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GEOGRAPHICALLY REFERENCED WATERSHED SYSTEMS RESEARCH: A SOCIO-ECONOMIC APPLICATION IN HAITI

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ABSTRACT

Maps are extremely useful tools in analyzing phenomena that exhibit spatial variation. Unfortunately, making a map is a time consuming and technically difficult task. As a result, maps are much less widely used than they might be. The ADS-II project has forged linkages between software packages, that, to a large extent, automate the mapping process. Since many of the time and skill requirements have been eliminated by the system, mapping has become much more widely available as an analytic tool.

The heart of the system is a combination of the Lotus 123 spreadsheet program from Lotus Development Corporation and the cartographic information system GIS from the Comprehensive Resource Inventory and Evaluation System (CRIES) developed by Michigan State University. A Lotus spreadsheet is used to establish a data base that is referenced to the spatial record keeping units on the map. The linkage mechanism allows data to be transferred between the two programs. The analytic and report facility used under any given set of circumstances depends on the nature of the data and the analysis to be performed. The real power of the combination comes from the ability to use the graphical output capabilities of the two systems. The time consuming tasks of constructing maps and graphs can be mostly relegated to the computer.

This paper describes how spatial variation of complex socio-economic variables can be mapped and studied within their regional and national contexts by linking GIS and Lotus databases. A description is first given of the GIS data base, with illustrative national/regional level information extracted from this showing specific program activities in one region of project intervention: Jacmel's plateau region of Haut Cap Rouge. This is followed by a portion of the socio-economic database in Lotus 123 form. The information contained in the Lotus file is subsequently presented in cartographic form.

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0.0 Introduction

Social scientists have long observed that most elements of human systems studied vary considerably across space and time. Much of what we know as anthropological and sociological research is based on an attempt at understanding and explaining complex issues and patterns underlying such variation. Describing the nature of such variation without cartographic tools can be very difficult indeed; and without such description subtle relationships can very easily be overlooked. The combined power of GIS and Lotus 123 data bases place powerful spatial analytic tools into the hands of researchers which are useful for numerous socio-economic applications. The present study will deal with a set of complex issues within the field of applied research known generally as farming systems reserch.

Since early 1984, the University of Arkansas and Winrock International have implemented in Haiti an on-farm applied research program and a national agricultural statistics program. As part of these endeavors, a geographic information system was established to permit spatial analysis of statistical data and to [illegible] natural resource inventories. An expected output was [illegible] enhanced ability of Ministry of Agriculture decision makers [illegible] to evaluate complex associations of [illegible] in a spatially consistent manner when planning new programs. As the GIS system data base presently established has become better known and as the number of variables digitized nationally and regionally have increased, demand for use of the system has grown dramatically.

The on-farm applied agricultural research program has been involved with small farmers in two Departments of Haiti, the Sud and Sud-Est. Interventions have centered on specific plain and mountain sites near the principal regional centers of Les Cayes and Jacmel. For the purpose of this paper, we have chosen to present farming systems applied research realized on the Jacmel mountain/plateau site of Haut Cap Rouge, with special attention to two sub watershed systems in the Morija Watershed System.

1.0 The Data Bases

1.1 GIS Data Base

The Geographic Information System (GIS) is one module of the Comprehensive Resource Inventory and Evaluation System (CRIES), developed by the CRIES Project at Michigan State University. "One of the major operations of a computer-based GIS is to conduct overlay analysis of multiple attributes... To perform this function, the file structures must be in a format which permit the vertical integration and comparison of a number of attributes in relation to their geographic location" (Schultink et.al., 1986:1.9). A grid-based reference system is created whose physical 'address' is based on the Universal Transverse Mercator (UTM) coordinates found on topographic maps world-wide.

The power of the GIS rests in the user's ability to analyse any geographically definable unit by or in combination with any other variable layer in the data base. Products from such analysis include cartographic products, statistical tables (eg. frequency distribution, cross-tabs), and graphs. One can most easily visualize the GIS data base as a potentially unlimited number of transparent map overlays, each overlay representing one set of related variables.

GIS data bases of two kinds have been created, one orientated towards national level planners and evaluators, the other to regional/local level technicians. The national level data base, created through digitization of information from already existing maps at a scale of 1:100,000 or greater, permits manipulation of aggregated statistics. Haiti, through the ADS-II project, presently possess the following layers in this data base:

1. Vegetative Cover (52 attribute classes (AC's)
2. Soil Potential (19 AC's)
3. Administrative Divisions:
   - Department (9 AC's)
   - Arrondissement (41 AC's)
   - Commune (130 AC's)
   - Section Communale (564 AC's)

   - District Agricole (22 AC's)
   - Agence Agricole (41 AC's)
4. Holdridge Life Classification Zones (9 AC's)
5. Elevation (30 AC's)
6. Bassin Versant:
   - Primare (30 AC's)
   - Primaire et Secondaire (55 AC's)
   - Sous-Bassins (AC's)
   - Sous-Sous Bassin (440 AC's)
7. Hydrology (2 AC's)
8. Climatology (4 AC's)
9. Infrastructure (5 AC's)
10. Population Density (to Section Communale level) (6 AC's
11. Mineral Deposits (5 AC's)
12. SNEM Malaria National Spraying Programs (5 AC's
13. Rainfall Patterns (13 AC's)
14. Landsat 1985-86 Thematic Mapper Data on Vegetative Cover (36 AC's)

Information, when digitized, is stored in grid cells, whose size depends upon the nature of the primary data being coded and the degree of accuracy sought. For our national, macro-level data base in Haiti, information digitized with a grid cell size of 300 X 300 meters was considered acceptable. Greater resolution would not have been consistent with the precision of the secondary data being encoded. However, to capture specific micro-level data for information such as the location of individual fields of corn or rice, the position of rock terraces across farmer property lines, land tenure patterns, etc., a grid cell size of 1 X 1 meter was

considered desirable.

1.2 The Socio-economic Data Base

The Haut Cap Rouge plateau, ranging between 500-800 meters in elevation, has been the focus of farming systems applied research since early 1984. With a surveyed population of about 7,976 people, making up some 2,180 households, the program has worked with farmers in on-farm testing (variety and fertilizer trials, improved management trials, etc. of all major crops found in the zone. These crops included corn, sorhum, yams, sweet potatoes, manioc, red and black beans, pidgeon peas, cowpeas, coffee, leucaena, sesbania and other legumeous plants, napier and Guatamala grass, grafted citrus and assorted other tree crops. Many of these crops were studied in the context of the watershed management program which included construction of rock terraces and erosion controlling vegetative barriers.

The biological aspect of this work was supplemented through complementary socio-economic studies among the households participating in the program. These studies have generated a sizable data base on a number of socio-economic variables which include population characteristics (ages, sexes, occupations, literacy, etc.) along with information on the agricultural and livestock systems practiced. The data has been analyzed using various statistical packages: MSTAT for agronomic trial analysis, STATPAC and LOTUS 123 for the socio-economic variables.

The remaining sections of this paper will attempt to demonstrate how, beginning with currently available GIS national/department level data, and moving on to more site specific data, one can gain an enhanced perspective of farmer communities and socio-economic and physical characteristics of the region through spatial interpretation of data. Creation of these data bases also presents the researcher with a flexible tool and realistic context within which change can be monitored in the future.

2.0 Placing Haut Cap Rouge Program into its National/Regional Context

The mountainous country of Haiti with some 27,000 sq. kms., occupies the north-western third of the island of Hispaniola in the Caribbean. Administratively, it is made up of 9 Departments. The ADS-II farming systems project has worked in the two Southern Departments, Sud and Sud-est. Within Haiti, Departments are divided into Arrondissements, then further divided into Communes and Sections Communales. The Department du Sud-est, in which Jacmel is located, has 50 Section Communales.

The population, estimated near 7 million, is unevenly distributed, with major concentrations in Port-au-Prince, Cap Haitian, Gonaives, Les Cayes, Jacmel and a number of other towns. However, one finds people everywhere, from the arid northwest to

the the rugged sides of most of the steep mountains which make up this country. Population density for the Department du Sud-est is no exception.

The Department du Sud-est includes a number of major watershed systems. With the GIS we are able to place the project region around the Haut Cap Rouge Area into its context. The Project Area itself, within this region, can also be highlighted.

3.0 THE PROJECT AREA

Using the Project Area boundaries as a kind of "cookie cutter", GIS software permits us to "cut" through other layers of data in the national/regional data base to summarize a series of statistics important to program planning.

Soil potential classes for the national data base include 19 variables, which when shown together, are difficult to interpret in any simple way. By grouping these into three classes: good soils, fair or medium soils, and poor soils, one may more easily see major patterns in the Project Area. It becomes quickly evident, for instance, that the Haut Cap Rouge plateau region is fairly fertile, while the slopes zone are poor. The plain region below again is fertile. Using the GIS to compute area by soil types for the project region, we obtained:

Project Area Soil Types

	Hectares
Good Soils	10,575
Fair Soils	3,420
Poor Soils	32,328
Other (urban,lakes,rivers)	495
Total:	46,818

Long term annual rainfall patterns for the region suggested a variation from 1400 mm in the lower altitutes to 2000 mm in the higher elevations. Project rainfall data for the past three years confirmed these patterns.

Topographically, the Haut Cap Rouge plateau varies between 600 and 800 meters and plunges fairly rapidly to a narrow coastal plain and the sea. Elevation contour data were aggregated to show the major plain, slopes, and plateau zones.

3.1 The Project Watershed Study Area

Within the Project Area, ADS-II field technicians selected a number of small watershed systems within which to concentrate activity. The rational was that attempting to improve crop production and improve soil/water management in a mountainous environment did not make much sense without addressing the entire hydrological physical unit involved. Improving the soils on the

lower part of a slope could not succeed unless the velocity of run-off water from higher up could somehow be controlled. Improving the irrigation systems in the Cyvadier plain was difficult when the same run-off caused heavy silting in hand-dug earthen canals.

Rapid run-off is caused by increasing deforestation on the plateau and heavy cultivation of the mountain slopes (where trees are already gone). With decreased moisture infiltration in the mountains, springs at the foot of these mountains give a less constant flow of water over an ever shorter period of time during the non-rain months of the year - once again effecting irrigation potential as well as water for normal domestic consumption. An entire drainage system or some complete sub-unit of this system therefore needed to be handled as a whole.

Therefore, within the Project Area, the Corail Watershed System was selected as one area of intervention. Within the Corail Watershed, one of the sub-sub upper watersheds was selected for special study. Having digitized the areas of interest from existing 1:25:000 base maps, we were able to determine the following:

The Haut Cap Rouge Project Region, including affected plain zone directly below the Corail Watershed System: 12,384 hectares

The Watershed Project Study Area:	1,674 hectares
The Corail Watershed System:	450 hectares
Morija sub-sub Watershed:	81 hectares

Looking at the GIS rainfall data again, we could see that rainfall patterns correlated directly with the rise in elevation. The high plateau region benefits from the most rainfall. The Morija sub-sub watershed area could also be seen to be located within the region of the rapidly descending slopes and decreasing rainfall.

4.0 The Morija Sub-sub Watershed

Seen from the air, the Morija watershed in reality represents only two small branches flowing into a larger stream representing the Corail Watershed System. The entire system evenually forms into a deep gorge which drops rapidly to the plain near the community of Cyvadier. Farmers of the region have names for all the branches and sub-branches, finally forming the Ravine du Normande.

In order to develop a low cost method of obtaining aerial photographs of the project region in a timely manner, the program contracted with a local pilot at a rate of $130/hour. Using a 35 mm. camara and flying in a small one engine plane with a rear door left open, project technicians have been photographing the

Project Area every three months from an altitude of 3500 feet. Flight time rarely has exceeded 1 hour. Kodacolor prints are mosaicked together in the central office where data are transferred to transparent overlays and subsequently digitized into the GIS database using a 1 meter grid cell size. Rock terraces, roads and paths, and the changing cropping cycles were all mapped in this way.

These same photographs were taken into the field and, with the participation of cooperating farmers, property boundaries were located, and the names of both the owners and the land tenure status of farmers exploiting the various field noted. For the study concerned, this activity took three days, using one research technician and two field assistants. These data became part of the Lotus 123 data base for the farmers in the project area. Property boundaries were used to create the digitized base map upon which subsequent data were superimposed. A small sample of these data is presented on the next page in Figure 1. The first column represents the individual fields, followed by the name of the field owner, land tenure, name of user of field if other than the owner, data on the family, field cropped and area.

Aggregated villages as such do not exist in this region; rather residential clusters of scattered farm households hold the high plateau ground. These households each usually possess a small area of mixed tree crops surrounding small two/three roomed grass or metal roofed houses. Fields are scattered around the area. Digitized data for the area therefore included the location of these households, the family grave sites often associated with home territory, and the location of the family fields.

4.1 Land Ownership

The nature of land ownership in Haiti has been a subject for both lively public and scholarly debate for years. One characteristic of such ownership, resulting from traditional inheritance laws, has been the fragmentation of fields and parcels. Field sizes are small, ranging from half to one acre in size. Families may possess 6-10 such fields. Field fragmentation is vividly portrayed using the cartographic output of the GIS on about 2/3 's of the land within the 81 ha. of the sub-sub Morija Watershed. Here, 168 separate fields were identified. These 168 fields belonged to 94 separate farmers. GIS maps illustrating field/owner patterns with the associated land tenure were created by importing specific data from the Lotus data base (see Fig.1 above) to the GIS. It became evident that the location of share-cropped and rented land was not random but tended to concentrate on the most infertile and steepest slopes. Land with a higher production potential, located on top of the hills or at the valley bottoms, was rarely given for outside of household use.

Of the 166 fields, 119 or 72% were claimed by farmers to be individually owned/exploited;
27 or 16% were sharecropped;
11 or 7% were rented; and
9 or 5% were on unpartitioned family lands.

FIGURE 1:

MORIZA SAILS HED LAND USE CLASSIFICATIONS

DU ARCELLE	PROPRIETAIRE DU PARCELLE	Prop. du Parc.	Nom de l'exploit si pas Prop.	Red Fond Land	CULTURES Tube Saison	CULTURES Pieme Saison	SEX OF HOUSEHOLD HEAD	[illegible]	# OF CHICKENS OWNED	# OF CATTLE OWNED	# OF PARCELS USED	[illegible]
6	David Julien[illegible]	13		1	11[illegible]25	21408	1		7	0	10	
7	Revilus Renvil	27	Samence Lundi	[illegible]	10510	7	1	[illegible]	20	2	26	[illegible]
	Suzanne Magloire	7		1	1208	29709	1	[illegible]	3	1	20	[illegible]
	Ogilet Jules (Habitation)	29		1	101203	809	1	[illegible]	19	3	11	[illegible]
	Denis Rosemond (Habitation)	30		1	1020507	20407	2	[illegible]	20	3	16	[illegible]
	Mme. Lasonian Joseph (Hab.)	31		1	810	509	1	[illegible]	13	5	16	[illegible]
	Mme. Presoir Marc	32	Mme.Amanque (Hab.)	2	1020718	[illegible]	1		13	7	13	[illegible]
	Darchille Marc	21		1	7	20508	1	[illegible]	9	7	14	[illegible]

The fact that so many of the farmers exploiting the hillside slopes in this region are also the owners of the land used could explain why the ADS-II project has had such success in motivating farmers to create soil conservation structures and vegetative barriers on the eroding slopes.

4.2 Crop Cover

Crop cover was photographed and ground truth tested for both agricultural seasons of 1987. GIS maps were prepared from information in the Lotus database to study the spatial relationships and areas covered by different crops and crop associations during these seasons. The data clearly show shifts in cultivation systems. Certain crop associations are more common during the first season (Feb - July) than during the second season (August - January).

The GIS permitted us to aggregate our data in [illegible] we wished. In order to simplify interpretation of complex crop association patterns by season, major crops were looked at individually along with the crops with which each was associated. Cartographic products were created for corn, sorghum and sweet potatoes. The spatial location of particular crop or crop associatons was important because it assisted the researcher in understanding farmer reasons for allocating his household food crop requirements given his land resources. Sorghum predominates during the second season, while maize predominates during the first. Sweet potatoes appear important during both seasons, but the crops with which they are associated change. Table 1 below summarized the area and percentage of different associations found during these seasons.

TABLE I: Crop Cover, Morija Watershed

CROP/ASSOCIATION	HECTARES / % OF ALL CROPS FIRST SEASON		SECOND SEASON	
CORN,BEANS	4	8%	4	8%
CORN,BEAN,SWEET POTATOES	3	5%	5	8%
CORN,BEANS,SW.POTATOES,SORGHUM	0		11	19%
YAMS,BITTER MANIOC,PIDGEON PEA	0		1	1%
BITTER MANIOC,PIDGEON PEAS	3	6%	1	1%
SORGHUM (MONOCROP)	1	2%	1	2%
SWEET POTATOES (MONOCROP)	14	25%	0	
SWEET POTATOES,PIDGEON PEAS	1	1%	0	
BITTER MANIOC,PIDG.PEA,SORGHUM	0		2	4%
CORN,YAMS,BEANS,PIDGEON PEA	1	2%	0	
PIDGEON PEA,SORGHUM	0		4	7%
SORGHUM,SWEET POTATOES,BIT.MANIOC	0		5	9%
SWEET POTATOES,BITTER MANIOC	0		1	2%
SORGHUM, SWEET POTATOES	0		1	2%
MISC.(CABBAGE,IRISH POTATOES,ETC.)	1	1%	1	2%
FALLOW LAND	17	30%	9	17%
HOUSEHOLD RESIDENCES				
GRAVES	1	1%	1	1%
HOUSEHOLD PLANTATIONS	10	19%	9	17%
Total:	56	100%	56	100%

5.0 Conclusion

The study described above has not yet been completed. The GIS staff is currently rectifying the field maps to evaluate the difference between unrectified area data and rectified data. This will permit us to assess the potential of aerial photography combined with a GIS to estimate crop area and production potential.

Yield studies are also being carried out in the Morija watershed, using selected fields based on their position in the system (hill tops, slopes, valley bottoms, or immediately above or below rock terraces). Digitization of the rock terraces actually constructed also permits us to estimate the # of meters of physical structures actually in place. Monitoring can then in the future determine continuation of the extension of this technique in the region as well as monitor the growth of the trees and vegetative barriers placed behind these rock terraces. These are yet too young to appear on the photography.

With a base map of the sub-watersheds, we will be able to monitor the placement by farmers of the on-farm cropping trials and evaluate the spread of crop innovations farmers have adopted. The project is extending a black bean variety in the area, which traditionally has planted a red bean variety. With the GIS, it will now be possible to follow farmer use of the

black bean variety. It already appears that adopting farmers are placing this crop (usually in an association with corn or sorghum) in those areas of poorest soil fertility and steep slopes. When asked about this, farmers indicated that the variety performed better than their own under conditions of limited moisture and fertility.

It is our belief that using a GIS system as described briefly here, combined with a data base, national and regional level planners and researchers in Haiti's Ministry of Agriculture will be in a better position to more effectively design and implement, as well as monitor future development programs. Other agencies involved with regional/national activities such as public health, education, road construction and upkeep, etc. should also be able to benefit through establishing similar systems in their central planning offices.