Application of GIS: A Case Study of the Cimanuk Watershed, West Java, Indonesia

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INTRODUCTION

The purpose of this paper is to provide a simple example of how GIS technology can be applied. The paper will identify the kinds of data input into a GIS and how this data was used to create useful interpretive maps.

A GIS project using data from a soil map of the Cimanuk watershed located in West Java, Indonesia (Click for map), was completed in Sept. 1992. The objectives of the project were to evaluate the spatial distribution of constraints to sustainable agriculture, to match soil conditions to crop performance and thereby recommend areas for crops, and to assess land use for the area to aid in land use policy decisions.

The watershed covers approximately 425,000 ha and has a tropical climate. The original survey was done in 1976 by the Food and Agriculture Organization of the United Nations and the Soil Research Institute of Bogor, Indonesia. The soil map was digitized at 1:100,000 scale and there are a total of 622 polygons with 158 different map units.

The following data was provided for each map unit: USDA Soil Taxonomy classification to the subgroup level, slope, depth, texture, coarse fragments, drainage, base saturation, cation exchange capacity, available P, exchangeable K, and pH.

METHODS

The maps were digitized using Geographic Resource Analysis Support System (GRASS) version 4.0 GIS software on the UNIX operating system. Click Appendix A to see some sources where more information on GRASS software can be obtained. The tabular attribute data was entered on a relational database system called INFORMIX and database queries were made using Standard Query Language (SQL) in INFORMIX.

PROCEDURES

First, the soil boundaries were digitized, and afterwards the digitized map was edited. Each polygon was then labeled with a map unit number from the original maps which relates it to the attribute data listed in a table. The tabular attribute data was later entered, using a code, into an INFORMIX database. Coding of the attributes is used to make queries to the data base, using SQL, easier to perform and also conserves computer storage space. Table 1 lists the codes used with the corresponding attributes (see Table 1). The data base contains a record for each of the 158 map units, and each record has a coded value for each of the different attributes.

The first map that was created was a map showing the USDA Soil Taxonomy classification at the order level. Maps showing some important soil properties were then created. Some of the soil property maps include: slope, depth, texture, drainage, pH, and available phosphorus.

INTERPRETATIONS

It is useful to identify areas where there may be biophysical constraints to implement sustainable agriculture. Based on some of the soil properties in the data base, a biophysical constraints map was developed.

Four biophysical constraint classes were defined: unsustainable, moderate, and few. A map unit was classified as unsustainable if: the slope was steep or very steep, or the depth was shallow, or the coarse fragment was skeletal, or the pH was very acid or very alkaline (see Table 2). The resulting map is a good example of how the attributes of different soil properties can be used to create an interpretive map.

In addition to maps, a report was output that lists the total area of each of the soil orders in the watershed and is shown in Table 3. Within each order the total area for each class of the biophysical constraints map is also reported.

Maps were then developed showing potentials for growing particular crops. Crop potentials were identified using three classes: high, medium, and low. The two most important soil properties that influence each crop were identified (see Table 4) and were used to create the crop potential classes shown in Table 5.

Maps were produced identifying potentials for traditional crops and include: paddy rice, upland rice, coconut, bananas and papaya. Maps identifying potentials for nontraditional crops were also made and include: cocoa, rosella, jute, oilpalm, and rubber. One reason for identifying potentials for these nontraditional crops is that they could possibly provide added economic stability to the area while maintaining the sustainability of the land.

CONCLUDING REMARKS

It is important to note that at a scale of 1:100,000 the resulting maps should only be used for making a general assessment. Site specific interpretations; i.e., for a small farm, are not appropriate using this data. Only with more detailed site information can a reasonable assessment be made for a specific location.

For this example, the interpretations are theoretical in nature and are based only on the data that was available. Validation of methods used in making these interpretations was not performed. Future study of this area to gather more data is necessary for a more comprehensive assessment. Crop selection and land use options are largely determined by the prevailing socioeconomic conditions occurring at a locality. Therefore, demographic data is crucial in forming a valid assessment of land use options and crop potentials.

Table 1. Tabular data base codes and attributes:

Map Unit

Numbered 1 to 158

Soil

Four letter code used in the Keys to Soil Taxonomy 1990 and Proposed ICOMAQ Keys 1991

Slope

L	=	0-5%	level
ML	=	0-15%	moderately level
GSL	=	5-15%	gently sloping
MSL	=	15-35%	moderately sloping
ST	=	35-50%	steep
VST	=	>50%	very steep

Depth

S	=	0-50cm	shallow
D	=	>50cm	deep

Texture

S	=	Sand
LS	=	Loamy Sand
L	=	Loam
SI	=	Silt
SL	=	Sandy Loam
CL	=	Clay Loam
SICL	=	Silty Clay Loam
SIL	=	Silt Loam
SCL	=	Sandy Clay Loam
C	=	Clay
SIC	=	Silty Clay
SC	=	Sandy Clay

Coarse Fragments

S	=	Skeletal
G	=	Gravelly
N	=	No fragments

Drainage

E	=	Excessive
WE	=	Well to Excessive
W	=	Well
MW	=	Moderately Well
SP	=	Somewhat Poor
P	=	Poor
VP	=	Very Poor

(Click to Continue)

Table 1. Continued:

Base Saturation

L	=	<35%,	low
M	=	36-75%	medium
H	=	>75%	high
ND	=	no data	

CEC (me / 100 gram soil)

L	=	<=10	low
M	=	11-20	medium
H	=	>20	high
ND	=	no data	

Available P (ppm)

VL	=	<10	very low
L	=	10-20	low
ML	=	20-40	moderately low
M	=	40-60	medium
M H	=	60-80	moderately high
H	=	80-120	high
V H	=	>120	very high
ND	=	no data	

Exchangeable K (me / 100 gram soil)

VL	=	<0.2	very low
L	=	0.2-0.3	low
M	=	0.4-0.5	medium
H	=	0.6-1.0	high
VH	=	>1.0	very high
ND	=	no data	

pH H2O (1:2.5)

VAC	=	<4.2	very acid
AC	=	4.3-5.2	acid
SAC	=	5.3-6.2	slightly acid
N	=	6.3-7.2	neutral
SA K	=	7.3-8.2	slightly alkaline
AK	=	8.3-8.7	alkaline
VA K	=	>8.7	very alkaline
ND	=	no data	

Note: Data base query Example:

Select map unit if slope = "L" or "GSL" and pH = "SAC" or "N". This query would output all map units that have a slope which is either level or gently sloping and a pH of slightly acid or neutral.

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Table 2. Biophysical Constraints to Implement Sustainable Agriculture: Attributes for each class.

Unsustainable:

- slope = ST, VST
- depth = S
- coarse fragments = S
- pH = VAC, VAK

Moderate:

- slope = GSL, MSL
- texture = C, S, LS
- coarse fragments = G
- drainage = E, P, VP
- base saturation = L
- cec = L
- available phosphorus = L, VL
- exchangeable potassium = L, VL
- pH = AC, SAK, AK

Few:

- slope = ML
- texture = SL
- drainage = WE, SP
- base saturation = M
- cec = M
- available phosphorus = ML
- pH = SAC

Very few:

- slope = L
- depth = D
- texture = L, SI, CL, SICL, SIL, SCL, SIC, SC
- coarse fragments = N
- drainage = W, MW
- base saturation = H
- cec = H
- available phosphorus = M, MH, H, VH
- exchangeable potassium = M, H, VH
- pH = N

Note: Beginning with Unsustainable, any category chosen in one class is excluded from all others. The Very few class has no categories because all were found in the first three classes. See Table 1 for a description of the attribute codes.

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Table 3. Raster Map Category Report

Order/Constraint Class	Hectares	%Cover
Alfisols	84200	20
Unsustainable	20700	25
Moderate	63500	75
Andisols	75200	18
Unsustainable	48700	65
Moderate	26500	35
Entisols	26200	6
Unsustainable	1000	4
Moderate	20000	76
Few	5200	20
Inceptisols	110100	27
Unsustainable	23700	22
Moderate	84100	76
Few	2300	2
Mollisols	5600	1
Moderate	5600	100
Ultisols	98600	24
Unsustainable	37600	38
Moderate	61000	62
Vertisols	10700	3
Moderate	10700	100
Water	500	<1
Water	500	100
TOTAL	411100	100

This table is based on a report output directly from GRASS GIS using a simple report generation command. The area occupied by each soil order is identified along with the area of each constraint class found within each order.

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Table 4. Selected crop requirements.

Rice (Oryza sativa)
optimum pH 5.5 - 6.5 dry
7.0 - 7.2 flooded
Alluvial soils of river valleys and deltas are usually better suited to rice than lighter soils. Level slope is best.

Bananas (Musa spp)
optimum pH 6.5 range 5.5 - 7.5
Thrive best on free-draining loam, will not tolerate any waterlogging.

Cocoa (Theobroma cacao)
optimum pH 6.5 range 5.5 - 7.5
Ideal soil consists of aggregated sand, silt and clay.

Coconut (Cocos nucifera)
Need freely draining light soils, and tolerate higher degree of soil salinity than most other crops.

Oil Palm (Elaeis guineensis)
Requires deep, permeable soils, terrain should have slopes < 8 to 10 degrees unless terracing already exists. Waterlogging is harmful.

Rubber (Hevea brasiliensis)
optimum pH 4.4 - 5.2
Needs deep, well drained soils.

Jute (Corchorus spp.)
Prefers fertile alluvial soils, in lowlands and is usually grown in rotation with rice.

Rosella (Hibiscus sabdariffa)
Requires permeable soils with good structure and good water retaining capability.

References:

Compendium for agricultural development in the tropics and subtropics. 1981. The Netherlands Ministry of Agriculture and Fisheries, The Hague.

Landon, J.R. ed. 1984. Booker tropical soil manual. New York. 450 p.

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Table 5. Crop Potentials: Attributes for select crops.

			POTENTIALS	
CROP	ATTRIBUTE	LOW	MEDIUM	HIGH
Rice:		*	*	
(paddy)	Slope	MSL	ML, GSL	L
	pH	AK, VAK	SAK, VAC	N, AC, SAC
Rice:		*	*	
(upland)Slope		ML	GSL	MSL
	pH	AK, VAK	SAK, VAC	N, AC, SAC
Banana:				
	Slope	L	MSL	GSL
	pH	VAC, AK, VAK	AC, SAK	SAC, N
Papaya:				
	Slope	L	MSL	GSL
	pH	VAC, AK, VAK	AC, SAK	SAC, N
Cocoa:				
	Slope	L	GSL	MSL
	Drainage	SP, P, VP	E, MW	WE, W
Coconut:				
	Slope	ML, MSL	GSL	L
	Texture	Sandy	Clayey	Loamy
Oil Palm:				
	Drainage	E, P, VP	WE, SP	W, MW
	pH	VAC, SAK, AK, VAK	AC, N	SAC
Rubber:				*
	Drainage	MW, SP, P, VP	W	E, WE
	pH	N, SAK, AK, VAK	VAC, SAC	AC
Jute:			*	
	Drainage	MW, SP, P, VP	E	WE, W
	Slope	MSL	ML, GSL	L
Rosella:		*		*
	Drainage	MW	WE, W	E
	Texture	Sandy	Clayey	Loamy

* - No categories were found meeting these attributes.

Note: Categories with a slope >35% were not included.
See Table 1 for a description of the attribute codes.

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Reference:

Detailed Reconnaissance Land Resources Survey of the Cimanuk Watershed Area (West Java). Soil Map 1:100,000. 1976. Ministry of Agriculture, Agency for Agricultural Research and Development, Food and Agriculture Organization of the United Nations. Soil Research Institute, Bogor, Indonesia.

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Appendix A. Sources of Information on GRASS GIS.

GRASS:

The Open GRASS Foundation
Boston University
Remote Sensing Center
725 Commonwealth Ave.
Boston, MA 02215, USA.

GRASS at NRCS:

Director, Resources Inventory and
Geographic Information Systems Division
USDA-NRCS
P.O. Box 2890
Washington, D.C. 20013, USA

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