land use categories for which statistics are periodically collected by the participating government.

A. Procedures and Methods of Delineation

Land cover/use maps for participating countries 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 interpreted using standard photogrammic visual interpretation techniques and these interpretations are verified during the initial ground truth activity. The second stage involves the 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, re-interpretation of these areas, and preparation of final map products.

The initial activity in the first stage is to review the available Landsat images of the participating country and select a set of test areas that are representative of land cover/use patterns of the country. Collateral information to familiarize interpreters with ground conditions in the participating country is obtained from government reports, maps, and agricultural statistics to guide the selection of the test sites. Preliminary Level I/II land cover/use interpretations of the test sites are made from the imagery. Tracing paper copies are made of these interpretations and transferred to a topographic map base. The next major activity involves field checking of test site interpretations so that interpreters can associate the interpreted patterns with actual land cover/use. Another function of ground truthing at this stage is to gain information that will contribute to a decision on the nature of the final classification system. Embodied in this activity is a matching of the definitions of the classification categories (where possible) with categories used by the participating country to report major land uses in its ongoing statistics program (if such exists).

The second stage involves the comprehensive mapping of land cover/use for the participating country from Landsat imagery aided by auxilary information acquired in the field checking of the preliminary test sites and other available supplemental data. False color composites are used as the basis for developing the preliminary land cover/use maps. These color composites are generated from black-and-white positive transparencies using a variety of image enhancement methods. The land cover/use interpretations are made directly onto frosted mylar topographic maps of the participating country using a back-lighted projection system. Precise scale matching is accomplished by placing a grid over the false color transparencies and taking measurements from the screen. Usually land cover/use patterns of discrete areas of 0.5 km^2 or larger are delineated from the projected image onto the frosted mylar base maps in the mapping process.

Depending upon the final use of the land cover/use information, discrete areas of larger than 0.5 km^2 can be employed. During the mapping process the interpreter projects 35mm slides of test site field conditions and reviews field notes to aid in the separation of tone, texture, and ground patterns into specific land cover/use categories. At the end of this stage a preliminary map and accompanying classification scheme are available for final field checking.

The final stage involves a field check of persistent problem areas encountered during the second stage, a re-interpretation of these areas after consideration of the additional field information, and preparation of final map products. The final field checking is most appropriately scheduled (for agricultural categories) at a time when plant growth is nearing maturity -- but prior to the harvesting season. The field work is concentrated in areas where interpretation was limited because of the lack of timely imagery (either sparse coverage in recent years or insufficient growing season coverage) or because poor quality imagery limited the interpretation. Needs for revision are noted. During the field activity descriptions of the classification categories are compared with the land cover/uses observed. Care is taken to assure the exclusivity of the classification categories. When the field activities are completed, re-interpretations are made for those problem areas requiring adjustments and a final land cover/use map with mutually exclusive classification categories is produced.

B. Classification Categories

A final classification scheme for a visually-delineated 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 uses such as cross-referencing with RPUs or comparison of the tabular information desired from the land cover/use

map with published statistics available on land use from an ongoing statistics program or some prior special study of a particular land use conducted in the participating country.

Generally Level I/II classification categories are used. To illustrate the content of the classification categories two classification schemes recently employed by the project are provided as examples. The first example is for a country with a large arid expanse. The second example is for a country with predominant tropical conditions.

For the predominately arid country, the classification categories were:

1. Intensive Agriculture — areas of major irrigation development, with evidence of multiple cropping.

2. Extensive Agriculture -- indicates areas normally with a single crop, usually but not exclusively, non-irrigated.

3. Range -- indicates areas where natural vegetation is predominantly grass-like plants, forbs, or shrubs that can be used for grazing.

4. Water — indicates areas covered in water year-round — lakes, reservoirs, and rivers.

5. Urban — indicates areas of intensive use with much of the land covered by man-made structures.

6. Forest — indicates areas of deciduous, coniferous and mixed forest.

7. Orchards — indicates areas of cultivated trees for fruit and nut production.

8. Barren — indicates areas of limited plant life with less than one-third of the area covered by vegetation.

For the tropical country the classification categories were:

1. Urban and Built-Up: Man-made structures for residential, industrial, commercial and transportation-related land uses in contiguous areas of more than 1 km^2.

2. Agriculture: Land use for the production of food and/or fiber.

   2.1 Sugar: Major agricultural areas with 75 percent or more of the land planted to sugar cane interspersed with few other major crops except improved pasture.

2.2 Intensive Agriculture: All other major agricultural areas with predominantly more than 75 percent of the land used for field and tree crops usually associated with prime agricultural areas.

2.3 Marginal Agriculture: Less intensive, agricultural areas of a predominantly subsistence nature with 25 to 75 percent of the land used for field and tree crops. Usually characterized by smaller fields interspersed with unimproved pasture, range, trees and open land in hilly terrain and foothills.

2.4 Pasture: Predominantly improved pasture used for grazing.

3. Rangeland: Areas with a predominant brush and grass vegetation cover. Limited potential for grazing. Presence of Xerophytic plants common in the foothills.

3.1 Limited Rangeland: Areas with major limitations for grazing caused either by steep slopes or heavy brush cover.

4. Forest: Forest lands predominantly with a crown closure of 75 percent or more.

4.1 Predominantly Deciduous

4.2 Predominantly Coniferous

5. Wetlands: Areas with a hydrologic regime accommodating aquatic or hydrophytic vegetation, excluding areas in rice production.

6. Barren/Open: Areas with exposed soil and little or no vegetation cover.

7. Water: Inland water surfaces.

8. Cloud Cover: Areas for which cloud free satellite imagery could not be obtained.

Particular attention should be directed to the descriptions of the classification categories. The sum of the categories totally exhausts the land area. The mutually exclusive nature of the categories allows the agricultural categories to be isolated from the nonagricultural categories. The agricultural categories are delineated and described to reflect the type of farming that is occurring within the category. For example, the "intensive agriculture" category for the arid country represents areas that are predominately irrigated and have a cropping pattern that allows more than one crop to be grown in sequence on the land area within the

same year. The "intensive agriculture" category for the tropical country represents areas where more than 75 percent of the land in the area delineated is field or tree crops.

C. Use of Land Cover/Use Delineations

There has been three major uses made of the information captured for the land cover/use maps developed for the participating countries. Other potential uses are possible, especially with some adjustments in the classification schemes.

One major use that has been made of the land cover/use information is direct cross-referencing to specify current land use within the physiographically-delineated RPUs. When PPAs are coarsely patterned within an RPU use can be inferentially obtained. When current use of the agricultural categories is obtainable by PPA the general interpretations and crop recommendations for agricultural potential for these areas can be compared with current uses. Some measure of the current intensity of agricultural activity compared to that considered desirable to maintain the resource base in a useable state through time can be obtained. Gross calculations can be made about the physical potential for expansion of cultivated lands in the RPUs and PPAs. Extreme care must be taken in such calculations to consider the possiblity of expansion of cultivated lands to recognize other competing uses (nonagricultural) for the land resource base and the affects of market allocations to the highest competing use and of allocations by decree, zoning, or other nonmarket means.

A second major use of land cover/use information derived through Landsat imagery interpretation has been the comparison with land use statistics generated by other means in the participating country. Census-type methods are often used. Landsat imagery can usually be matched to the census periods that occur at five or ten year intervals. However, if considerable time has elapsed since the most current census, field verification of Landsat-interpreted major land cover/use

patterns is of dubious value because of the possibility of changed land cover/use patterns during the period subsequent to the census. This problem is minimized if the census collection just preceeds or is conducted concurrently with the visual interpretation of the relevant Landsat imagery. Such a situation existed during a recent technical assistance activity where data collection was conducted on an annual basis. The participating country requested that the agricultural categories of its census-type data be compared to the agricultural categories delineated from the interpretation of Landsat imagery. Comparison of the results indicated less than one percent difference in the area estimates for the agricultural categories at the national level. In such a comparison there is no a priori or ex post means of specifying one data set as the "actual" or theoretically correct and the other as the empirical estimate. The value to the participating country of this test was that the estimates by independent means of major land use categories for agriculture were similar; this similarity seemed to dispell the judgements made from qualitative assessments of the census-type data that under-reporting of the cultivated agriculture categories was occurring.

The third major use that has been made of major land use information taken from maps derived from interpreted Landsat imagery is the joint use of the major land information from Landsat interpretation and other sources of data to specify crop use of land by administrative units and/or RPUs. Perhaps this use can best be described by example. Administrative unit "A" is totally exhausted by RPUs 1 and 2 and no portion of either RPU lies outside of administrative unit A. RPU 1 constitutes the northern one-third of the administrative unit and RPU 2 the southern two-thirds of the administrative unit. The visually interpreted Landsat imagery indicates that all the cultivated agriculture in the administrative unit is located in the southern one-half of administrative unit. Census-type statistics on major agricultural land uses, which are reported to be 50 percent of the land area

in the administrative unit, (and crop distribution patterns for the major land use categories) can be assigned directly to RPU 2. For symmetry, if the interpreted Landsat imagery indicated forest cover occurs only in the northern portion of the administrative unit, the statistical information on land use that indicates only about 10 percent of the unit is forested would be allocated to RPU 1. In this example the interpreted Landsat imagery provides some locational specificity to the land use data reported in the statistical information for the administrative unit and provides a vehicle to associate statistical information that is correlated with land use.

It is recognized that the example presented for the third major application of Landsat-derived major land cover/use information is highly simplified. In actual situations, there are sometimes parts of several RPUs within an administrative unit. The allocation of statistical information using the Landsat-based information to provide geographic specificity has a sufficient number of possible combinations to require the use of computer-based routines. This is one of several uses for which the Geographic Information System is designed.

V. CRIES GEOGRAPHIC INFORMATION SYSTEM

One of the prime needs in conducting an agricultural resource inventory and assessment of agricultural production potential is an ability to relate the spatial location, extent, and quality of the resource base to other factors. Among the other factors are current land use and the administrative subdivisions of the country used for program implementation. The Geographic Information System provides this ability.

A. General Conceptual Structure

The Geographic Information System (GIS) provides the ability to retrieve all or portions of mapped inventory information, to add new information to the geographic information base, to conduct statistical analyses of geographically-referenced information, and to display analyses in tabular or map form. Typical

products include area measurements of single maps, area measurements of combinations of two or more maps, and computer printer-maps of various scales for single or combined mapped data.

The system is used primarily to meet the analytical needs for assessing agricultural production potential. The information obtained from the map bases can be used in technical evaluations of the existing resources or to provide information formatted for incorporation into analytical models. Virtually any phenomena located on a map or assigned to a map location, either at a point or within a boundary (map unit), may be incorporated into the information system in the form of either identity codes or measurement parameters. The system uses a grid cell concept to geocode, process, and retain geographic identity in computer format. It is important for the user to understand that the information captured in digital format is a geometric approximation, in units equal to the cell size used, of smooth boundaries and/or continuous data sets. While the system is independent of cell size, applications to date have usually used a one km^2 grid cell. When a one km^2 grid is used, points are located no more precisely than within a single km^2, and magnitude data refers to the average or most typical of the population of a measurement variable within a km^2 map unit.

Each type of map included in the information system is called a <u>factor</u>. Each factor may have many values and/or codes assigned which are called attributes. Factors are usually captured in two forms — <u>contiguous</u> and <u>discontiguous</u>. Contiguous factors refer to mapped data that share a common boundary for each map unit. The sum of contiguous factors is equal to the surface area in the study area. An identifying code is associated with every grid cell. Discontiguous data may occur only in discrete areas and/or individual grid cells. For discontiguous data only part of the grid cells of concern area have codes. For example, irrigated land might be coded by map unit or weather stations might be coded by the grid cell in which they occur.

Attributes are generally of two types — identity and magnitude. Identity attributes are merely identification codes and have no arithmetic properties; e.g., soil codes or region codes. Magnitude data sets are in the form of measurement or dimension of some variable; e.g., average rainfall or crop yields.

The system is initiated by geocoding the "official" base map of the area to determine standard dimensions for the information system. Normally, the information system is established to confirm to the outside boundaries of the study area — usually the official administrative boundaries of a country. Sub-administrative boundaries are also normally geocoded as part of this map factor. In any event, one map and its map factor must be chosen as the standard base to dimension the outside boundaries of the information base. As subsequent factors are geocoded, they are cartographically calibrated to the boundaries of the base map and then computer checked and adjusted to ensure identical data dimensions for every factor. A basic file will generally consist of maps depicting administrative boundaries (countries, states, provinces, regions, etc.), the RPUs delineated in the inventory of the agricultural resource base, and current land cover/use. Other maps that could be added to the basic file, depending upon availability and relevance to the participating country, are those showing irrigation development, agricultural crop types, forest areas, and so forth.

Once the attributes of each factor (map) have been geocoded (in a digital format compatible for computer use), data are available for processing and analysis. The computer system consists of fourteen separate phases. These phases are of four general types — (1) Technical — input, output, and program communication; (2) Data Restructuring; (3) Data Analysis; and (4) Data Display. The technical phases provide the capability for data retrieval, file editing, and program control. The data restructuring phases provide various data manipulation and reconstruction features for use by the analyst. There are three major data analysis phases. The

one that has generally received the most use has been the cross-tabulations phase which phase produces frequency tables for up to nine factors. In addition to the frequency count of cells by factor combinations, row and column percent or totals for each cell in the data system are provided. Statistical tests, such as Chi-square, can be provided for each table of cross-referenced factor attributes. The display phases provide for scale and unscaled maps for use as visual aids in presentations of analytical results and for data verification purposes.[4/]

B. Use of GIS in CRIES Project Technical Assistance Activities

In each country the Geographic Information System has been used to record and make available for subsequent analyses mapped information political boundaries, RPUs, and land use features. Tabulations of administrative areas from the system have been compared with published statistics to identify discrepencies between mapped information and published area total available in statistical abstracts or other secondary sources. Interpreted land use information mapped from Landsat imagery has been compared with major land use statistics from statistical abstracts to check expressed concerns on the census-reporting of major land use. Cross-tabulations between current land use and RPUs have been made to provide general indications of land areas available or expansion of cultivated agriculture. A variety of other uses of the Geographic Information System have been made for particular technical assistance activities in participating countries.

VI. AREA-FRAME CONCEPTS AND PROCEDURES

A. Introduction

The underlying concepts of area-frame sampling are very simple: divide the total area to be surveyed into "N" small blocks without any overlap or omission; select a random sample of "n" blocks; obtain the desired data from reporting units of the population that are in the sample blocks; and estimate the population totals

[4/] Considerable detail on the capabilities of each phases are provided in "GEORAP, A User's Guide to Version 3.1 of the Geographic Resource Analysis Program", an accompanying report in this series.

by multiplying the sample totals by the inverse of the sampling ratio (by $\frac{N}{n}$).[5/] The simplicity of the approach is in striking contrast to the complexity of successful application of the concepts.

B. Application in the United States

Area-frame sampling in the United States is employed by the Economics and Statistics Service, U.S. Department of Agriculture, in its June and December Enumerative Surveys and for several specialized uses. In these two major surveys, the area frame is the basis for the expansion of sample totals of enumerated information obtained by interviews on crop area plantings (or intentions), harvested acreage of crops, livestock inventories, livestock and livestock product production, farm labor, farm income categorization, and other physical and economic factors relevant to tracing the performance of the agricultural production sector.[6/]

There are other sources of information on the agricultural production sector in the United States that are provided on a less frequent basis. The U.S. Department of Commerce conducts a census on agriculture at five year intervals. The census provides more detailed geographic information on many of the information series reported by the Economics and Statistics Service. Furthermore, the census provides information series that are not covered by the data acquisition and reporting processes used by the Economics and Statistics Service. Some of these additional census series include farm size distributions by counties, state, and nationally. Others include types of farms — i.e. "farms with dairy cattle", etc. Additionally, the census provides a rather complete information series on major land use categories such as cropland by farm type, by farm size, etc., and woodland

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5/ Houseman, Earl E. Area-Frame Sampling in Agriculture Statistical Reporting Service, U.S. Department of Agriculture, SRS. No. 20, Nov. 1975. Much of the technical information that will be discussed in this section is drawn directly from this publication. This publication provides a discussion of area frame sampling methods and comparison with alternatives.

6/ This agency uses list frames and other frame designs to obtain other information of the agricultural production sector. Some of the other information is estimated annually. Other information is estimated and reported more frequently such as quarterly estimates of cattle on feed.

by farm size, etc. The major land use information reported by the census is summarized at county, state, and national levels.

The Economic and Statistics Service, through its state offices, has developed a comprehensive agricultural statistics program. In each state, cooperative agreements between state departments of agriculture or land grant institutions and ESS for the collection and dissemination of agricultural data exist. Enumeration is conducted by a trained staff of enumerators. Most data editing procedures are computerized as are expansions of edited and summarized data to population totals. Analyses of the data and the distribution of the information is organized to meet publication dates that are established for a year at a time on reporting calendars. Published reports are distributed for producers of agricultural products, buyers and handlers of agricultural products, and through the media to the general public to provide information to those making production and marketing decisions.[7/]

C. Application in Developing Countries

Area-frame sampling is being introduced into selected developing countries by the Economics and Statistics Service as a technical assistance activity funded by the U.S. Agency for International Development. The goal of all these activities has been to set up data acquisition, estimation, and reporting procedures to provide useful statistics for each country's agricultural sector. The various technical assistance efforts have varied in scope from setting up an area frame for an entire country with accompanying enumeration, expansion, and reporting procedures to more limited projects where pilot area frames were designed for particular regions of a country.

Country-level agricultural statistics programs in place at the time that area frame concepts were introduced have varied widely from country to country. In

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7/ The U.S. Department of Commerce also publishes and releases information for public distribution to the media subsequent to the completion of each census. Special purpose summarizations that are not regularly prepared by the census for the publication can be obtained by analysts in public agencies.

many countries the introduction of an area-frame activity constituted an initial attempt by the country to establish a formalized agricultural statistics program.

Demands on those developing the area frame have been high. Those providing technical assistance in the construction of the frame and putting in place the accompanying functions of enumeration, sample total expansion, and reporting have found their implementation and transfer tasks difficult due to political and budget constraints and because participating country personnel were not familiar with techniques required to perform the associated functions. Considerable formal and informal training has been required.

When area-frame sampling has been introduced into a country as the initial formalized statistics program demands for useful information is generally high.[8/] Information is needed to provide a baseline for monitoring agricultural development programs and for providing information from which to make production and marketing decisions to meet domestic food and fiber production and export goals. Most area frame projects are designed to provide useful statistical series on area, yield, and production of major crops and inventory and product estimates for livestock at the national or subnational level. Additionally, project's are often designed to provide statistically reliable estimates of key socio-economic variables at the national or subnational level. Seldom have area frames been designed to provide estimates of major agricultural uses of land (cropland, rangeland, etc.) with high statistical reliability at the national level.[9/] Because of limited resources available for area-frame survey activities in most countries, sampling rates that have been used do not provide detailed statistics at regional

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8/ This is a universal problem for most information generating and/or information management projects. Too often, the participating country personnel do not fully recognize the long-term nature of such endeavors. These expectations of immediate useful results are held more often by the ranking government officials than by the technicians that participate directly in project activities.

9/ Estimation of major uses of land could be accomplished by the proper allocation of the samples; however, the historical emphasis in most countries has been on acquiring agricultural performance and socio-economic data, not general land use data.

and area levels of sufficiently high statistical reliability in the judgement of those providing technical assistance to be expanded and published.

D. Concepts Underlying Area-Sample Frames

The construction of an area frame should be viewed as a major investment in the agricultural information system of a country to be amortized over a long period of time and many surveys. There are numerous resources which can be used in constructing an area frame and the flexibility of the frame will depend upon the materials available. However, there are some general principles that prevail irrespective of the available resources.

Principles of single-stage stratified random sampling apply to area-frame sampling. To minimize sampling variance, the sample designer defines strata and sample segments so that variation among sample segments within strata is as small as practical. The sample designer is concerned with (1) the choice of criteria for stratification and the allocation of the sample among strata and (2) the definition of the sample segments including control of variation in size of the segments. Within strata, variation among sample segments will be relatively small when the segments are nearly equal in "size" and have similar characteristics. Auxiliary data available to the designer are useful in obtaining greater homogeneity within strata and in obtaining sample segments similar in "size" -- where "size" is a variable that is correlated with variables to be included in surveys and not necessarily a measure of land area.

Strata are often defined by land use criteria. For example, a country could be divided into four land use areas (classes): tree crops, cultivated crops, grazing land, and nonagricultural land. The definitions for each of the classes might state that 75 percent of more of the existing land use within each strata be in the dominant use indicated by the class name, i.e. -- the cultivated crops class have at least 75 percent of its total area in cultivated crops.

Frame units, areas of land which are collections of the ultimate sampling units, are the most permanent part of an area frame. Each stratum is first divided into mutually exclusive frame units. Frame units provide economy in the selection of segments. A frame unit need not be divided into segments unless a sample segment is to be selected from it for a particular sample.

The delineation of land use in the stratification process prior to delineating frame units is one way of compiling information about frame units. The availability of auxiliary data varies among countries and applications from almost non existing to information that is highly relevant and effective in the design of area frames to minimize sampling variance. Auxiliary data are utilized which have a potential for improving sampling efficiency or reducing bias. Total land area is a necessary item of information for each frame unit. Estimates of the amount of land in each frame unit by land use classes might be important, depending on the kind of surveys that are expected.

The concepts of area frame sampling can be summarized as follows:

(1) Principles of single-state stratified random sampling apply to area-frame sampling.

(2) Strata, frame units, and segments are delineated wherein strata are the major divisions of the area for which a frame is constructed, frame units are portions of strata, and segments (sampling units) are subdivisions of frame units. The selection of frame units and the selection of segments within should not be confused with two-stage sampling. The delineation of frame units and the subdivision into segments are two selection steps in a single-stage sampling plan.

(3) When land use criteria are used to delineate strata, there may be a trade-off between homogeneity within the strata and the maintenance of recognizable boundaries for the frame units.

(4) Auxiliary data should be used in the construction of the area frame, especially the frame unit delineation step, when the cost of acquiring the auxiliary data weighs favorable with the potential for reducing sampling variance.

E. Construction of Area-Sample Frames

The commonly used method of initiating the construction of an area frame is the classification of the total land area to be included in the frame into land use

classes to form the strata and then the delineation of frame units within each strata. Stratification by land use class is done to achieve homogeneity within strata and to achieve sampling efficiency.

A variety of materials are useful in the delineation of strata. Current general land use maps are directly pertinent. A small scale topographic base map is an appropriate map on which to record the strata. When current land use maps are unavailable, aerial photography or other materials such as Landsat materials can be interpreted to delineate major land uses for stratification purposes.[10/]

Care is usually taken in the breakdown of strata into frame units to maintain recognizable boundaries for the frame units. There are several possible sources of information available to assist in the delineation of frame units within each stratum specified. Among the sources that might become useful are census data, land use maps, aerial photographs, and visual estimates from field observations.

When the point is reached to breakdown the frame units into segments, auxiliary mapped products (beyond topographic maps and small scale aerial photographs) are used. These mapped products may include maps of irrigated areas, soil types, and detailed land use. The division of frame units into segments generally requires more detailed maps or aerial photography than those used to delineate frame units within strata. Large scale maps are generally more useful in the final delineation of accurate segment boundaries and for location of the sample segments in the field. Aerial photography is particularly helpful for delineating segment boundaries.[11/]

10/ There are several options available for the interpretation of Landsat materials ranging from photo-interpretation of Landsat film products, using a variety of enhancement techniques to computer-assisted digital processing of Landsat tapes using a variety of classification algorithms.

11/ A variety of references on the alternative methods of frame construction are available. A general reference is Houseman, op. cit. Those desiring more specific references should contact the Statistical Research Division, ESS.

APPENDIX A: Example RPU/PPA Descriptions

Concepts Illustrated in the Example RPU/PPA Descriptions

RPU 4 illustrates the differentiation of an RPU into several PPAs on the basis of soil differences. Over two-thirds of this RPU is comprised of PPA 4-1. This PPA is characterized by poor drainage and flooding. The main treatments identified to increase PPA 4-1's potential for agriculture are drainage and flood protection. The interpretation for agriculture provided for the PPAs in this RPU illstrates the discussions presented in the text of this report. There was not sufficient source materials for the inventory to provide a basis for crop recommendation.

RPU 27 illustrates the differentiation of an RPU into several PPAs on the basis of both soil and climatic characteristics. PPA 27-1 is differentiated from the three other PPAs because of principal soil components and depth to bedrock. PPAs 27-2, 27-3, and 27-4 differ from each other because of annual and seasonal precipitation levels. The RPU contains a limited discussion of water resource supply and use conditions. The crop and crop group recommendations illustrate that the agricultural production potential is much greater in PPAs 27-2, 27-3, and 27-4 than 27-1. PPA 27-4 is the only PPA in the RPU considered to have much potential for rainfed crops.

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	Management Type	Management Type	Management Type
	I II III IV	I II III IV	I II III IV	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;erodability

RPU 27

GENERAL DESCRIPTION:

RPU 27 is a gently sloping basalt plain with shallow, stony soils located south of Jebel al-Ansariye and west of Homs. 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 precipiation.

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 three crop climate areas occur 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 montly 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 observed 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
GENERAL		
elevation	800-1200 m	900-1800 m
dominant slope	3-15%	16- 30%
portion of RPU	55%	45%
CLIMATE		
- Annual		
wet seasons (no.)	1	
average precipitation	900-1000 mm.	
average temperature	22-25°C	
- Wet Seasons		
average monthly precipitation	100-150 mm.	
average monthly temperature	22-25°C	
months	May-October	
- Dry Seasons 1/		
average monthly precipitation	33 mm.	
months	November-April	
SOILS		
principal components	Typic Ustropepts Lithic Ustorthents	Lithic Ustorthents Lithic Haplustalfs
depth to bedrock	50 cm.- 200 cm.	50 cm.
texture	mod. coarse/medium	mod. coarse/med.
coarse fragments	stony	very stony
permeability	mod./mod. rapid	mod./mod. rapid
available moisture capacity	mod./low	mod./low
drainage class	well/somewhat excess. drained	well/somewhat excess. drained
flooding	rare	none
INTERPRETATIONS FOR AGRICULTURE		
soil potential for cropland	Management Type I II III IV fair fair poor fair	Management Type I II III IV poor poor poor poor
factors limiting land use	slope; erodibility; urbanization; seasonal dryness	slope; shallowness; stoniness; seasonal dryness

1/Dry season data are residually estimated by subtracting wet season data from annual data.