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APPLIED GEOGRAPHIC INFORMATION SYSTEM TECHNIQUES FOR ASSESSING AGRICULTURAL PRODUCTION POTENTIAL IN DEVELOPING COUNTRIES: A HONDURAN CASE STUDY

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I. ABSTRACT

A micro-computer based Geographic Information System (GIS) was used to assess the agricultural potential in the Choluteca Department in Honduras. The resource attributes included soils information, slope, elevation, precipitation, temperature, ecological zones and current land cover/use. Agro-ecological zones (AEZs) were developed by combining resource attributes such as soil and slope information with Holdridge Life Zones. Crop production potentials were determined for each Agro-Ecological zone. A comparison with current land use/cover derived from Landsat data indicates that significant areas of agro-ecological zones with medium to high crop production potential exist which are under-utilized from an agricultural perspective. This is specifically significant in view of existing food production deficits in the region, affecting availibility and price of the basic commodities.

II. INTRODUCTION

Many developing countries can only achieve a balance of payments through import substitution and/or increasing the export of agricultural products. Expansion of crop production without regard to physical production potential may eventually, however, lead to lower productivity than expected and/or increased soil erosion. Unless necessary precautions are taken, soils susceptible to erosion will be severely degraded and adjacent lands may also be affected. The final result will be a reduction of export production and available domestic food supply.

Expanding export crop production at the expense of domestic crops could further exacerbate hunger and malnutrition. The simple prioritizing of agricultural land use in favor of export production may solve immediate balance of payment problems but short and/or long range domestic food shortages may result. With this simple land policy use change, domestic crop production is likely to be forced onto less productive and/or steeper lands where erosion is a major threat. Subsistence farmers have to cultivate larger areas or food production deficits will result. Where shifting cultivation is practiced, the length of time the land remains fallow is reduced. Consequently fewer nutrients are replenished, lowering nutrient levels and crop yields without proper application of fertilizer. As a result erosion is likely to increase on sloping lands.

III. GEOGRAPHIC INFORMATION SYSTEM

A micro computer-based Geographic Information System (GIS) was used to assess the agricultural production potential in the Choluteca Department in southern Honduras. The entire Department (434,100 hectares) was digitized in polygonal form and then converted to a grid format with a cell size of 6.25 hectares. The GIS files include soils information at the family level, slope, elevation, precipitation, temperature, current land use/cover, and Holdridge Life Zones.

A. SOILS

The soils information was obtained from soil maps at a scale of 1:20,000. The mapping units of these maps were defined by one or two soil series and by slope ranges. Each soil series had been classified to the family level using USDA Soil Taxonomy (USDA/SCS, 1975). The soils in Choluteca vary from sandy to clayey, from shallow to deep, from well drained to poorly drained and from nearly level to very steep.

A more general soil map at a scale of 1:250,000 was prepared from these maps. The soils were grouped based on association within the landscape and soil properties. The classifications of the dominant soils in the new mapping units are given (Table 1).

The major soil properties which affect crop production in Choluteca are profile texture, natural drainage, soil depth or depth to bedrock, pH and salinity. These properties are described for each mapping unit (Table 2).

Table 1.

Classification of Soil Units in Choluteca Department

Soil Unit	Classification
1	Typic Pellusterts, fine, montmorillonitic, isohyperthermic
2	Udic Haplustalfs, fine-loamy, mixed isohyperthermic Ustic Dystrochrepts, fine-loamy, mixed isohyperthermic Lithic Ustiorthents, fine-loamy, mixed isohyperthermic Lithic Argiustolls, fine loamy, mixed, isohyperthermic
3	Udic Haplustalfs, fine-loamy, mixed isohyperthermic Lithic Ustiorthents, fine-loamy, mixed, isohyperthermic
4	Fluventic Haplustolls, fine, mixed isohyperthermic Aquic Haplustolls, fine, mixed, isohyperthermic
5	Typic Udifluvents, fine-loamy, mixed, isohyperthermic Typic Udifluvents, coarse-loamy, mixed, isohyperthermic
6	Aquic Haplustalfs, fine-loamy, mixed, isohyperthermic Vertic Tropaqualfs, fine, mixed, isohyperthermic
7	Udic Haplustalfs, fine-loamy, mixed, isohyperthermic Udic Argiustolls, fine-loamy, mixed, isohyperthermic Lithic Haplustolls, loamy-skeletal, mixed, isohyper-thermic
8	Udic Haplustalfs, fine-loamy, mixed, isohyperthermic Vertic Tropaqualfs, fine-loamy, montmorillonitic, iso-hyperthermic
9	Typic Hydraquents, fine-silty, mixed, isohyperthermic Hydric Tropaquepts, fine, mixed, isohyperthermic
10	Typic Haplustolls, sandy, mixed, isohyperthermic
11	Lithic Ustropepts, loamy skeletal, mixed, isothermic
12	Ustic Dystrochrepts, fine-loamy, mixed, isothermic Udic Paleustalfs, fine-loamy, mixed, isothermic Lithic Troporthents, loamy-skeletal, mixed, isothermic Udic Argiustolls, fine-loamy, mixed, isothermic
13	Vertic Tropaquents, fine, montmorillonitic, isothermic
14	Udic Argiustolls, fine-loamy, mixed, isothermic Vertic Tropaquents, fine, montmorillonitic, isothermic

Table 2.
Soil Unit Properties in Choluteca Department

Soil Unit	Family Texture*	Natural Drainage**	Depth (cm)	pH range	Salinity	Slope (%)
1	f	swp,pd	>100	7.4-8.4	low	0-2
2	fl	wd	25-100	5.6-7.3	low	30-60
3	fl	wd	25-100	5.6-7.3	low	7-15
4	f,fl	swp,pd	>150	6.6-7.8	low	0-2
5	cl,fl	wd	>150	6.1-7.3	low	0-3
6	fl,f	swp	>150	6.1-6.5	low	0-2
7	fl	wd	25-100	5.6-7.3	low	15-30
8	fl	swp	>150	6.8-8.4	low	3-15
9	fs,f	pd	>150	7.9-8.4	high	0-3
10	s	swp	>150	>6.8	low	0-3
11	ls	swp	>50	6.1-7.3	low	2-7
12	fl	wd	50-100	5.1-7.3	low	30-60
13	fl	swp	>150	6.1-8.4	low	0-3
14	f	swp	>100	6.1-7.3	low	15-30

* f=fine, fl=fine loamy, cl=coarse loamy, s=sandy, fs=fine silty, cs=clayey-skeletal, ls=loamy-skeletal

** swp=somewhat poorly drained, pd=poorly drained, wd=well drained

B. TOPOGRAPHY

The primary topographic factors affecting crop production are slope gradient and elevation. Slope gradient information, was obtained from existing soil maps. Because slope affects the rate of runoff and resulting erosion, it also affects cultivation and harvesting practices. Elevation contours were digitized from 1:250,000 topographic maps. The influence of elevation on crop production can generally be related to the mean annual precipitation and temperature and the resulting variation of evapotranspir-ation.

C. CLIMATE

Climatic information was available from three primary stations - Choluteca, Pespire and San Marcos de Colon. Monthly and annual precipitation and temperature means were available from general contour maps developed by the National Cadaster.

Annual precipitation in the Department ranges from 500 mm in the northeast to over 2400 mm in the southwest. Annual temperature ranges from 18°C in the northcentral region to 29°C in the southeast. Because of the variability of the climatic records, the distance between stations, and the mountainous terrain of the Department, the climatic data were considered less representative of the spatial variation than the climatic information interpreted from the Holdridge Life Zone classifications.

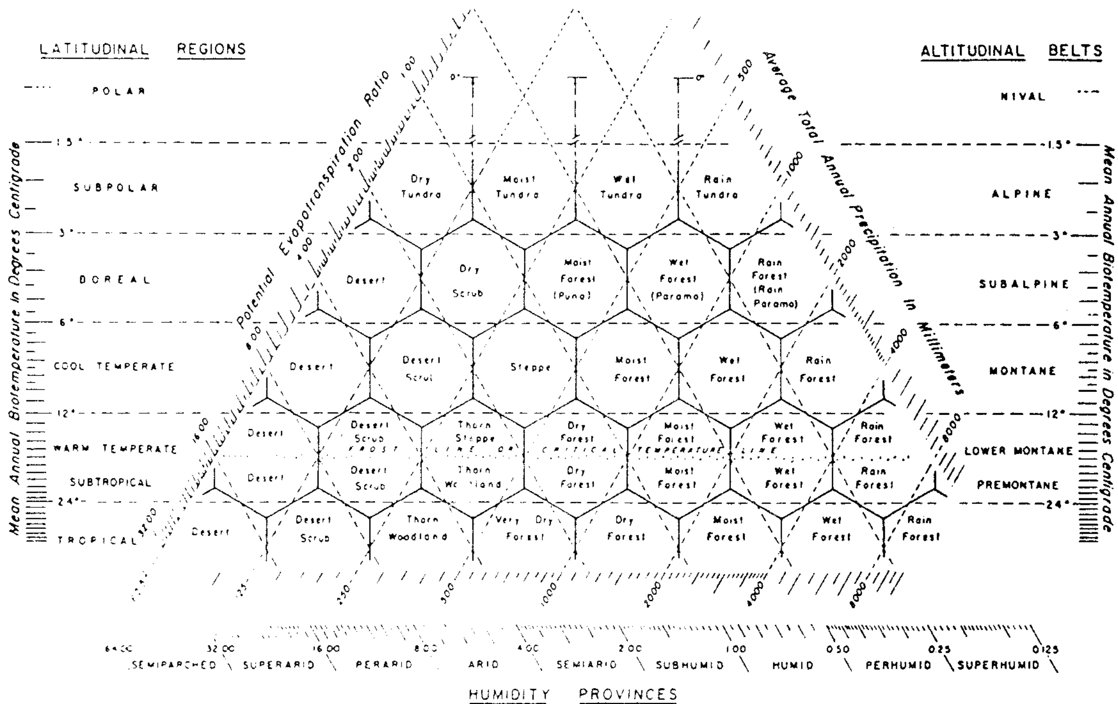
D. BIO-CLIMATIC ZONES

Inadequate representation of spatial variation by existing climatic data required the use of bio-climatic indicators to define temperature and moisture regimes. From the various bio-climatic zonation schemes, like Koppen (1931, 1936), Thornthwaite (1948, 1957), Holdridge (1947, 1967), and Walter (1960 and 1971) available, the life zone classification developed by Holdridge (HLZ) was used.

Holdridge (1979) explains that the HLZs are defined primarily by three major climatic factors, mean annual temperature, average total annual precipitation and resulting potential evapotranspiration. This last factor determines largely the most critial factor affecting biological productivity in the tropics, namely moisture availability. The life zones are represented by hexagons defined by latitudinal regions, altitudinal belts and humidity provinces. Thus, hexagons represent individual life zones and associated vegetation communities within a series of latitudinal and basal life zone (at sea level) combinations that exist with identical biotemperature, precipitation, and potential evapotranspiration range ratios.

The life zones represented in Choluteca are described (Table 3).

Figure 2 Diagram for the Classification of World Life Zones or Plant Formations



Source: Holdridge, C.R., 1966, Tropical Science Center

Table 3.

Holdridge Life Zones Represented in Choluteca Department

Life Zone Symbol	Name	Temperature (°C)	Precipitation (mm)	Potential Evapotranspiration Ratio
Bms-T	Very dry forest-Tropical	>24	500-1000	2.00-4.0
Bs-T	Dry forest-Tropical	>24	1000-2000	1.00-2.0
Bh-T	Moist forest-Tropical	>24	2000-4000	0.50-1.0
Bs-S	Dry forest-Subtropical	17-24	500-1000	1.00-2.0
Bh-S	Moist forest-Subtropical	17-24	1000-2000	0.50-1.0
Bmh-S	Wet forest-Subtropical	17-24	2000-4000	0.25-0.5
Bh-MBS	Moist forest-Lower Montane/Subtropical	12-17	1000-2000	0.50-1.0
Bmh-MBS	Wet forest-Lower Montane/Subtropical	12-17	2000-4000	0.25-0.5

E. LAND USE/COVER

Knowledge of existing land cover/use patterns plays an important role in agricultural development planning and watershed management. It provides the comparative framework between current production status and resource production potential for a given location. Land use information is, therefore, an essential component of the CRIES Geographic Information System. And, when combined with physical resource attributes such as soils, climate, and agro-ecological information, the inventory becomes a valuable instrument for assessing current and potential agricultural production. The categories mapped and their resulting areas are listed (Table 4).

Table 4.

Land Cover/Use Category Totals for the Choluteca Department

Category		Area (ha)	Area (%)
11	Cities	231.96	.05
21	Sugar Cane	17,793.7	4.10
22	Mixed Cropping	22,084.99	5.09
31	Improved Rangeland	56,885.02	13.10
32	Limited Rangeland	44,326.	10.21
33	Very Limited Rangeland	64,155.12	14.78
41	Deciduous Forest Land	35,471.	8.17
42	Pine Forest Land	22,066.6	5.08
43	Mixed Brush Land	114,087.45	26.28
51	Lakes	122.08	.03
61	Forested Wetland	22,292.5	5.14
62	Non-Forested Wetland	24,355.75	5.61
Total		434,100	100.00

IV. ASSESSMENT OF AGRICULTURAL PRODUCTION POTENTIAL

With the use of the CRIES-GIS and the primary physical attributes, optimal production locations for selected crops can be determined using predefined requirements. These locations can than be compared with the actual land cover/use information to determine <u>unrealized production potential</u>. Eighteen main crops were selected for this comparitive analysis: sorghum, corn, beans, sugar cane, rice, melons, plaintain, cotton, coffee, bananas, sesame, papaya, cassava, cashews, mangos, avadaco, pasture, and timber. Because the primary agricultural practice for all crops other than sugar cane and cotton is intercropping it was impossible to make a direct comparison between the crops listed and the land cover/use inventory without aggregating first. Consequently, the crops listed were aggregated into the categories used in the inventory. Cropping patterns were compared by municipio boundaries to establish crop distribution by political unit for reference with reported crop type and yield statistics. Next, a determination was made where crop change and crop expansion could take place. To do this, it was necessary to delimit regions which were physically homogeneous with respect to agricultural production potential of the crops under consideration.

A. AGRO-ECOLOGICAL ZONES

An agro-ecological zones (AEZ) is a unit of land considered physically homogeneous with respect to soil, topography, and climate and with an almost uniform potential to produce a given crop. AEZ's were primarily developed by combining the soil map and the HLZ map. To determine crop potentials the soil, topographic and climatic properties or conditions of the AEZ's were compared with the crop requirements. Crop potentials were developed for each crop and each AEZ. Potentials for some crops and some AEZs are given (Table 5). Zones with a high potential for specific crops meet the requirements of that crop. Zones with a low potential rating do not meet one or more of the important requirements of that crop.

There is considerable variation in the current land use of the AEZ (Tables 6 and 7). Some AEZ's, such as Bh-S4 and Bh-S5, are used primarily for crop production. Other AEZ's, such as Bh-S1 and Bh-S3, are used primarily for range. Still other

Table 5.

Crop Potentials for some Agro-Ecological Zones in Choluteca Department*

	Agro-Ecological Zones						
	Bh-S			Bh-T		Bmh-S	Bs-S
Crop	5	6	7	2	8	12	13
Sorghum	H	M-H	L	L	M	L	M
Corn	H	M	L	L	M	L	L-M
Beans	H	M	L	L	M	L	L-M
Sugar Cane	M-H	L-M	L	L	L	L	L

* A partial listing as an example.

zones, such as BmS-T11, Bh-T2 and Bs-S13, are primarily in forest or mixed brush.

AEZ's with medium, medium - high or high potentials for most crops are not entirely used for crop production (Table 6). About 75 percent of AEZ Bh-S1 is currently used for range. AEZ's Bh-T4, Bh-S4, and Bh-S5 have the highest overall potential but only 12, 69 and 71 percent, respectively, are used for crop production. Less than 26 percent of AEZ's Bms-T5, Bh-T6, Bh-S6, Bh-T8 and Bh-S8 are currently used for cropland. Consequently, from a physical standpoint there is considerable potential for crop expansion in the Choluteca Department.

B. PRELIMINARY RECOMMENDATIONS

Areas of pasture, improved range, limited range and mixed brush represent the most obvious and least costly land use changes to cropland. To compensate for the loss of pasture or range, areas with low or low-medium crop potential could be converted to range. Also the productive capacity could be raised through improved management practices. Thereby, smaller areas of pasture and range would be required. Areas too steep for sustained agricultural use should be reforested to help reduce erosion. However, careful consideration is needed when recommending land use changes for export crop production and reforestation to eliminate or minimize negative effects on domestic food production and to ensure adequate food supplies at reasonable prices for the locations under consideration.

Currently, less than 10 percent of the sugar cane grown in the Department is produced in AEZ's with less than medium potential (Table 7). Nearly one-third of the mixed cropland occurred in areas with low or low-medium potentials. Almost 20 percent of the cane, mixed cropland and cotton/pasture produced in the Department is cultivated on these lands. These areas, undoubtedly, make up a portion of subsistance farming systems. Any land use conversions must, therefore, carefully be considered with respect to their impact on the food production potential and income distribution in the area.

In many instances the practice of cultivating lands with low or low-medium potentials has led to increased erosion. If erosion is allowed to continue unchecked, the soils on the steep slopes will soon be lost for crop production. The crops grown should be limited to those crops or cropping systems which protect the soil from erosion. Management practices such as terracing and mulching should be used to maintain the basic productive capacity of southern Honduras.

Table 6.

Current Land Cover/Use of AEZs with Medium, Medium-High or High Potentials for Crop Production

	Agro-Ecological Zones								
Land Use/Cover (area %)	Bh-S 1	Bh-T 4	Bh-S 4	Bms-T 5	Bh-S 5	Bh-T 6	Bh-S 6	Bh-T 8	Bh-S 8
Urban	0.0	0.0	0.0	0.0	1.3	0.0	0.4	0.0	0.0
Sugar cane	4.8	0.0	33.5	0.0	50.1	0.0	3.5	0.0	0.0
Mixed cropland	10.4	12.2	10.4	18.9	15.1	13.2	16.0	0.0	25.1
Cotton/pasture	0.2	0.0	25.1	0.0	6.2	0.0	0.0	0.0	0.0
Improved range	64.4	1.2	14.4	0.0	19.4	25.3	59.8	3.6	28.4
Limited range	10.4	15.7	3.7	9.0	0.0	10.8	12.4	0.0	30.0
Very limited range	3.6	55.8	0.9	19.4	0.4	17.7	2.2	87.3	4.6
Deciduous forest	0.0	1.2	2.3	0.0	0.0	8.1	0.0	5.5	0.6
Coniferous forest	0.3	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.2
Mixed brush	3.5	14.1	1.1	53.0	5.8	24.5	5.0	3.6	7.8
Lakes	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Forested wetlands	2.4	0.0	5.4	0.0	0.0	0.0	0.3	0.0	0.0
Non-forested wetlands	0.0	0.0	2.9	0.0	0.0	0.5	0.4	0.0	3.4

Table 7.

Cropland on AEZs with Low or Low-Medium Potential for Crop Production (in hectares)*

Agro-ecological zones	Sugar cane	Mixed cropland	Cotton/ pasture	Total cropland
Bms-T 2	0.00	439.49	0.00	439.49
Bs-T 2	0.00	53.41	0.00	53.41
Bh-T 2	0.00	38.15	0.00	38.15
Bs-S 2	0.00	65.62	0.00	65.62
Bh-S 2	15.26	639.39	97.66	752.31
Bh-S 3	45.78	86.98	0.00	132.78
Bh-T 7	0.00	16.79	0.00	16.79
Bh-S 7	7.63	314.36	0.00	321.99
Bh-S 9	123.61	259.42	317.41	700.44
Bh-S 10	0.00	76.3	12.21	88.51
Bms-T 11	0.00	21.36	0.00	21.36

* Partial list as an example.

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