Integrated Remote Sensing, Spatial Information Systems, and Applied Models in Resource Assessment, Economic Development, and Policy Analysis

Gerhardus Schultink
Department of Resource Development, Michigan State University
East Lansing, MI 48824

ABSTRACT: Key concepts, procedures, adapted land classification schemes, and potential contributions of applied remote sensing, information systems, and applied models are discussed, to formulate an integrated framework for quantitative performance assessment of natural resources and their respective use alternatives in lesser developed countries. This framework represents a set of procedures and software requirements designed to support database compilation and comparative spatial/temporal analysis to derive information for decision support in sustainable development planning and policy analysis.

The procedures are designed to define a Comparative Site Index (CSI), a quantitative performance indicator related to the comparative advantage among competing land-use alternatives, including potential environmental impacts. To provide a dynamic land evaluation framework and a realistic decision-support system, the framework permits calculation of the CSI based on the most timely and accurate information available as represented in the spatial, thematic, and temporal domain. An overview is provided of the four consecutive phases of a systems approach to resource development planning and policy analysis. Within this context, the current and potential contributions of geographic information system (GIS), applied remote sensing, and its essential linkage with performance or impact assessment models are specifically identified.

INTRODUCTION

THE NEED TO DEVELOP A LAND EVALUATION FRAMEWORK for development planning using a commonly accepted set of objectives and concepts has evolved since the late seventies. Various FAO publications—Beek (1978), Vink (1975), and Dent (1981)—have provided major contributions to this end. During this period, most land evaluation was conducted in qualitative terms and defined in land capabilities (e.g., USDA, 1973), ordinal performance measures, or general economic feasibilities. At the same time, the need emerged to address land evaluation in quantitative terms as derived from land qualities, use alternatives, associated costs/benefits, and aggregate environmental impacts of related enterprise activities. To improve the utility of information for use in comprehensive development planning, it is necessary to evaluate aggregate (agro- ecological, regional, or national) impacts in terms of socioeconomic benefits derived under sustained productivity (constraint use) conditions (Schultink, 1987). "Sustained" in this context refers to environmentally compatible use alternatives that preserve the long-term productive capacity of the resource base (Schultink, 1991) or, viewed from an ecological perspective, relates to a system's ability to maintain a level of productivity under conditions of external stress (Conway, 1985).

This sustainability perspective may assist in the identification and evaluation of realistic land-use alternatives. However, other challenges remain in extending or applying empirical or scientific knowledge among nations and agroecological zones, based on differences in farm management practices, input and technology constraints, distorting price effects, socioeconomic considerations, or political preferences. Consequently, achieving practical measures or realistic estimates of many types of potential development impacts is difficult. Nevertheless, assessing development potential without regard to long-range plans, sustainability, and systematic impact consideration must be judged as unrealistic, if not futile.

To assist developing countries in effectively meeting this need, an ***integrated land evaluation approach*** to resource development planning and policy analysis must be considered, using appropriate technologies including those offered by applied remote sensing and spatial information systems. The main objective of this approach is to assist in the systematic evaluation of public and private benefits derived from specific land-use alternatives and development policy scenarios. Examples of major policy objectives in the developing world may include the creation of food self-sufficiency under sustained production conditions, meeting rural employment objectives or balance of payment goals through the expansion and/or intensification of the production of food and cash crops, resulting in increased exports earnings and import substitution.

Within this application framework, three general objectives may be identified:

- Application of a consistent, systematic, and nationwide approach to land resource assessment which provides adequate information detail (spatial and temporal) to support decision analysis for resource conservation, agrotechnology transfer, resource allocation, and development planning.
- Application of integrated resource surveys and inventory support technologies needed in the compilation of a comprehensive resource database that permits analysis of land-use alternatives, development scenarios, policies, and aggregate impacts.
- Institutionalization of indigenous capabilities and relevant technologies to inventory and classify renewable resources; predict agricultural or renewable resource production potential under conditions constrained by inputs, management, technology, and product prices; and classify land according to its comparative advantage from a relevant economic and public policy perspective.

The major contribution of remote sensing and spatial information systems in this context is to provide cost-effective support in integrated resource inventories, including current land-use mapping and the development of a comprehensive data-

PHOTOGRAMMETRIC ENGINEERING & REMOTE SENSING,
Vol. 58, No. 8, August 1992, pp. 1229–1237.

0099-1112/92/5808-1229$03.00/0

base for resource assessment, land suitability classification, and impact analysis for public policy design and evaluation.

AN INTEGRATED APPROACH TO DEVELOPMENT PLANNING AND POLICY ANALYSIS

In most developing countries, agricultural productivity—its aggregate sector outputs and benefits primarily expressed in employment and income indicators—largely determines the quality of life of rural populations. The long-term, sustainable production capacity of renewable resources determines to a large extent the availability and price of basic food commodities and the potential to generate most of the export earnings often required to meet other basic needs. Most foreign technical assistance is used to enhance or restore the productive capacity of renewable resources. This may be achieved through the introduction of appropriate technologies, the elimination of significant production constraints, the implementation of soil and water conservation practices, and the optimization and allocation of scarce production factors. In a public policy context and considering long-term planning objectives, the allocation of production factors should identify and consider critical socio-economic issues and policy concerns.

Although varying in scope and objectives, effective assistance should always address a comparative evaluation of production alternatives based on input and management options *by location and over time.* Therefore, a comparative analysis should, ideally, provide decision makers with quantitative information, defined in its spatial and temporal dimensions, to enhance the timeliness and relevance of planning efforts and policy decisions. The comparative analysis of current and potential land use, resource productivity, and development options requires a ***systematic and nationally consistent evaluation*** of the bio-physical and socio-economic variables that determine current and future production potential. The aim of the evaluation should be to estimate the aggregate derived public or private benefits derived that are associated with clearly defined development alternatives.

To achieve such a nationally consistent land evaluation, a comprehensive inventory and evaluation of land resources is required, which must be combined with quantitative performance indicators pertaining to relevant production and land-use options. This evaluation should address regional and national feasibilities and provide essential information for development planning, policy analysis, and implementation. Such an effort requires the use of a multidisciplinary, integrated approach to resource planning and policy analysis, carried out in close co-operation with host country governments and key institutions. Four project phases (Figures 1, 2, 3, and 4) are identified with relevant remote sensing and spatial information system technology support, providing a logical sequence of activities, including the essential monitoring and feedback linkage. This sequence of activities may be summarized as follows:

- ***Phase I: Land Capability Analysis*** — Involves the execution of integrated surveys, compilation of a comprehensive, national resource data base, assessment of relevant land-use options, and **ordinal** measures of resource production potential on the basis of **basic** agroecological production options and constraints. Specific inputs from medium- to high-resolution satellite data include current land-cover/land-use inventories (e.g., supervised image classification) and thematic information on vegetation/ecosystems, including potential indicator species and derived measures of seasonal moisture availability (e.g., band-ratios of AVHRR-derived greenness index), soils, topography, and surface hydrology. GIS-based spatial analysis in this phase is typically restricted to carrying capacity considerations, including measures of soil and wind erosion risk (linkage with erosion modeling), denoting sustainability of constrained physical production levels. Essential GIS analytical functions in this phase include statistical summaries (e.g., cross tabulations) and algorithms for editing, grouping, weighted overlay analysis, and mapping.
- ***Phase II: Quantitative Land Evaluation*** — Involves the assess-

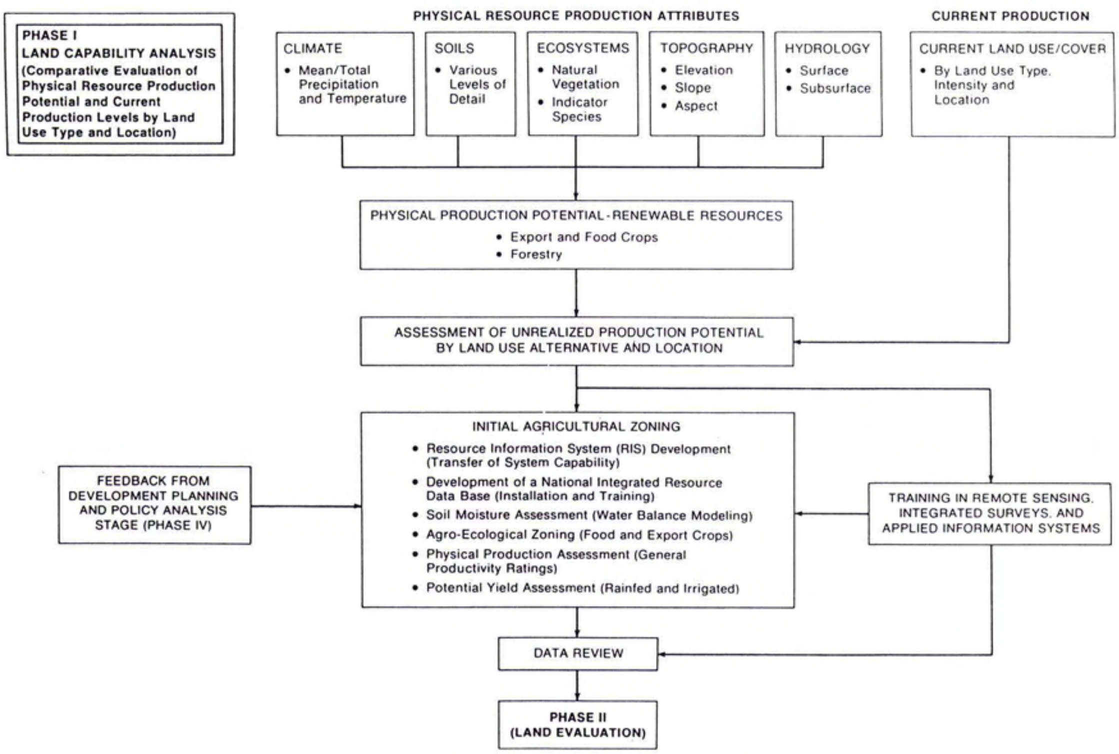

FIG. 1. PHASE I—Land capability analysis.

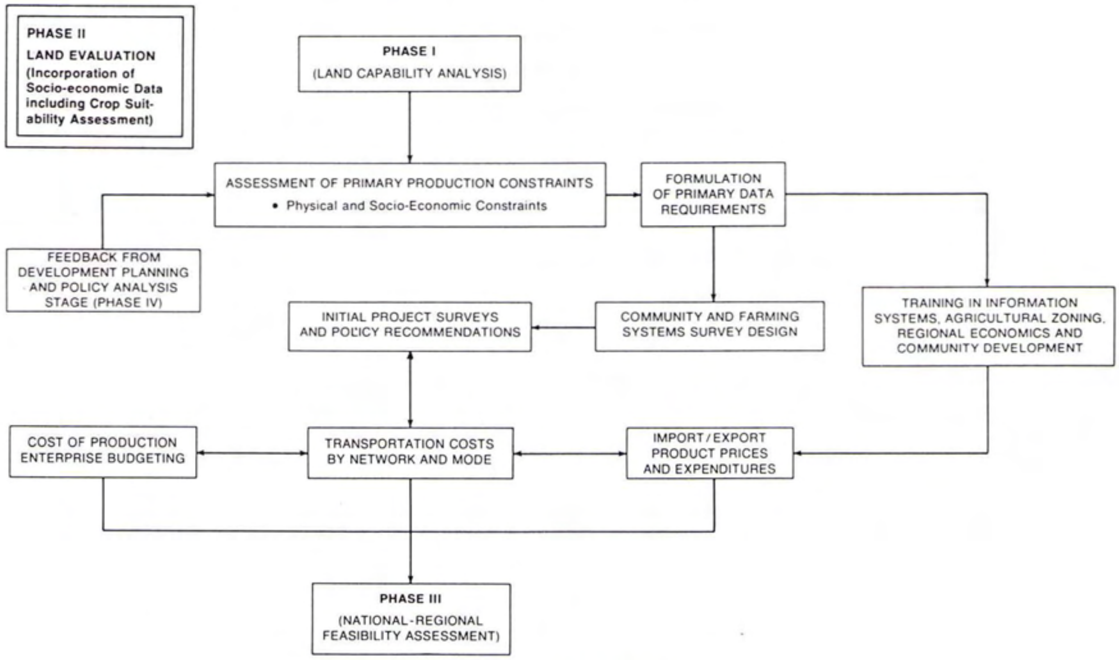

FIG. 2. PHASE II—Land evaluation.

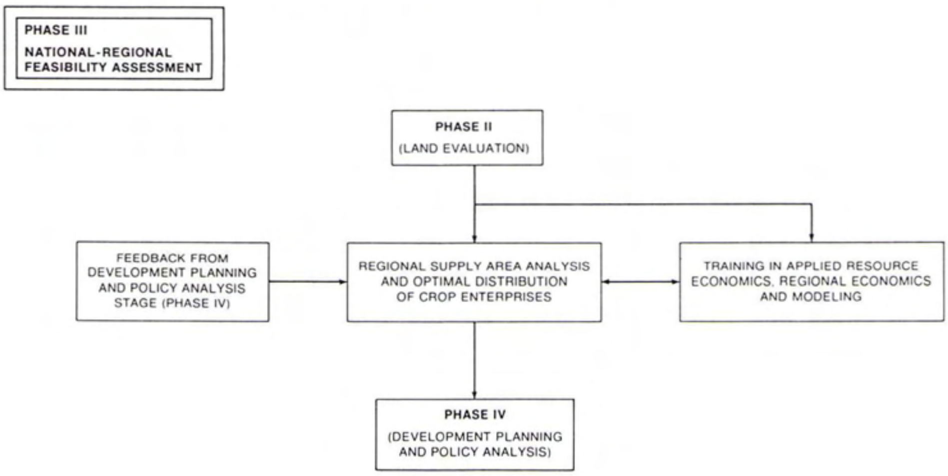

FIG. 3. PHASE III—National and regional feasibility assessment.

ment of agricultural production potential based on **quantitative** measures of physical and economic performance (e.g., agroecologically determined crop yields under rainfed or irrigated conditions) and relevant socioeconomic, management (input), and technology (efficiency) constraints. This requires the identification of relevant farming systems, compatible land utilization classification, corresponding farm enterprises, and the execution of enterprise analysis related to the land utilization types considered. This analysis may also include transportation, marketing, and processing (value added) considerations resulting in aggregate measures of economic feasibility, at the farm or local level. Important GIS support includes overlay functions, grouping and aggregation algorithms, proximity and network analysis, and operational interfaces with a relational database and performance assessment models, such as commodity-specific crop yield and enterprise analysis models. The latter provide the ability to translate farming system (land-use type) yield data into measures of farm profitability (e.g., net farm income) or economic efficiency (e.g., net income per unit of land). In essence, these measures reflect farm level indicators that may be aggregated to the community (local) level on the basis of representative fractions of agroecological zones and land utilization types.

- *Phase III: National and Regional Feasibility Assessment* — Considers **regional and national** socioeconomic **feasibilities, aggregate socioeconomic impacts** (e.g., income and employment), and **environmental** (e.g., sedimentation, pollution) **impacts and risks.** If necessary, optimal distribution of land-use activities on a local or regional basis—including considerations regarding product and service supply/demand (e.g., resettlement needs), cultural preferences, community development, and public policy considerations—may be included. In essence, this phase reflects comprehensive development impacts, including environmental impact assessment (EIA) considerations, if nonmarket goods and services are incorporated. Increasingly, the need to include these development "externalities" is recognized as an essential prerequisite in the identification of sustainable development alternatives. This requires that project externalities be converted into public cost and benefits and assessed for the area directly affected and for the region or nation as a whole. In EIA this means the quantification of the spatial (e.g., watershed) and temporal (pres-

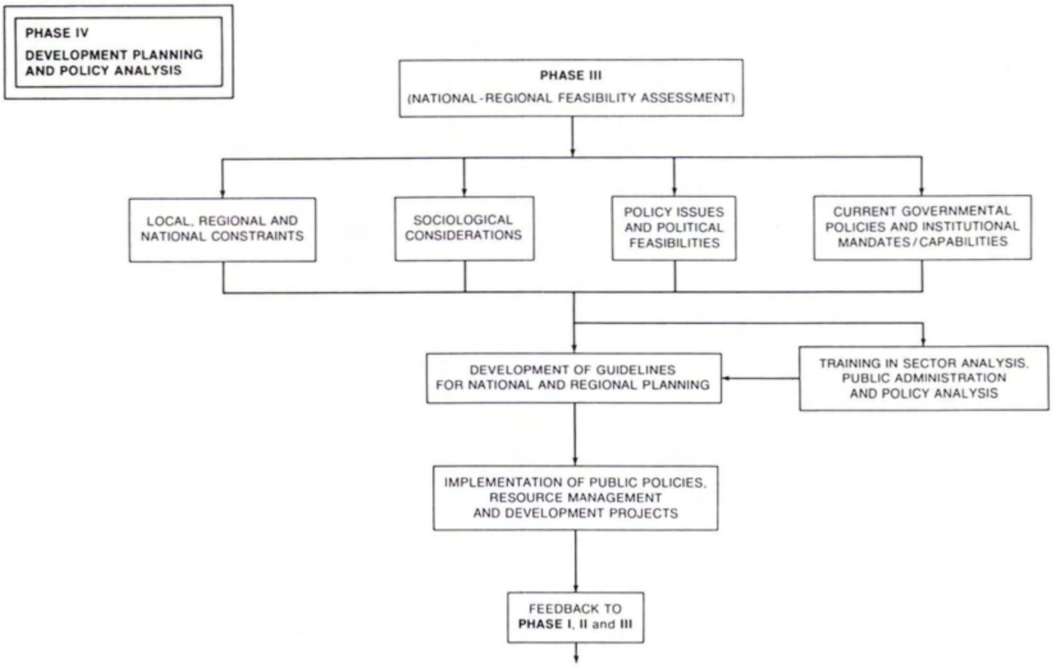

FIG. 4. PHASE IV—Development planning and policy analysis.

ent values of cost and benefits) effects using appropriate economic valuation methods.

- *Phase IV: Development Planning and Policy Analysis* — Considers **constraints, policy objectives,** options, and **implementation considerations** while providing **guidelines for policy implementation, physical planning, and monitoring.** This may be accomplished in part by the use of GIS and impact assessment models to quantify the spatial and temporal effects (e.g., direct benefits such as increases in income and employment, public benefits of food security, external cost of downstream sedimentation, and flood risk over time). In this process, GIS methods permit simulation of impact benefit/cost scenarios by the aggregation of the effects of empirical or limited ecosystem impacts into national and regional impacts based on perceived trends and alternative development scenarios. The latter provides an essential linkage between the planning implementation and monitoring process and provides a feedback linkage with relevant policy issues and concerns.

LAND-USE CLASSIFICATION AND EVALUATION IN INTEGRATED PLANNING

The primary goal of integrated development planning is the preparation of a comprehensive plan relating to single or multiple sectors of the economy, its performance on the basis of productivity or economic indicators, its linkages, and its ability to render public benefits or meet specific policy objectives. In this context, land-cover/land-use classifications represent alternative ways of using public or private land, each with its complex and unique sets of interactions. Major uses such as agriculture, forestry, tourism, or recreation may be characterized by their input mix, management and technology level, reliance on transportation and marketing systems, land tenure, and type of industrial production. Resource use systems include all land- cover/land-use types, from man-made to natural state and may be defined in locally relevant classification systems, including varying use intensities and cover types.

Four key concepts and specific definitions are introduced to permit a consistent land use inventory and systematic evaluation of their use alternatives. They are (1) Current Land Use, (2) Land Use Production Potential, (3) Unrealized Production Potential, and (4) Land Utilization Type (LUT) (Tables 1, 2, 3, and 4).

TABLE 1. THE CONCEPT OF CURRENT LAND USE

* **CURRENT LAND USE**—relates to the resource use system, the nature, quality, and availability of natural and human resources, their cultural, socioeconomic, historical, and technological use context.

<u>PREMISE:</u> Current land use rarely reflects optimum and most suitable use as a result of time delays; systems response to new use perspectives (changes) incorporating current socioecomonic, technological, institutional or cultural factors, relationships, and constraints.

- Reflects current land utilization type (LUT) derived from remote sensing sources
- Defined by land cover/use classification scheme (custom adapted)
- Differentiates rainfed and irrigated agriculture or other farm management options
- Incorporates existing production constraints (physical, socioeconomic, managerial, and cultural)—spatially referenced in a geographic information system by agroecological zones
- Can be related to existing farming systems (including physical, socioeconomic, farm management descriptors)
- Can be related to inputs, fixed and variable costs, yields, and product prices at the enterprise location or at market locations
- Defines the spatial analytical unit at the enterprise and aggregate (local, regional, and national) level

To develop a representative land-use classification (see also Anderson, 1976) and permit realistic evaluation of alternative resource use (land-use) systems, a number of conditions have to be met:

- **A land use (or resource use) system has to be defined in its agroecological setting, use context,and management intensity.** "Management intensity" denotes the level of inputs, technology, and environmental impacts that define the **sustainable use perspectives according to the ecological concepts and principles.** A Resource Use System (RUS) is a more holistic concept than the Land Utilization Type (LUT) used in the land evaluation literature. The LUT primarily reflects farming systems alternatives composed

TABLE 2. THE CONCEPT OF LAND USE PRODUCTION POTENTIAL

* **PRODUCTION POTENTIAL**—relates to the optimum use aspect, incorporates the concept of economic net return (land rent) and other derived benefits (private and/or public) of a land utilization type (LUT)

PREMISE: Optimum land use and intensity for a given land parcel may be selected with regard to short- **and** long-term cost/benefits and impacts to the landholder and the society at large, within a sustained production (carrying capacity) framework.

- Theoretical concept of production potential
- Assumes limited constrained production potential (rainfed or irrigated)
- Limiting condition is agroecological (except for water, no input technology or management constraints, no disease-induced production loss, no demand, marketing, or processing constraints assumed)
- Reflects alternative land utilization types (farming systems)
- Requires the development of profiles of farming systems or land utilization types considered as production alternatives

TABLE 3. THE CONCEPT OF UNREALIZED PRODUCTION POTENTIAL

* **UNREALIZED PRODUCTION POTENTIAL**—theoretical difference in production which may be realized by changing current land use to a higher and better LUT. Defined in qualitative terms (e.g., yields or land rent) or as comparative site index (CSI). Difference between current and potential production level.

- Provides a theoretical, quantitative indicator for agroecological zones, political/administrative districts or regions that have the highest unrealized production potential
- Provides a theoretical framework to spatially identify land areas which may have the highest comparative advantage for certain land use options
- Provides a method to define comparative site indices—quantitative indicators denoting preference ratios among competing land uses
- Provides a comparative indicator which may be used to assign rural development priorities by location and over time (dynamic land evaluation framework)

of different mixes and intensities of crop types, input, and farm management, and focuses on measures of productivity and economic efficiency, rather than on the basic concepts of sustainable resource use and the principles of "steady state" or system stability, resource constraints, conservation, or impacts and risks standards denoted in the RUS concept.

- **A comprehensive, hierarchical land-cover/land-use classification system must be defined to permit nationally consistent resource inventory, classification, identification, and suitability assessment** using applicable remote sensing and spatial information system techniques to quantify and monitor land-use status, distribution, trends, and change impacts. This classification system must directly, or by its associated groupings, relate to alternative resource (land) use systems, the spatial analytical units of performance, and impact assessment.
- To permit performance assessment, **the basic agroecological variables must be defined and organized in a spatial information system to quantify biophysical resource production potential,** such as for agriculture and forestry. Typical variables include soil moisture-holding capacity (e.g., texture, depth of horizon, and profile), climatic variables permitting waterbalance calculations (such as rainfall, temperature, relative humidity, solar radiation, and windspeed) or ecological classification (e.g., Holdridge), and topographic characteristics (elevation, slope gradient, -aspect and -length). The **agroecological zones** and derived resource capability classification (inherent agroecological system's capacity to produce food and cash crops in a sustained manner) **should be viewed as a relatively static, spatial framework for long-term development planning and analysis.**
- On the basis of resource production capacity, **an economic suitability classification must be carried out considering the relatively dynamic, spatial assessment of resource production capacity.** This may reflect short-term (e.g., 3 to 5 year) considerations regarding the availability and cost of stock and flow resources, human capital, manufacturing and other durable assets (e.g., transportation or irrigation infrastructure), fixed and variable inputs, actual and anticipated product prices, and technology level. This economic classification may be specific (e.g., addressing the feasibility of single crop or crop group production) or of a more generic nature (denoting the feasibility of food or cash crop production associated with certain farming systems).

TABLE 4. THE CONCEPT OF LAND UTILIZATION TYPE (LUT)

* **LAND UTILIZATION TYPE**—actual or alternative way of using the land, generally or specifically described in terms of key attributes, which may include one or more of the following, depending on the detail needed and data available:

1. Type of production (e.g., crop types or crop group and/or livestock and/or agroforestry components) and related to a land cover/use classification scheme
2. Land use index: the proportion of the land use type used for certain enterprises (non-vacant and vacant)
3. Cost of variable and fixed inputs such as—
   a. Type, amount and cost of labor
   b. Capital (and discount rate)
   c. Material inputs, such as fertilizer, seed, chemicals, fuel, etc.
   d. Fixed inputs such as property taxes, depreciation, insurance, and interest on debt
4. Product prices and market orientation (farmgate or at market location)
5. Management
6. Technology level
7. Scale of operation
8. Land tenure
9. Agroecological and physiographic setting

GENERAL DESCRIPTIVE EXAMPLE: A medium-scale (5–10 hectare), rainfed farming system producing cash crops (including coffee, cocoa, pimento, and bananas), some food crops, and with some livestock, fruit, and vegetable production for on-farm use. The associated land/cover use category is **medium-scale/mixed agriculture dominated by tree crops.** Some seasonal hired labor is used. Management is intensive without mechanized inputs. Capital inputs and level of technology is limited. Some crops are marketed by the farmer. This type of LUT is mostly found on the lower foothills with slopes of 8–20 degrees at an elevation of 600–900 meter A.S.L. where adequate shade cover is present. Farms are mostly privately owned. Agroecological setting is defined by the Holdridge classification as tropical moist forest premontane belt transition.

EVALUATION OF FARMING SYSTEMS AND LAND UTILIZATION TYPES

As land utilization types, farming system alternatives (which may be defined as variable sets of characteristic attributes denoting specific socio-economic, management, physiographic, and other relevant characteristics) can be evaluated with respect to specific performance indicators, such as gross revenue, land rent, or other comparative site indices. To compare current agricultural land use and production practices within a given country with production options, farming systems strata have to be identified in terms of physical and socio-economic parameters. The stratification should reflect farming systems which, at some level of aggregation, can be **directly associated with existing land-use/land-cover categories, LUTs, and mapping units** (such as agroecological zones) using GIS-based analysis.

TABLE 5. MAJOR FARMING SYSTEM CLASSIFICATION CRITERIA[1,2]

CROPPING INTENSITY CATEGORY	AVERAGE SIZE RANGE	MAJOR PHYSIOGRAPHIC REGIONS	GENERAL WATER MANAGEMENT	ASSOCIATED CROP/LIVESTOCK
Monocropping	>500 acres	Lowland/alluvial	Rainfed	Sugarcane
Multiple/cropping	100–500"	Coastal plains	Irrigated	Banana
Mixed/cropping	25–100"	Wetlands	Dry land	Coconut
Mixed/farming	5–25"	Highland		Cocoa
Improved/pasture	<5	Highland/gentle slope		Tobacco
Unimproved/pasture		Highland/steep slope		Coffee
Subsistence		Karst		Citrus
Aquaculture		Mountain		Vegetables
				Rice
				Pimento
				Other
				Forest
				Livestock

1) Proposed farming system classification criteria for Jamaica
2) A summary of the nomenclature used is provided below:

***Multiple cropping** refers to farms with more than one stand of different crops (e.g., x acres of banana, y acres of coconut, and z acres of vegetables). These crops are all produced on different sections of the farm at any one time.*
***Mixed cropping** (or intercropping) refers to a number of crops, in possible combination with livestock, being produced in the same stand or farm plot, simultaneously.*
***Mixed farming** refers to farms with distinct crop and livestock enterprises in separate plots.*
***Lowland/alluvial** refers to areas such as found in mature river valleys.*
***Coastal plains** refers to coastal strips. This includes most of the plains not classified as alluvial.*
***Wetlands** refers to inland wetland areas.*
***Highland/gentle slope** refers to regions not classified as coastal or alluvial because of elevation, but with minimal relief.*
***Highland/steep slope** includes those areas with much relief, steep sloping valleys, and sharp ridges found mostly in upland river valleys and the foothills of mountain areas.*
***Karst** refers specifically to areas where land cover/use is strongly influenced by Karst topography. (e.g., the Cockpit Country in Jamaica or the northeastern central portion of Hispaniola).*
***Mountain** includes all other areas not classified as highlands.*

Through the development of a farming systems classification representing current cropping systems (with optional livestock or agroforestry components), physiographic and agroecological conditions, socioeconomic and farm management variables, farming systems can be identified and mapped. This identification creates the baseline for the evaluation of alternative **and** relevant LUTs by location by determining its economic comparative advantage. A comparative site index (Schultink, 1991) may be calculated using a comparative analysis of crop yield response or enterprise analysis. Production options may be analyzed based on variable input mix (including rainfed or irrigated production), costs of inputs, labor and capital, products prices, and farm management technology, as reflected in production functions on a farm site-specific and commodity (mix) basis.

FARMING SYSTEM AND LAND-COVER/LAND-USE CLASSIFICATION CRITERIA

To identify and compare farming systems (existing agricultural land uses) with land utilization types (alternative and relevant production options), a general farming system classification should be used. It is suggested to use different criteria that incorporate, at a general level of detail, biophysical, broad socioeconomic, and farm management factors. The following classification system based on five broad classification criteria may be considered (and should be adapted based on country-specific conditions):

- Major cropping system
- Average size range of enterprise
- Major physiographic regions, incorporating elevation and drainage characteristics
- Crop water management
- Major type and associated farming enterprises

As an example, an originally proposed farming system for Jamaica is provided (Table 5). Farming systems are classified on the basis of two **major** criteria: crop cultivation systems and physiographic regions. Crop cultivation systems are defined based on cropping intensity, size of holding, general water management practices, and associated enterprises.

To extend the utility of the farming system classification for the comparison and evaluation of land-use change options, a given farming system classification scheme, such as the example provided, should be (made) compatible with existing land-cover/land-use information. This may be done by adapting a new classification system or be revising the grouping of previous land-cover/land-use categories (CRIES, 1987). As an example, the abbreviated version of the land-cover/land-use classification adapted for Haiti is provided (Table 6). It differentiates between two major resource domains or physiographic regions—the *Flatland Resource Domain,* in which most intensive (sometimes irrigated) agriculture production takes place, and the *Mountain Resource Domain,* which is characterized by extensive, rainfed agriculture of a primarily subsistence nature. At the same time, other crop cultivation aspects—relating to cropping system, size of holding, water management regime (if present and distinct), and enterprises (including some nonagricultural)—are identified. The Flatland Resource Domain represents the alluvial coastal plains, the floodplains, their adjacent uplands, and coastal and highland plateaux with slopes of less than 8 percent. The Mountain Resource Domain encompasses the foothills and mountains with slopes of 8 percent or more.

Such land-use classification schemes should be designed to ensure mutual category compatibility with land utilization or farming systems options, either on a one-to-one basis or by

TABLE 6. SELECTED LAND-COVER/LAND-USE CATEGORIES FOR HAITI, INCLUDING NUMERICAL CODE, NAMES, AND SUMMARY DEFINITIONS

CODE	TITLE	DESCRIPTION
1	FLATLAND RESOURCE DOMAIN	LAND USE ASSOCIATED WITH LOW-LAND PLAINS AND ELEVATED PLATEAUX
11	**Intensive, predominant cash crop, flat-Land agriculture**	Areas with more than 50% of the land area in crops. Delineations represent areas equal or greater than 9 hectares.
111	Intensive, flatland, monocultures	Large- and medium-scale agriculture with dominating monocultures of contiguous areas greater than or equal to 18 hectares.
1111	Rice	Rice dominant crop including most field conditions associated with its production.
1112	Sugarcane	Sugarcane dominant crop including most field conditions associated with its production.
1113	Banana	Banana dominant crop including most field conditions associated with its production.
1114	Coconut	Coconut dominant crop including most field conditions associated with its production.
1115	Vetiver	Vetiver dominant crop including most field conditions associated with production.
1116	Coffee	Coffee dominant crop including most field conditions associated with its production, including shade trees.
112	Intensive, mixed	Mixed, small- and medium-scale agriculture. Agro-forestry (cash and food crops under shade).
1121	Dominated by tree crops	Field cultivation with dominant shade trees (fruit trees, fuel wood species, etc.)
1122	Dominated by nontree crops	Mixed small- and medium-scale agriculture with numerous cash and some food crops.
12	**Extensive, predominant cash crop, flat-Land agriculture**	Areas with less than 50% of land area in crops. Delineation represent areas equal or greater than 9 hectares.
121	Extensive, flatland monocultures	Large- and medium-scale cropping with an area equal to or greater than 9 hectares. Dispersed in nature.
1211	Sisal	Sisal is the dominating crop. All field conditions are associated with sisal production
122	Extensive, mixed flat-land agriculture	Small- and medium-scale fields occupying less than 50% of the land area. Delineations equal to or greater than 9 hectares.
1221	Extensive, mixed cropland	Mixed crops with limited grazing. Crops include scattered fields of corn, sorghum, sisal, vetiver, beans, tubers, bananas, coconut, and some fruit trees.
1222	Open grass savannah	Unimproved grassland with sparse (40%) shrub cover. Grazing use of the more recently abandoned fields.
1223	Sparse shrub savannah	Grassland with sparse (40–70%) shrub cover. Limited grazing in abondoned fields.
1224	Shrub savannah	Grassland with dense (>70%) shrub cover. Very limited grazing in abandoned fields.
13	**Forest in the plains and plateaux**	Forest cover with associated crown closure percentages.
131	Deciduous forest	Broadleaf forest lands with land areas equal to or greater than 9 hectares.
1311	Dense deciduous	Broadleaf forest cover >70%
1332	Open deciduous	Broadleaf forest cover 40–70%
1333	Sparse deciduous	Broadleaf forest cover >40%
132	Coniferous forest	Evergreen soft wood forest with a land area equal to or greater than 9 hectares.
1321	Dense coniferous mountain agriculture	Coniferous forest cover >70%
1322	Open coniferous	Coniferous forest cover 40–70%
1323	Sparse coniferous	Coniferous forest cover <40%
2	MOUNTAIN RESOURCE DOMAIN	RESOURCE USES ASSOCIATED WITH FOOTHILLS AND MOUNTAINS
21	**Intensive agriculture in the mountains**	Agriculture associated with mountain environments. Areas with more than 50% of the land area in crops. Delineations represent areas equal or greater than 9 hectares.
211	Intensive, mountain monocultures	Large- and medium-scale agriculture with contiguous land areas equal to or greater than 16 hectares.
2111	Rice	Rice dominant crop including most field conditions associated with its production.
2112	Sugarcane	Sugarcane dominant crop including most field conditions associated with its production.
2113	Banana	Banana dominant crop including most field conditions associated with its production.
2114	Coconut	Coconut dominant crop including most field conditions associated with its production.
2115	Vetiver	Vetiver dominant crop including most field conditions associated with its production.
2116	Coffee	Coffee dominant crop including most field conditions associated with its production, including shade trees.
212	Intensive, mixed mountain agriculture	Mixed small- to medium-scale farming systems occupying more than 50% of land area. Delineations represent areas equal to or greater than 9 hectares. Limited marketing orientation.
2122	Mixed agriculture	Small- and medium-scale agriculture with scattered corn, beans, potatoes, other tuber crops, etc.

TABLE 6. SELECTED LAND-COVER/LAND-USE CATEGORIES FOR HAITI, INCLUDING NUMERICAL CODE, NAMES, AND SUMMARY DEFINITIONS (CONTINUED)

CODE	TITLE	DESCRIPTION
2121	Agroforestry	Mixed small- and medium-scale agriculture with dominant tree crops, scattered fruit trees, fuel wood, construction wood, mangos, etc.)
22	**Extensive mountain agriculture**	Agricultural land occupies less than 50% of the area delineated. With the exception of monocultures, primarily subsistence in nature.
221	Extensive mountain monocultures	Large and medium scale farming systems dominated by monocultures. Delineations represent areas equal to or greater than 18 hectares.
2211	Sisal	Sisal is the dominating crop. All field conditions are associated with sisal production.
222	Extensive, mixed mountain agriculture	Small and medium-scale fields that occupy less than 50% of land area delineated.
2221	Extensive, mixed cropland	Mixed crops with corn, sisal, vetiver, banana, coconut, beans, potatoes, other tubers.
2222	Open grass savannah	Unimproved Grassland with sparse (<40%) shrub cover. Grazing use of the more recently abandoned fields.
2223	Sparse shrub savannah	Grassland with sparse (40–70%) shrub cover. Limited grazing in abandoned fields.
2224	Shrub savannah	Grassland with dense (>70%) shrub cover. Very limited grazing in abandoned fields.
23	**Forest in the foothills and mountains**	Forest cover with associated crown closure percentages.
231	Deciduous forest	Broadleaf forest lands with land areas equal to or greater than 9 hectares.
2311	Dense deciduous	Broadleaf forest cover >70%
2332	Open deciduous	Broadleaf forest cover 40–70%
2333	Sparse deciduous	Broadleaf forest cover <40%
232	Coniferous forest	Evergreen soft wood forest with a land area equal to or greater than 9 hectares.
2321	Dense coniferous	Coniferous forest cover >70%
2322	Open coniferous	Coniferous forest cover 40–70%
2323	Sparse coniferous	Coniferous forest cover <40%
31	Urban	Urban land use with a total land area equal to or greater than 9 hectares.
311	National and regional urban centers	Urban centers with a total land area of more than 18 hectares.
312	Rural urban centers	Small communities and associated subsistence farming with a total land area between 9 and 16 hectares.
41	Non-agricultural Land Use	No significant agriculture present.
411	Wetlands	Areas dominated almost equally by vegetation and water with a land area equal to or greater than 9 hectares.
4111	Coastal	Wetlands in the tidal zone. Mangrove swamps.
4112	Inland	Fresh water swamps.
412	Surface mining	Areas with evidence of surface extraction of 9 hectares or greater.
4121	Limestone	Active or abandoned limestone quarries.
4122	Other	Other surface mining including bauxite.
413	Barren land	Exposed or denuded areas of 9 hectares or greater.
4131	Barren sand and rock	Areas without vegetation cover, including eroded areas.
4132	Eroded areas	Areas with locational evidence of advancing and severe surface erosion.

TABLE 7. EXAMPLES OF COMPATIBLE FARMING SYSTEMS AND LAND-COVER/LAND-USE CATEGORY SCHEMES PERMITTING EVALUATION OF CURRENT AND ALTERNATIVE LAND-USE POLICY SCENARIOS

FARMING SYSTEM CATEGORY AND DESCRIPTION	LAND USE CATEGORY AND DESCRIPTION
Monocropping, >500, alluvial, irrigated, sugarcane	Intensive, flatland, large- and medium-scale agriculture with dominating monocultures of contiguous areas greater than or equal to 18 hectares: Sugarcane dominant crop including most field conditions associated with its production.
Monocropping, >500, alluvial, rainfed, banana	Intensive, flatland, large- and medium-scale agriculture with dominating monocultures of contiguous areas greater than or equal to 18 hectares. Banana dominant crop including most field conditions associated with its production.
Monocropping, 25<100, highland, steep slope, rainfed, coffee	Intensive, mountain large- and medium-scale agriculture monocultures with contiguous land areas equal to or greater than 16 hectares (type size). Coffee dominant crop including most field conditions associated with its production, including shade trees.
Multiple-cropping, 5<25, highland, steep slope, rainfed	Intensive mountain agriculture. Mixed, small- and medium-scale farming systems.
Mixed-farming, 5-25, alluvial, rainfed	Intensive, mixed, small- and medium-scale agriculture with distinct crop and livestock enterprises in separate plots, dominated by tree crops. Agro-forestry (cash and food crops under shade). Field cultivation with dominant shade trees (fruit trees, fuel wood species, etc.)

means of category aggregation. An example of such compatible categories is provided (Table 7). The land-cover/land-use categories may be used to establish regional and area-specific base line data reflecting current land-use information. These "base line data," reflecting **current** land use, should be used in conjunction with **potential** land use (reflecting relevant land utilization types) to estimate socioeconomic benefits on an aggregate (regional, administrative district, or national) and location-specific basis. The estimated aggregate benefits by location and over time, may than be used to evaluate impacts associated with alternative development policies.

REFERENCES

Anderson, J.R., et al., 1976. *A Land Use and Land Cover Classification System for Use with Remote Sensor Data.* Geological Survey Professional Paper 964, U.S. Government Printing Office, Washington, D.C.

Beek, K.J., 1978. *Land Evaluation for Agricultural Development.* International Institute for Land Reclamation and Improvement, Publication 23, Wageningen, Netherlands.

Conway, G., 1985. Agro-ecosystem Analysis. *Agricultural Administration* 20: 31-55.

CRIES, 1987. *Land Cover/Use Mapping, Region du Sud, Haiti. Final Report.* ADS II Project, in cooperation with USAID and the University of Arkansas. CRIES Project, Michigan State University, East Lansing, Michigan.

Dent, David, and Anthony Young, 1981. *Soil Survey and Land Evaluation.* George Allen and Unwin, London.

Schultink, G., 1986. Micro Computer-based Geographic Information Assessment Technology for Resource Assessment and Rural Development Planning, *Geocarto International,* Vol. 2, pp. 33-43.

———, 1987. The CRIES Resource Information System: Computer-aided Spatial Analysis of Resource Development Potential and Development Policy Alternatives, *Journal of Soil Survey and Land Evaluation* Vol. 7, No. 1, pp. 47-62.

———, 1991. Evaluation of Sustainable Development Alternatives: Relevant Concepts, Resource Assessment Approaches and Comparative Suitability Indicators. *International Journal of Environmental Studies.* (in press) 26p.

Schultink, G., N. Amaral, and D. Mokma, 1987. *User Guide to the CRIES-Agro-economic Information System - YIELD Model,* Version 1.0. CRIES, RDOP-CRIES-87-1, Michigan State University.

Schultink, G., B. Buckley, D. Brown, S. Nair, W. Enslin, and Sei-Wang Chen, 1987. *User's Guide to the CRIES Geographic Information System,* Version 6.1. CRIES, RDOP-CRIES-87-2, Michigan State University.

U.S. Department of Agriculture, 1973. *Land-Capability Classification,* Soil Conservation Service, Ag. Handbook No. 210, Washington, D.C.

Vink, A.P.A., 1975. *Land Use in Advancing Agriculture.* Springer-Verlag, New York, Heidelberg, Berlin.

BOOK REVIEW

Viewing the Earth: The Social Construction of the Landsat Satellite System, by Pamela E. Mack. The MIT Press, Cambridge, Massachusetts, 270 p., 1990.

IT WAS THE BEST OF TIMES; it was the worst of times. Heroes walked in space and took a giant step forward for mankind on the Moon. The world hung close to their television sets, 10..9..8.. and only a few cars were abroad on normally crowded streets, 7..6..5.. while the Viet Nam dilemma was momentarily forgotten, 4..3..2..1 and we have blastoff. To stand at Cape Canaveral and *feel* the overwhelming sound waves of a thousand jets rolling over the marshes and hear the collective gasp as a thousand people released their breath in a single wild cheer was for a fortunate few to share a genuine piece of the right stuff.

Into this euphoric era came the less glamorous but more utilitarian communication and weather satellites and, in 1972, the first Earth Resources Technology Satellite, ERTS 1, soon renamed Landsat. The communication satellite program evolved successfully as a government-industry partnership, the weather satellites are government operated and equally successful, and the Landsat program?—well, that's the story of the book. Did it fail, or has it just not succeeded—yet?

There is little question that the technology worked mostly as designed, sometimes with amazing results. But the real drama unfolded among the individuals and their institutions who championed or subverted Landsat. It's a history lesson well worth examining because, in the age of high technology with flashing lights and pretty pictures, it is easy to be beguiled and to forget that technology will only be adopted when it serves to the advantage of individuals in the context of a social and economic system. For this understanding, Pamela Mack provides us with a valuable contribution.

Discovering all the players and their roles was a major exercise in detective investigation, as she points out. One quote by a NASA administrator bemoans the situation in 1970 when ... no useful records or files pertaining to the ERTS Program are in existence ... communication has been largely by telephone with no records kept ... correspondence and action papers lost ... meetings missed ... and an inability to reconstruct past actions and decisions. Her visits to other agencies produced similar results, with a few exceptions oftentimes due to files kept by individuals. One advantage she gained was an extensive number of interviews with key individuals conducted between 1978 and 1981. Thus, she has the story about right.

Photogrammetry and aerial photographic interpretation were two of the big technical disciplines for studying Earth resources from about 1930 to the 1950s with major applications in cartography, military intelligence, and all the Earth sciences such as geology, soils, forestry, and agriculture. Then remote sensing burst on the scene and, while the spectrum expanded into the infrared and microwave, computers allowed an almost limitless realm of digital image processing and analysis.

Sputnik orbited in 1957 (the same year that the first intercontinental ballistic missiles were tested and the cold war became some degrees colder). The defense and intelligence communities that had been exploring the capability of captured German rockets went super secret with spy satellites to replace the ill-fated U2 aircraft overflights. The National Aeronautics and Space Administration rocketed like a phoenix out of the National Advisory Committee for Aeronautics with the crusading high technology mission of landing a man on the Moon and developing the peaceful uses of space. And some individuals in the Earth science agencies like the Department of the Interior and the Department of Agriculture together with commercial interests such as the oil and mining industries saw remote sensing from space as the new frontier. This was the basic triad of interests.

Triangles are stable geometrically but not in marriage. And not here either as NASA, the defense and intelligence agencies, and the Earth science and industry interests squabbled and at-