Methodology for Identifying Parts of Irrigation Systems Suitable for Crop Diversification During the Dry Season

D. Cablayan and C. Pascual [1]

Abstract

The study aimed to develop a computerized methodology to identify areas suitable for irrigated diversified crops under the service area of an irrigation system and list computer software package with the same capability. The study used techniques developed for Geographical Information Systems (GIS) which is concerned with the digital capture of spatially related data (maps).

The software listed was the Map Analysis Package (MAP). It was used to analyze data from the Laoag Vintar River Irrigation System. The result obtained using maps was very gross because MAP was designed to analyze large areas requiring less precision.

The developed methodology was named Camputer Aided Mapping Program (CAMP). It was used to analyze data from the Allah River Irrigation Project. It was found that CAMP was more accurate than MAP. CAMP's output map was also clearer because it had the ability to super-impose live maps with thematic maps for easier identification of areas while MAP's output was only thematic maps.

Introduction

Most irrigation systems in the Philippines and in Southeast Asia are run-of-the-river type. Such systems consist of dams to raise water elevation in rivers or creeks for diversion to the canal networks. These systems were mostly designed to irrigate lowland rice. During the wet season these irrigation systems have reliable water supply to serve the entire service area for lowland rice planting. During the dry season, water is limited and only a part of the system, mostly planted to lowland rice, is served. Production of upland crops, which uses less water than lowland rice, could increase the irrigated area during the dry season. This strategy has been adopted by a few systems in the Philippines.

Recently plans to include irrigation of diversified crops was considered in the construction of irrigation systems. A methodology to identify areas suitable to upland crops under the service area of an irrigation system is needed. The methodology would be useful for irrigation planners in designing the irrigation network in areas suitable for diversified crops. It will also aid irrigation managers in the development of their seasonal irrigation plans and to identify suitable areas for diversified cropping. The computer-based methodology will provide for the efficient storage, retrieval, and analysis of data.

Identifying potential areas using computers for diversified cropping is a relatively new field in irrigation systems management. Gines and Kaida (1982) have developed a methodology which is macro in scope for classifying land suitability in relation to its potential for multiple cropping system in some areas in Central Luzon.

Objectives

The study aimed to develop a methodoldgy to analyze the service area of irrigation systems so as to determine the suitability of different areas for diversified crops during the dry season. The methodology used a microcomputer software to store, analyze and output spatial data (maps). The study also compared an existing microcomputer software with the developed software for mapping.

Methodology

The study used maps on soil types, land use, topography, and other spatial and physical data

[1] Respectively, Research Associate, International Irrigation Management Institute, and Assistant Professor and Chairman. Department of Agricultural Engineering, College of Agriculture, Mariano Marcos State University, Batac, Ilocos Norte.

which determine the suitability of areas for upland crops. The output were also maps showing the suitability ofdifferent areas in the irrigation system for diversified crops during the dry season. Computer softwares designed to handle spatial data (maps) are called Geographical Information Systems (GIS) which is concerned with the digital capture of spatially related data and their linkage relative to one another (Tomlin, 1980). Specifically, GIS deals with query, analysis, reporting and output of these data (Archibald, 1986). A **GIS** is a set ofcomputerprograms whichprovidesencoding, storage, analysis and output of spatially related information (Figure 1).

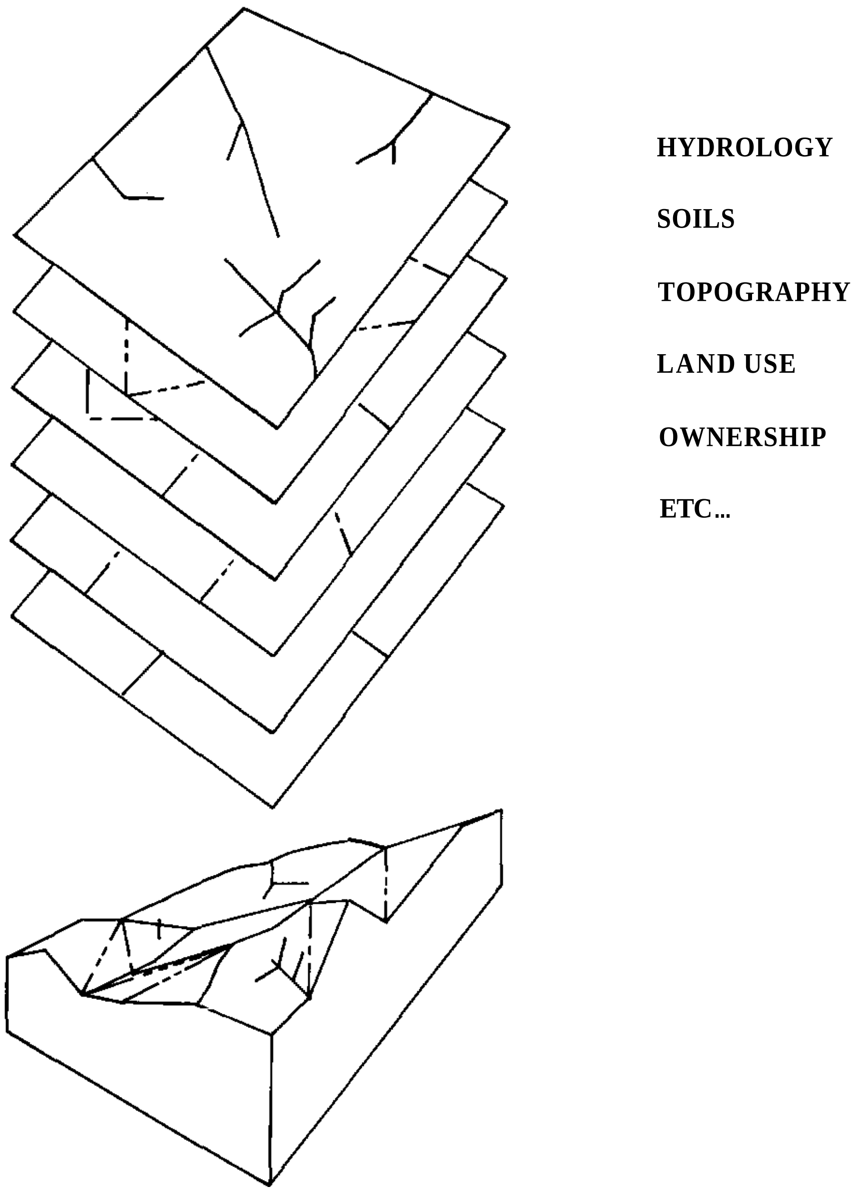


Figure *1.* Conceptual Framework of a GIS

There are two kinds of maps in GIS, graphic or line and thematic maps. A graphic map consists of lines representing roads, rivers, creeks, soil type boundaries, contours, ownership boundaries, etc. A thematic map is a color-coded map wherein the different areas show themes or colors representing area classifications. An example of a thematic map is a soil map wherein the areas representing different soil types appear in different colors or themes.

The input into a GIS are line maps. The first process in a GIS is to reduce these lines into digital units for the computer. This process is called *digitization*. The lines are reduced into point coordinates that determine the line (Figure 2). The first step in digitization is to assign a point in the map as the origin with 0,0 X,Y coordinates. All other points in the map should have positive coordinates. The point coordinates that determine lines in the map are the data input required by a GIS tocapture the map in a digital format. Figure3 shows an output map showing the ***digitized*** Line boundaries of soil types in the Allah River Irrigation Project.

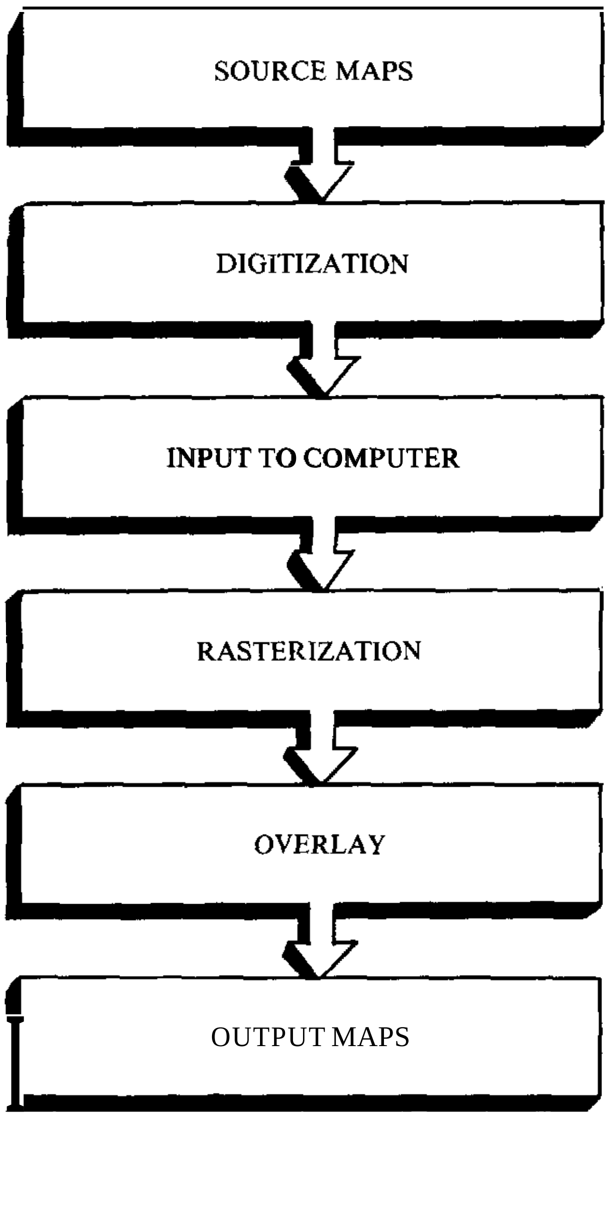


Figure 2. The GIS Flow Chart.

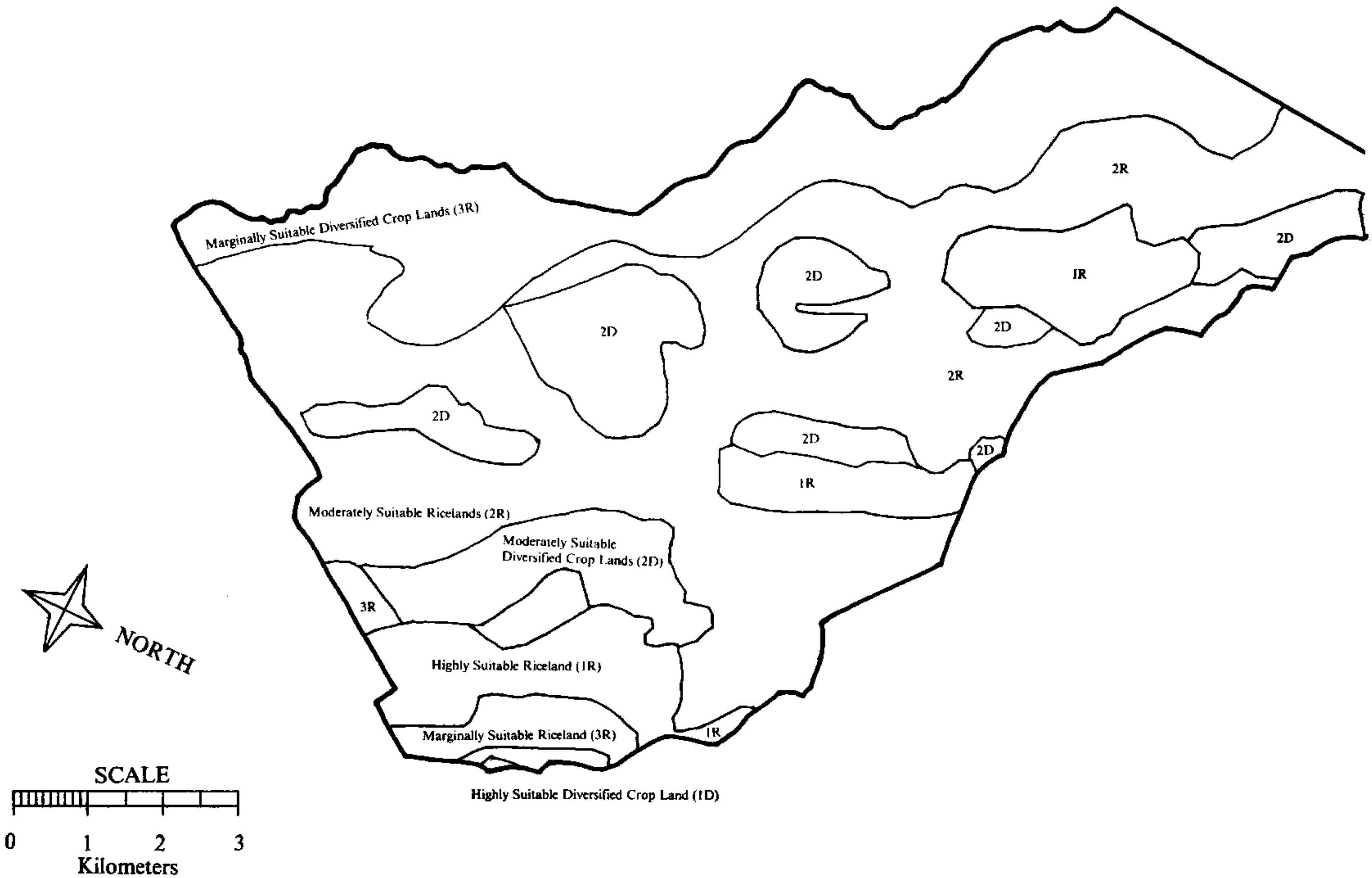


Figure 5. Digitized Line Boundaries for Land Class, Allah River Irrigation System, South Cotabato, Philippines.

The next process is called ***rasterization*** which is concerned with defining polygons bounded by lines in the map. The different polygons produced by this process are then assigned themes to produce thematic maps. In data output, different themes are assigned different colors or print styles. Figure 8 shows the result of rasterization of the lines shown in Figure 3.

The map analysis process is called ***overlay*** which is explained as follows: if we have a soil type thematic map with themes A, B and C, with theme A classified as best suited for diversified crops, and if we have a topographical thematic map with themes D, E and F, with theme D as best suited for diversified crops, overlay would produce the areas both with soil type theme A and topography theme D which identify areas best suited for diversified crops.

The Map Analysis Program (MAP). The GIS software tested for this study was the Map Analysis Package (MAP) which was designed for micro-computers. The microcomputer should have a fixed disk, a math coprocessor and an active memory of 640,000 bytes. Data inputed into the MAP were thematic maps. Maps stored in the computer were divided into grids. A theme (numerical data) was assigned to each grid cell based on the source map. The GIS flow chart for MAP is shown in Figure 4. Rasterization was manually done before data was keyed into the computer.

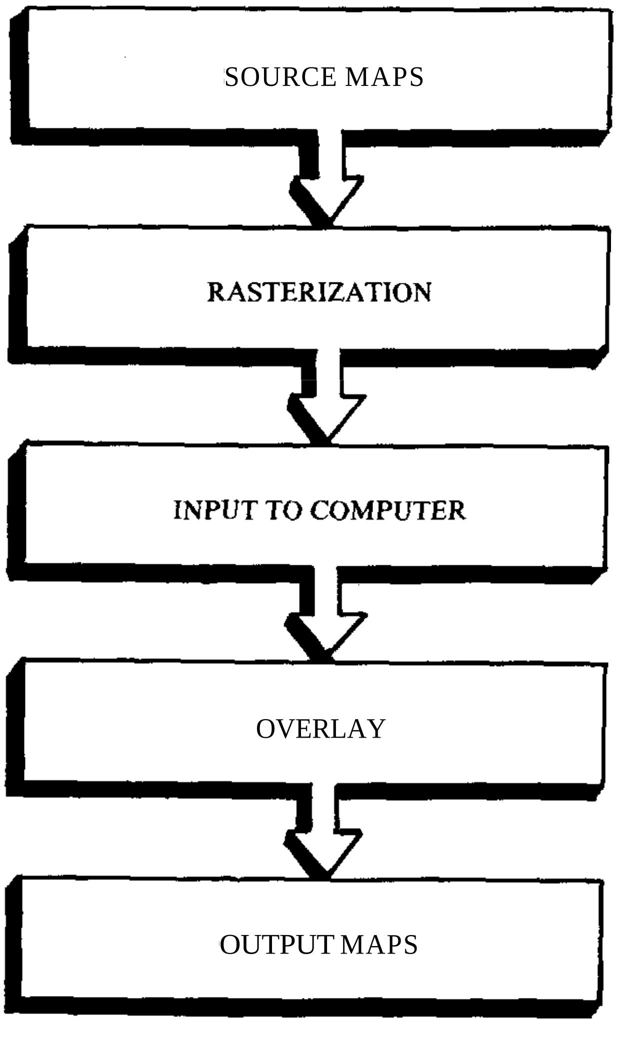


Figure 4. The GIS Flow Chart for MAP.

The processing capabilities of MAP are organized **as** a series of commands entered by the **user.** These commands resemble simple english phrases. The process involves information flow between the central processing unit of a computer, a digital storage device and input/output media. The input medium is the keyboard, the digital storage is the fixed disk, and the output medium is an ordinary line printer. The process is controlled by commands issued by the computer user. The MAP software is simple to use and assumes no prior computer programming experience of the user.

MAP was used to analyze the 2377-hectare service area of the Laoag Vintar River Irrigation System (LVRIS). Source maps used had scales of 1:100,000 and 1:50,000. These maps were enlarged to ascale of 1:40,000 which is the output map scale. Source maps were on soil type, land use, irrigability or accessibility to water source, settlements, roads, water adequacy and topography, and maps showing the location of rivers, creeks, canals, roads and residential areas. The resulting grid cell size was 125×125 meter. The area was covered **by** 75×60 grid cells. In each thematic map, each theme was assigned a number, which was encoded into the map cells whichcorrespond to the different themes. The different thematic maps were overlayed to produce interaction of spatial attributes.

Computer Aided Mapping Program ***(CAMP).*** CAMP was developed and written using BASIC language. CAMP is a menu driven package. **To** key-in a map into the computer, map lines are first digitized; any scaled map can serve as a source map. The source map is divided into grids of 1.0 mm width. This **is** easily done by redrawing the source map on an appropriate sized cross section paper. The left bottom-most point of the source map is assigned **as** the origin. The point coordinates of lines on the map can be determined based on this origin. The resolution (lowest measurable distance) on the output graphic maps (line maps), by the computer is 0.1 mm. On the thematic maps the resolution is **1.0** mm.

The output map has a maximum dimension of 34 cm×25 cm. This explains the difference in resolution between the graphic and thematic maps. Using the same resolution would result into **8,500,000** grid cells which entails a lengthy analysis and a large computer memory. Microcomputers used for this program were limited in speed and memory space.

The output scale can be determined based on source maps. This scale is keyed into the computer together with the scales of different source maps. The user can then input actual point coordinates based on the source map. The computer reduces these coordinates to correspond to the output scale.

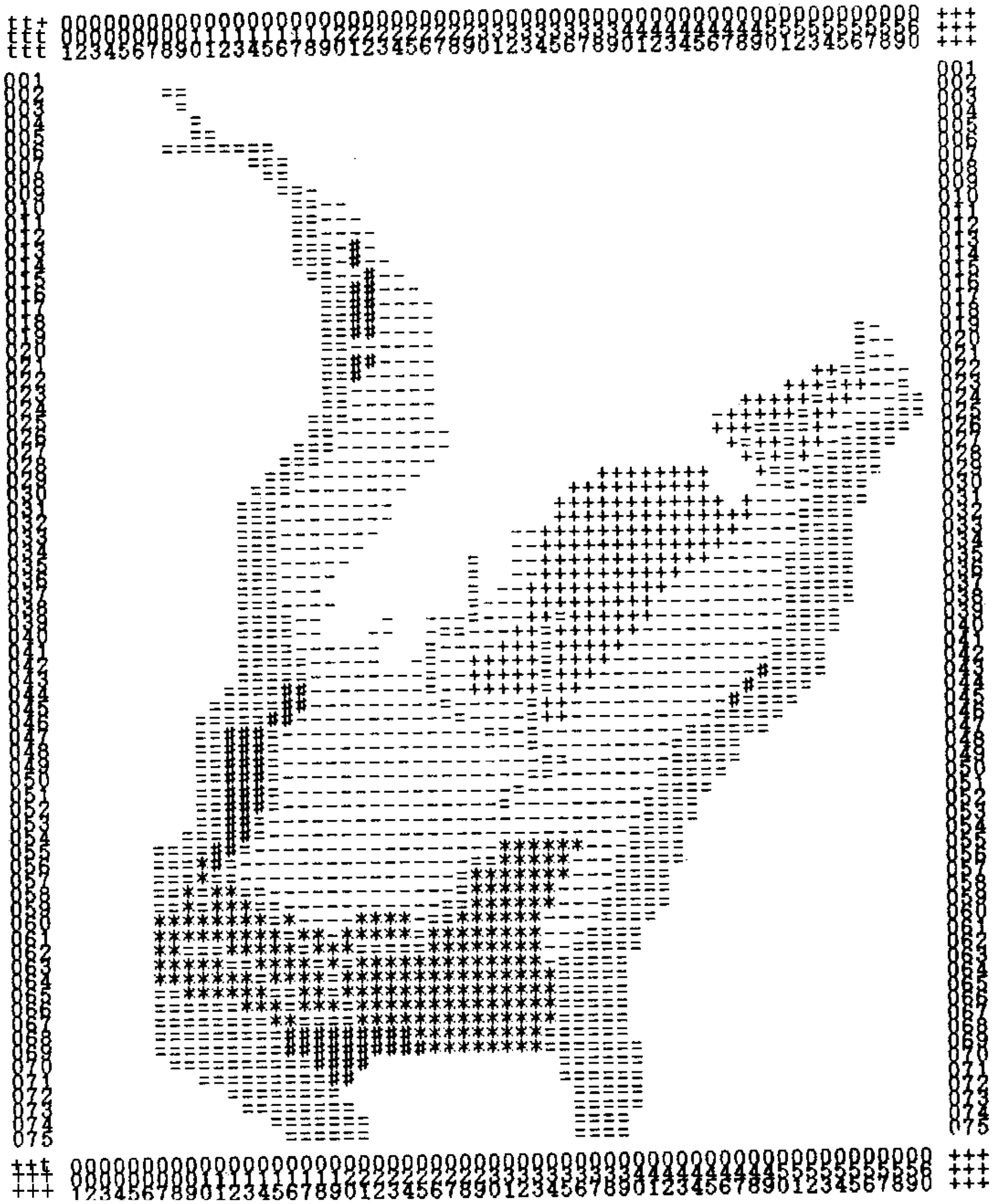
The input medium is the keyboard. The output medium is a Roland DG **DXY** 880A Plotter which is equivalent to the Hewlett Packard series 3000 Plotter. The microcomputer should be an IBM PC-AT or an equivalent.

After line maps have been keyed-in, the subprograms **for** analysis enable the user to convert the line maps into thematic maps (rasterization). The thematic maps are then overlayed to produce interactions of different map attributes.

CAMP was used to analyze the service area **of** the Allah River Irrigation Project (ARIP) served by Dam No. 1. The data available were maps showing the location of roads, canals, creeks, rivers; soil type map; soil series and general slope map; and pre-project land use map.

Results and Discussion

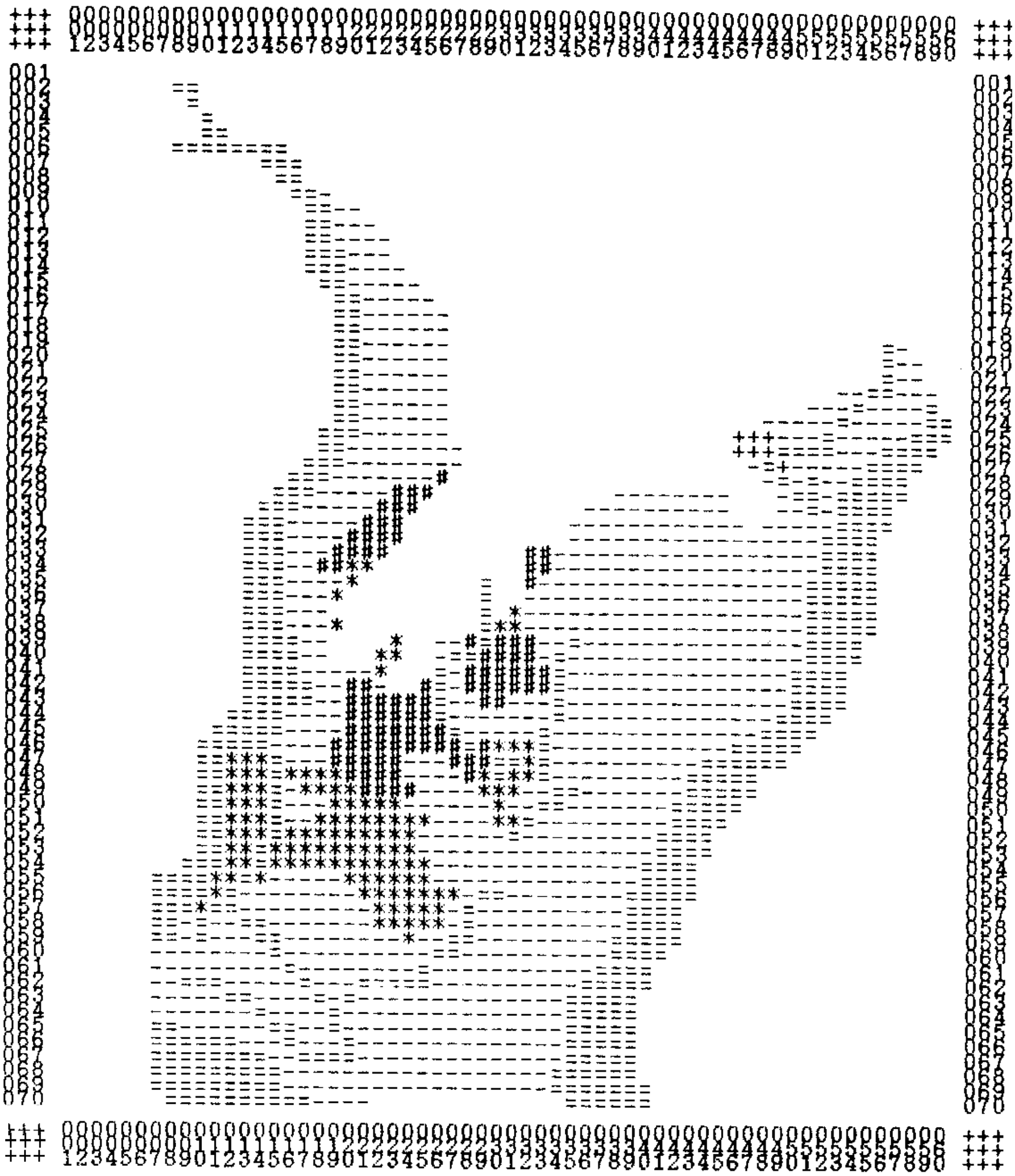
Suitability to irrigated diversified ***crops*** during ***the*** dry **season** *at* ***LVRIS*** using MAP. Soil was classified as heavy, medium and light textured. Heavy textured soil (clay to clay loam) covered 311 hectares while medium (loam to silt loam) and light textured (sandy loam) soil covered 1103 and 352 hectares, respectively (Figure ***5).*** Land **slope** was characterized as flat, gently sloping, undulating and steep. Flat lands covered 972 hectares, gently sloping 7 hectares, undulating 127 hectares and steep slopes **96** hectares (Figure 6). The land suitability map was obtained by overlaying topography with soil type (Figure **7).** Medium textured soils with slopes of 0-3% were considered **as** highly suitable and these covered 832 hectares. Heavy soil, relatively sloping (with slopes of 5-8%) were considered **as** moderately suitable and these covered 302 hectares. Light textured soil (sandy loam) with steep slopes were considered as marginally suitable and these covered 522 hectares. Built-up areas, flood areas and sand dunes were considered **as** unsuitable and these covered 270 hectares. This suitability map could be further enhanced with inclusion of drainage in the area.



SOILS

Symbol	Type/Description	Grid cell count	Area, ha
----	Rivers and creeks	581	
_	Heavy textured soils	199	311
++++	Medium textured soils	706	1103
*****	Light textured soils	225	352
#####	Flood areas and sand dunes	73	114
	Unclassified		497
	TOTAL SERVICE AREA		*2371*

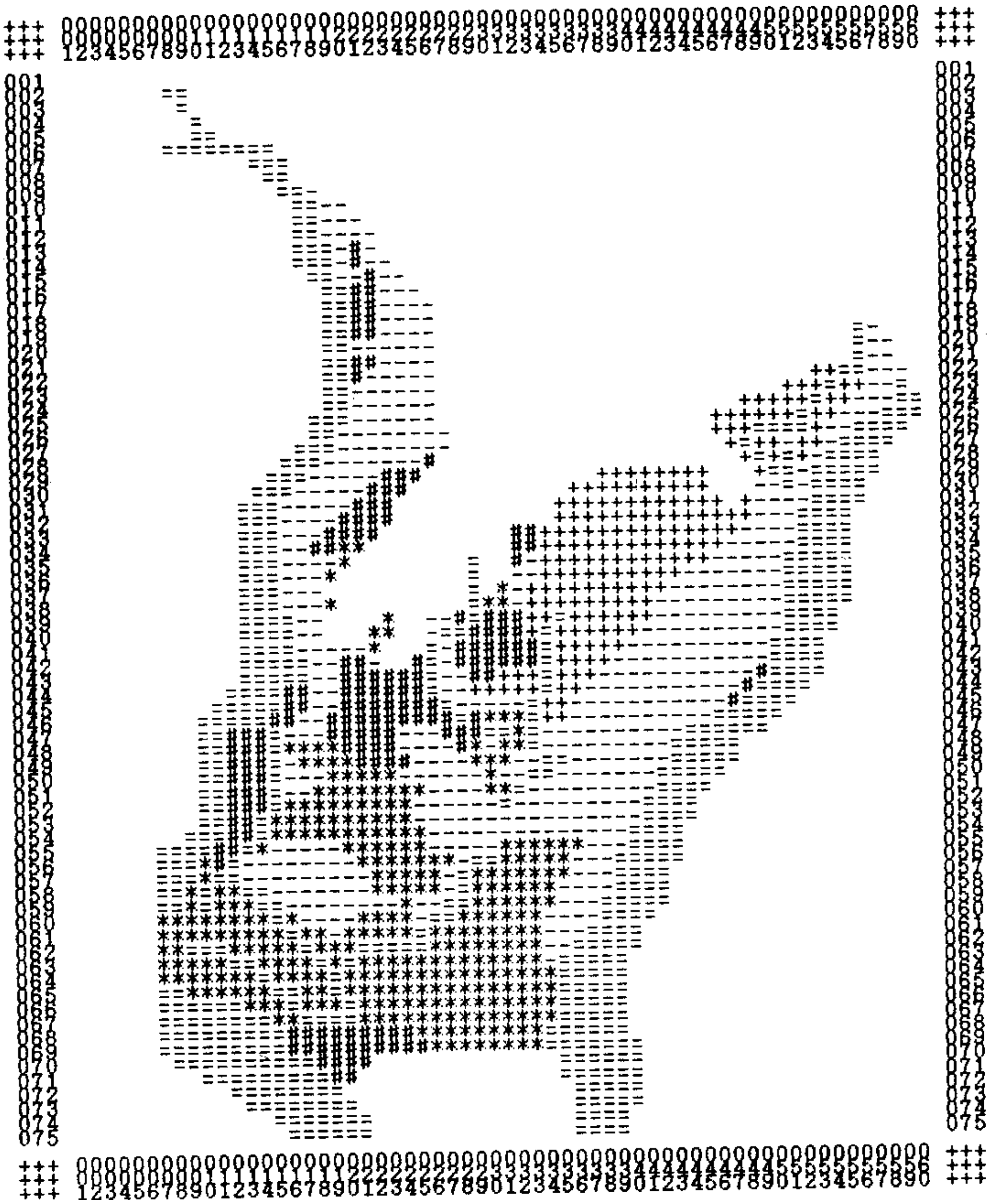
Figure 5. **Soil types, Laoag-Vintar River Irrigation System, Ilocos Norte, 1988.**



TOPOGRAPHY

Symbol	Type/ Description	Grid cell count	Area. ha
====	Rivers and creeks	582	
	Flat (0-3% slope)	972	1519
++++	Gently sloping (4% slope)	7	11
*****	Undulating (5-8% slope)	121	198
#####	Steep slopes	96	150
	Unclassified		519
	TOTAL SERVICE AREA		2311

Figure 6. **General land, slope, Laoag-Vintar River Irrigation System, Ilocos Norte, 1988.**



LAND SUITABILITY

Symbol	Type/Description	Grid cell count	Area. ha
———	Rivers and creeks	581	
———	Highly suitable	520	832
++++	Moderately suitable	189	302
******	Marginally suitable	326	522
######	Unsuitable	169	270
	Unclassified		451
	TOTAL SERVICE AREA		*2311*

Figure 7. Suitability of different areas to irrigated diversified crops during the dry season, based on topography and soil type, LVRIS, Ilocos Norte, 1988.

There was an attempt to overlay present land use with the produced suitability map. However, the land use map entered into the computer needed further verification. Water adequacy and accessibility thematic maps were also developed for overlay process to further refine the suitability map.

MAP can only handle maps with 100 by 100 grid cells. In the scale used for LVRIS, one grid cell was equivalent to **1.5** hectares. Errors in encoding were encountered when a grid cell was at the boundary of two themes: the user usually assigned the grid cell to a theme occupying a greater part of the cell. The calculated areas did not equal the computed areas if one used a planimeter. The output map was not readily understandable as it did not show line attributes and names. For the output to be useful, it should be redrawn with line attributes superimposed to actually identify the locations of different themes. Compared with other **GIS** softwares, MAP was found to have some limitations. MAP may be used for regional planning hut not for location-specific planning activities which require greater precision. However, anybody can use it even with minimal knowledge on microcomputers.

Using *CAMP to the ARIP Service Area*

Soil type. In ARIP Dam No. 1 area, there arc six soil types; three are diversified croplands (DCL) and three are ricelands (RL) (Table 1). DCL and RL were further classified as highly, moderately, and marginally suitable. Marginally suitable DCLs were found near the hanks–of the Allah River (Figure 9). They had very light textured soil (sandy loams) with slopes of 0-2%. With adequate irrigation, these can be highly suitable DCLs during the dry season and moderately suitable RLs during the wet season. Moderately suitable DCLs had sandy clay loam soil with slopes of 0-1%. With sufficient irrigation they can become highly suitable DCLs during the dry season and highly suitable RLs during the wet season. Highly suitable DCLs had clay loam soil with slopes of 0-1% and will have the same classification under irrigated condition.

Marginally suitable RLs had clay to clay loam soil and were either low lying flat lands located near drainage waterways or with very steep slopes which need to be levelled before they can he planted to lowland rice. Moderately suitable RLs had clay loam to sandy clay loam soil and were relatively flat lands with poor to good drainage and high water tables during the wet season. Highly suitable RLs had clay to clay loam soil with good drainage.

Table 1. Soil Types, ARIP dam #1 area, 1988.

Soil Type	Area (ha)
Ricelands (RL)	5,300
Highly suitable RL	1,080
Moderately suitable **RL**	**3,980**
Marginally suitable RL	**240**
Diversified croplands (DCL)	3,260
Highly suitable **DCL**	40
Moderately suitable DCL	**1,470**
Marginally suitable **DCL**	**1,750**
Total Service Area	8,560*

* Includes areas occupied by roads, irrigation canals and creeks.

Pre-project ***land use.*** The **ARIP** Dam No. 1 area had four general land use classes before the project. Residential areas comprised 100 hectares, coconut areas 140 hectares, corn areas **3,950** hectares and rice areas **4,370** hectares (Table **2** and Figure 10). Regardless of **soil** type, areas planted to corn and coconut were characterized **as** having good drainage while areas planted to rice had good to poor drainage.

Table 2. Pre-project land use, ARIP dam #1 area.

Land **Use**	Area (ha)
Residential areas	**100**
Coconut areas	**140**
Corn areas	3,950
Lowland rice areas	**4,370**
Total Service Area	**8,560***

* Includes areas occupied by roads, irrigation canals and creeks.

Suitability ***to*** irrigated *diversified* ***crops*** during the ***dry*** season. Corn and coconut areas regardless of **soil** type were classified **as** highly suitable for irrigated crop diversification during the dry season. Highly suitable ricelands had good drainage and were classified **as** moderately suitable. Marginally and moderately suitable ricelands had good to poor drainage and were classified **as** marginally suitable. Areas classified **as** diversified crop lands regardless of pre-project land **use** were also classi-

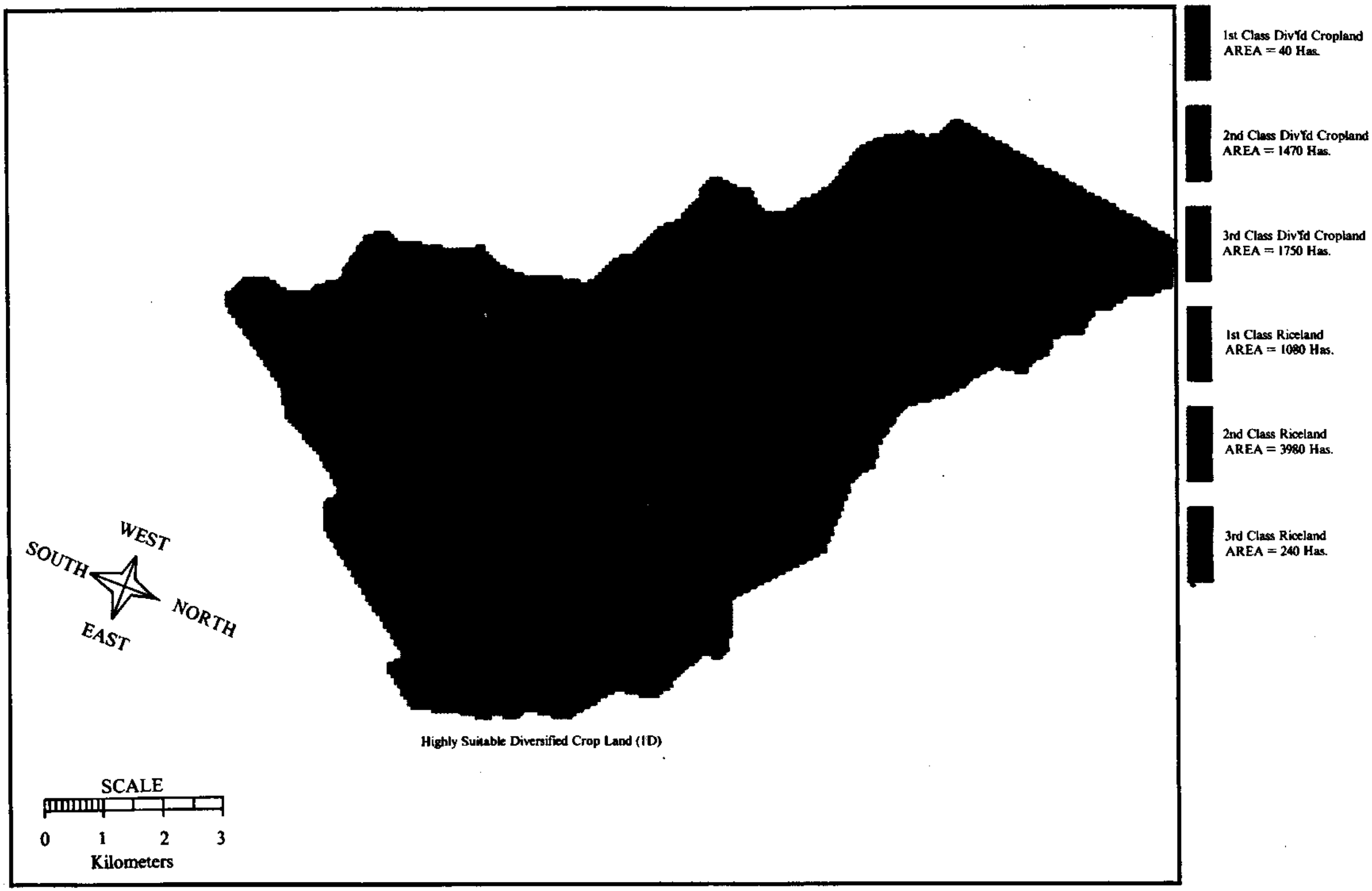


Figure 8. Thematic Map for Land Class Produced by Rasterization, Allah River System, South Cotabato.

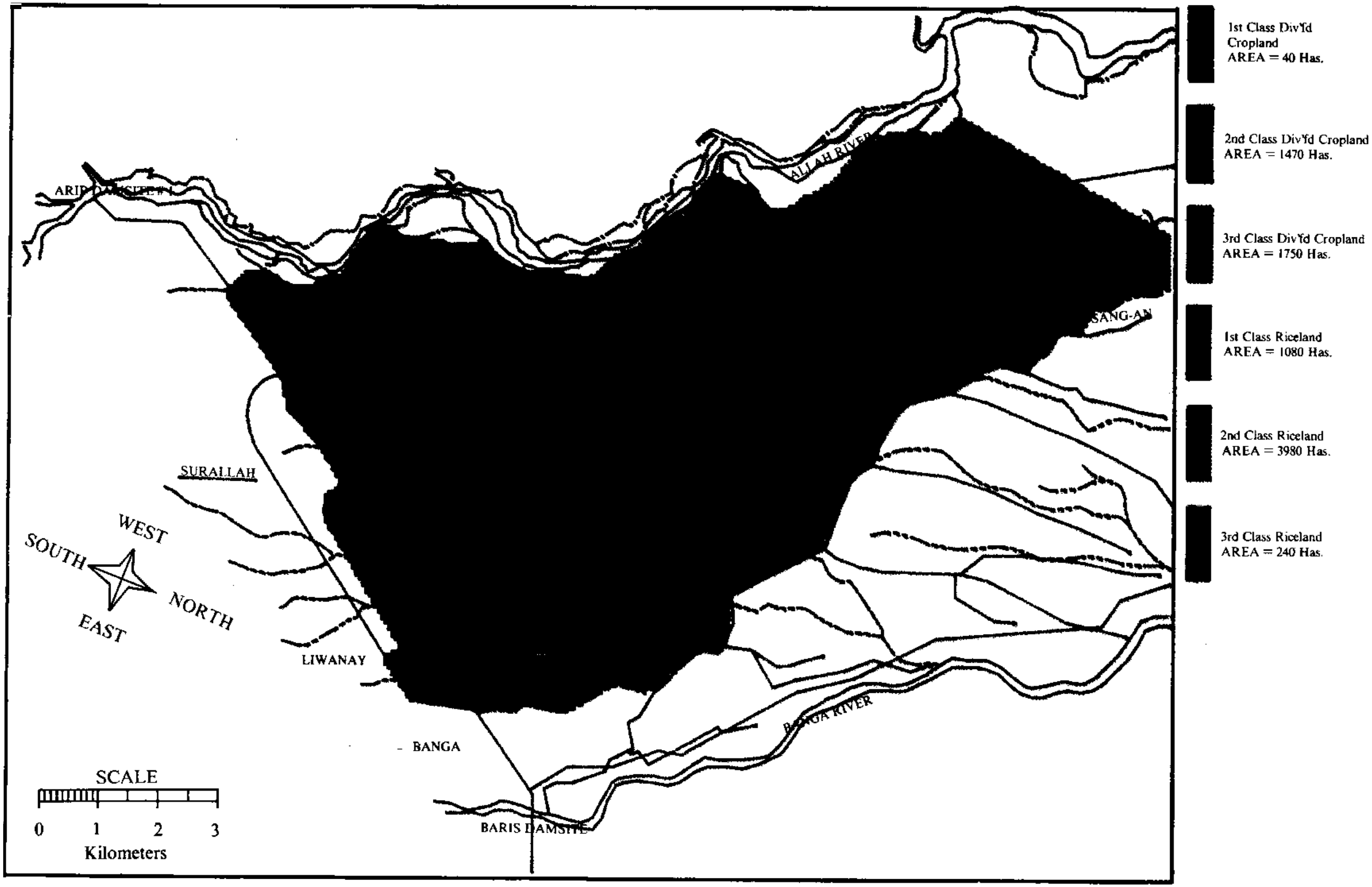


*Figure 9.*Soil Class Map, Allah River Irrigation Project, South Cotabato.

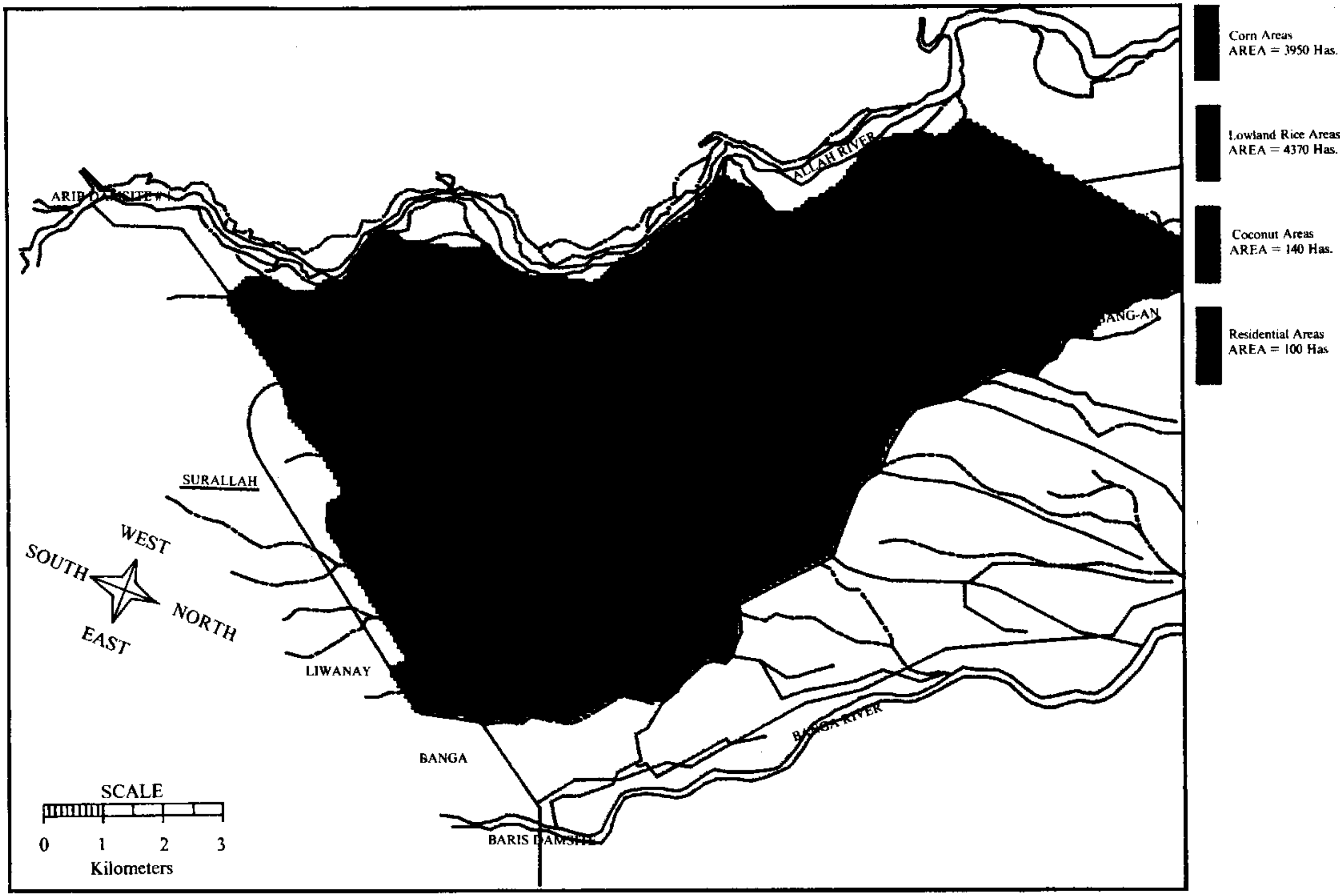


Figure 10. Pre-Project Land Use Map, Allah Irrigation Project, South Cotabato.

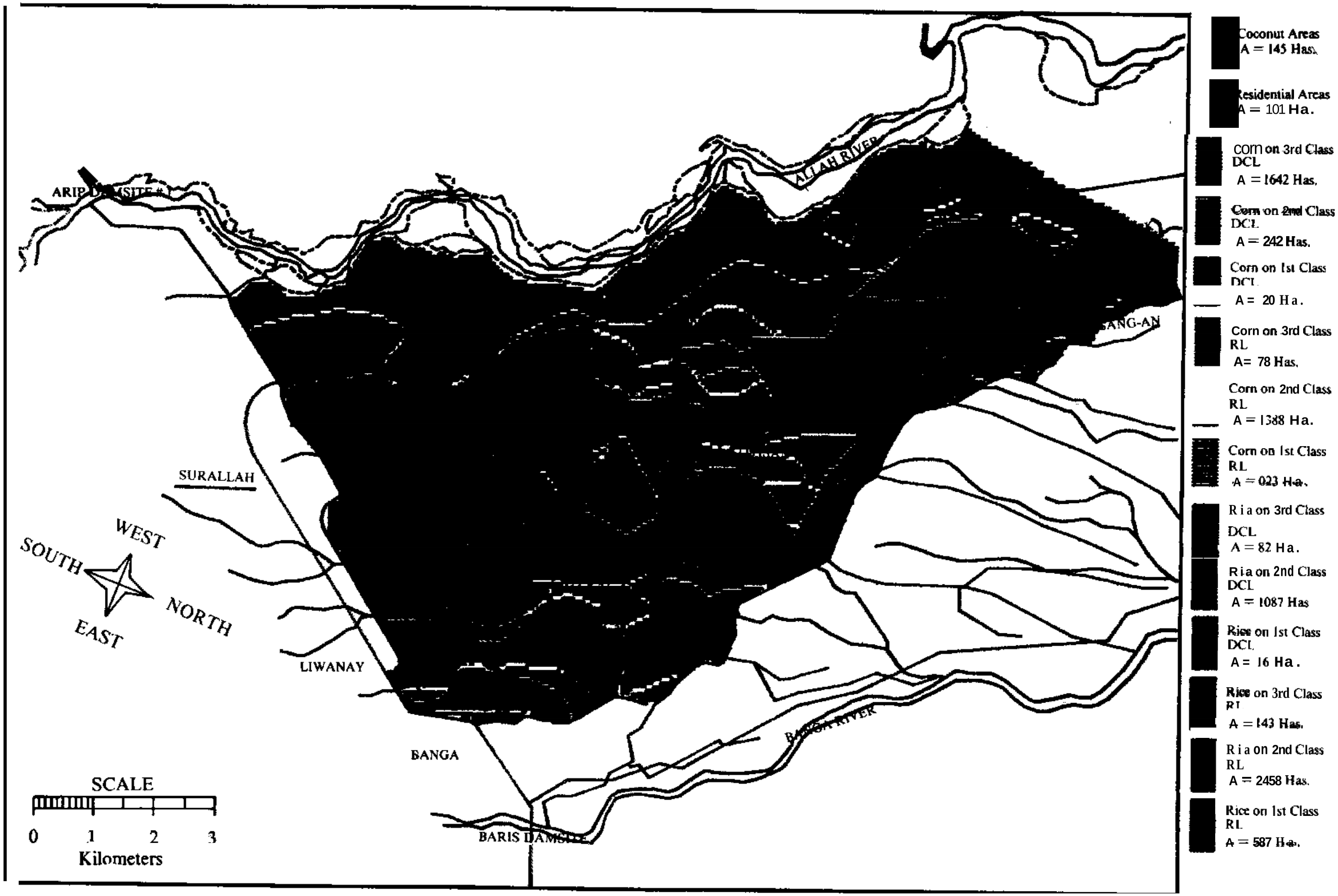


Figure 11. **Soil Class and Pre-project Land Use Overlay, Allah River Irrigation Project, South Cotabato.**

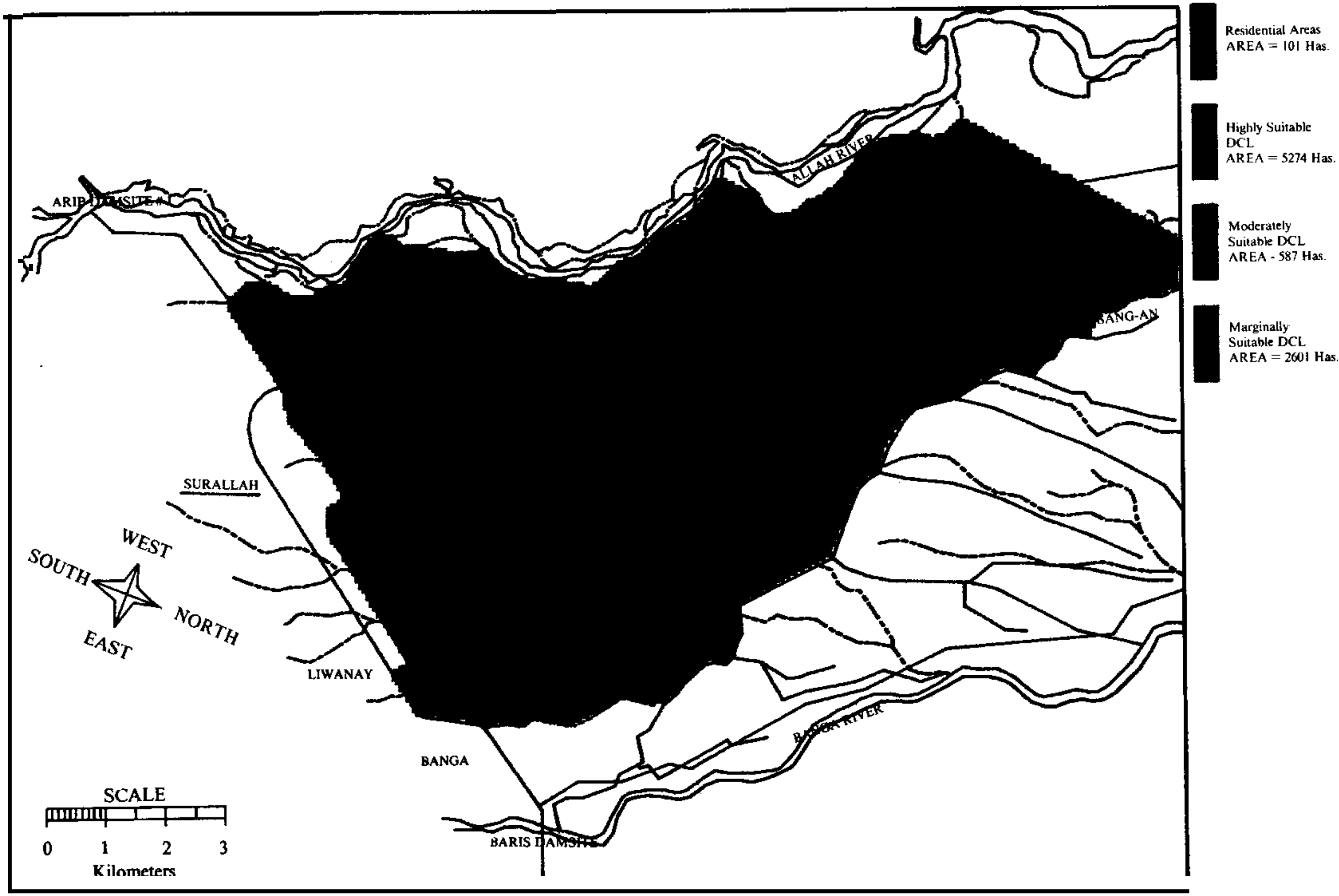


*Figure 12.*Suitability Map to Irrigated Diversified Crops During the Dry Season, Allah River Irrigation Project, South Cotabato.

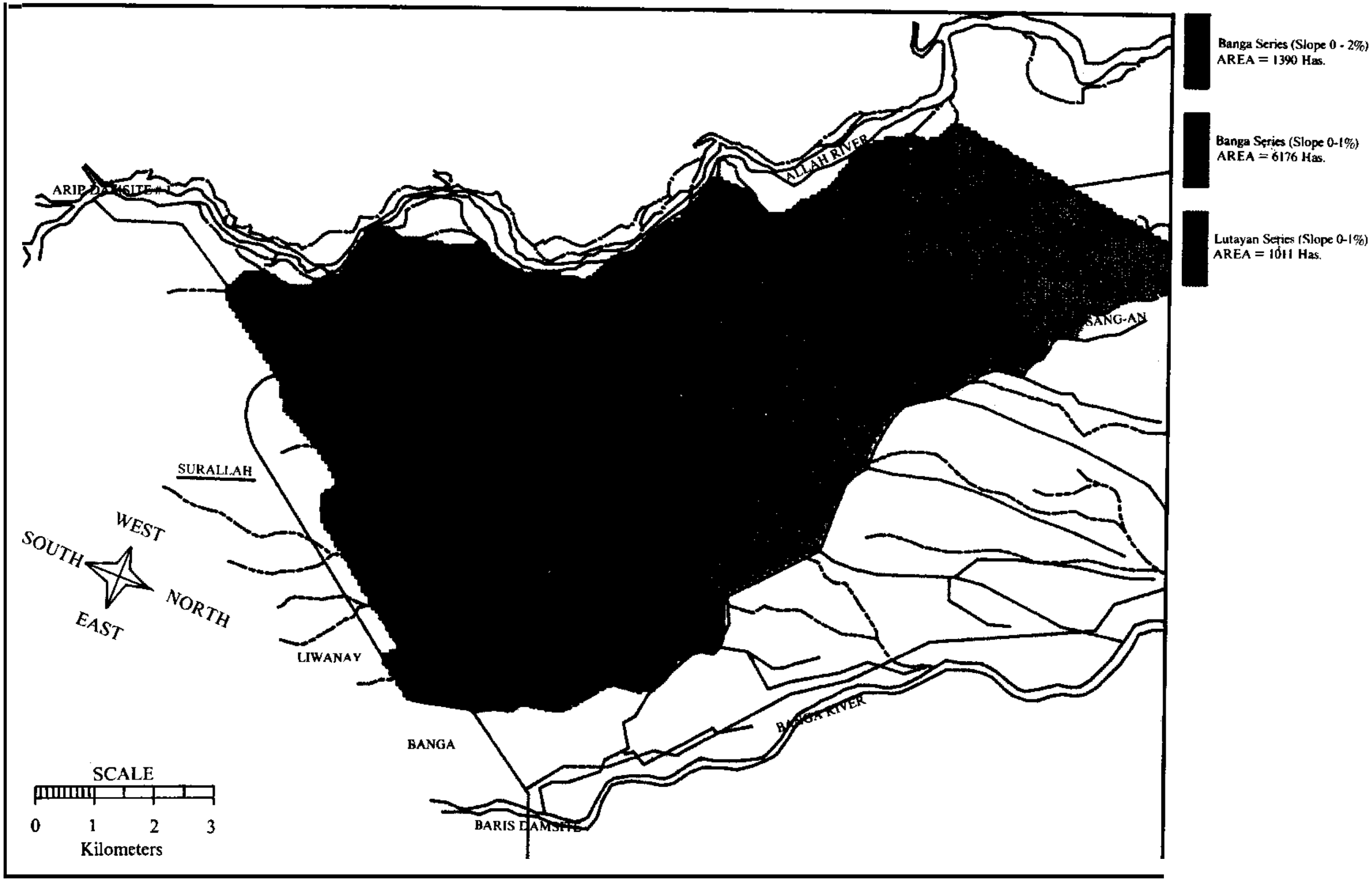


*Figure 13.*Soil Series and General Landslope Map, Allay River Irrigation Project, South Cotabato.

fied as highly suitable. The output map showing this suitability classification was obtained by overlaying the soil type thematic map to the pre-project land use thematic map (Figures 11 and 12). Classified areas which were highly suitable for irrigated crop diversification during the dry season covered 5,270 hectares. Areas with moderate and marginal suitabilities covered 590 and 2,600 hectares, respectively. Of the total service area of 8,560 hectares, 100 hectares were residential areas. However, the total service area includes roads, irrigation canals and creeks, thus the difference from the estimated service area of 7,300 hectares. For a more accurate classification, drainage characteristics should be well defined and used in the overlay process.

Soil** series **and general land slope. The map available for this purpose was very gross in terms of land slope classification (Figure 13). This was not used in overlay process as most of the areas classified with 0-2% slope were mostly classified as corn areas before the project.

CAMP was more accurate than MAP. For ARIP which was three times larger than LVRIS. CAMP had grid cell sizes of one-third hectare. With this accuracy, errors at boundaries of different themes were minimized. However, CAMP was not capable to display contour lines and conduct three dimensional analysis. It was not designed to produce raster maps using laser or ink-jet printers, which is a faster way to produce raster maps. Output of raster maps with CAMP is slow not because of computer speed but rather of plotter speed. CAMP also provides for viewing of maps on the computer visual display unit (VDU). Like MAP, anybody even with minimal knowledge on computers can use CAMP.

Conclusions and Recommendations

MAP, a GIS software was very gross and was not adoptable for accurate analysis of irrigation system. It was capable of identifying the position of areas suitable to diversified crops in a system but not to accurately represent the area. The developed software CAMP was more accurate. The output maps accurately identified the areas with different suitability to upland crops. CAMP can produce thematic maps overlayed with line features, like roads, canals and creeks for easier identification of canal networks serving the different areas. The CAMP output can be readily used by irrigation managers for planning.

To improve CAMP, a digitizer could be included with the hardware set-up. A program to use the digitizer as the input medium should then be developed. A digitizer is a computer peripheral consisting of a board and a digitizer pen or similar gadget. A map is attached to the digitizer board. A coordinate in the map is established for reference and entered into the computer. Lines are then traced using the digitizer pen. The digitizer pen relays the pen's position to the computer as the point coordinates of the line being defined. The digitizer simplifies the input process of maps to the computer. An ink-jet printer will facilitate printing of raster maps. Additional programs for contour line drawing and three-dimensional analysis should also be added to the CAMP software. Three-dimensional analysis is useful in identifying location of canals and other irrigation structures and computation of earthwork volumes for cost estimation.

References

Archibald, P.D. 1986. The Integration of Digital Image Analysis and Geographic Information Systems. A paper presented at the B.C. Remote Sensing Committee Workshop, Risks and Rewards, B.C. Research, Vancouver, B.C., 24-25 June 1986.

Gines, H.C. and Y. Kaida. 1982. Paddy land suitability classification in relation to its potential for multiple cropping systems. Southeast Asian Studies. 2(3).

Tomlin C. D. 1980. The Map Analysis Package Manual. Yale School of Forestry and Environmental Studies, Connecticut, USA.