GTZ-FINANCED MEASURE: GEOGRAPHICAL INFORMATION SYSTEMS IN AGRICULTURAL RESEARCH

PROCEEDINGS OF THE GIS AWARENESS WORKSHOP
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MELKASSA RESEARCH CENTER

Edited by Friew Kelemu

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Mr. Chairman,
Dear participants

The Soil Science Society of Ethiopia in collaboration with GTZ/ LUPO trained three researchers on GIS using MAPINFO and IDRISI for nine months and the trainees successfully completed the training, which has now started to bear fruit. During the training period the trainees generated documents, which can serve as training guidelines for future trainees. The documents included; guidelines for using IDRISI, MAPINFO software, Garmin GPS and a digitizing manual using ARCINFO. Besides the group generated useful information on suitability of Enset intensification for Weliso Goro, which was later, published in the Ethiopian Journal of Natural Resource. The group also forwarded to EARO and GTZ a project proposal for the establishment of pilot GIS laboratories at the National Soils Laboratory, Debrezeit and Melkassa research centers, where the three trainees originally came from in order to make the GIS an integral part of the research system.

This proposal has now finally been accepted and today's workshop can be called the official GIS project-launching workshop. Today’s workshop is an awareness creation workshop. This will be followed with object oriented training programs in GIS for the three center’s research staff, which help them in their research undertakings.

GIS is a computer based system that integrates the data input, data storage and management; data manipulation and analysis; and data output for both spatial and attribute data to support decision making activities. Given this major definition, the major GIS functions can be grouped into data input and outputs, data storage, data management and analysis, and output generation in the final analysis. The workshop will focus on giving highlights to this activities and as GIS is a spatial data capturing, analysis and decision support system, the presentations will be geared to feature this fundamental characteristics of GIS. At this workshop papers on different data capturing, data analysis and output generating systems will be presented where all
will have a chance of exploring what GIS can do, and where one can utilize it in the research undertakings.

The ultimate aim of GIS is to support spatial decision-making. Any decision making process can be structured into major phases of intelligence, design and choice. GIS is more transparent and facilitates decision-making process. Researchers operating in a vast country like that of ours need to learn this expedient tool to handle research works in a more efficient and cost effective way. GIS will definitely help in your research undertakings; at the stage of problem identification, technology generation and verification; and popularization work.

This workshop is the first of the list of activities, which are going to be undertaken under the project. The papers to be presented at this workshop will lay the ground for future GIS users and hope besides creating awareness, many of you will be motivated to further use GIS in future research programs. Seven papers are expected to be presented today which will be both on the concepts and practical application of GIS. I wish you the best of all in your deliberations and officially declare the workshop open.

Thank You!
CONCEPTS AND CAPABILITIES OF GIS

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INTRODUCTION

GIS is a computer based system that integrates the data input, data storage and management; data manipulation and analysis; and data output for both spatial and attribute data to support decision making activities. Given this major definition, the major GIS functions can be grouped into data input and outputs, data storage and management, data management and analysis, and output generation in the final analysis (Jack 1999).

GIS has its roots in cartography. Regional maps like that of Doncaster, England started to appear at around 1922, Survey of New York and its Environment started to come out in 1929. In 1950 the technique of map overlay now common in GIS packages was invented by Tyrwhitt (Steintz et al 1976). In 1962 Waldo Tobler a graduate student (Tobler 1959) wrote about the use of computer in cartography. The Canada geographic Information System came into being in 1964 and the Land Use and Natural Resource Inventory System in New York appeared in 1967. The Harvard University group came up with the Arc/Node or vector data structure called Odyssey in 1960. In 1974 the International Geographic Union surveyed in the mapping science area and found enough GIS software to publish an entire volume entitled, "Complete Geographic Information Systems". While in the early days many different terms were used to describe a GIS, this report began the convergence of the term GIS as a generic name for this new application and research field. With the coming of the PC, GIS really took off.

The ultimate aim of GIS is to support spatial decision-making. Any decision making process can be structured into major phases of intelligence, design and choice. GIS is more transparent and facilitates decision-making process. Researchers operating in a vast country like that of ours need to learn this expedient tool to handle their research work in a more efficient and cost effective way. GIS will definitely serve researchers
in their undertakings at the stage of problem identification, technology generation, verification and popularization work.

GIS is an integrating technology, which allows the integration of a variety of geographical techniques such as remote sensing, global positioning system, computer aided design, automated mapping and facilitates management. An ultimate aim of GIS is to provide support for making decisions can be seen as a decision support system involving the integration of spatially referred data in a problem-solving environment. GIS should be viewed as a process rather than merely as a software or hardware.

The system contains a set of procedures that facilitate the data input, data storage, data manipulation and analysis and data output for both spatial and attribute data.

GIS can be used not only for producing maps automatically, but integrates and spatially analyses multi source data sets such as data on population, topography, hydrology climate and vegetation, transportation networks and public infrastructures.

DATA INPUT
The data input component converts data from their raw or existing form into one that used by a GIS. Data required for a particular purpose are available in different forms:
- Analog maps
- Tables
- Charts Satellite images
- Existing digital data sets
- Aerial photos
- Surveys

The data input component converts data from their raw or existing form into one that can be used by a GIS. Prior to anything, the kind of data required for a certain purpose need to be identified and then gathered. The data could be available in a certain format on a diskette and in a certain tabular form. These need to be reformatted in a way applicable to the particular GIS program. If need be, it should be reformatted and
geo-referenced to give it spatial dimension. Thus these need to be compiled and documented.

Different systems can be used to feed the data into the computer. Among these the most common ones are:

Keyboard
Digitizer
Computer mouse
Scanning
Data import

**Digitizing:** Digitizing involves encoding analog data (hard copy or graphics) into digital data. The method uses a digitizing table and a mouse with a cursor to trace and record points, lines and polygons needed for a particular data set. Most digitizing errors can be attributed to poor map bases and scales.

**Scanners:** A scanner converts an analog source document into digital raster form by using either a flat bed scanner or a drum scanner. The scanning method is usually chosen when large amounts of data need to be captured.

**Remote Sensing:** It is a process of gathering data about the surface of the earth and the environment from a distance usually by aircraft, space sensor or satellite system. The huge amount of information available from orbiting satellite must be processed before it can be incorporated into GIS. These steps are image processing, image enhancement and classification. Since the raw remote sensing image contain radiometric and geometric errors, they have to be pre processed to remove the radiometric and geometric errors. The image enhancement process involves a variety of point and local image enhancement operations. The former operations modify the brightness value of each pixel in an image independently, while the later operations modify the value of each pixel in the context of brightness value surrounding it. Remote sensing data need to be classified. Classification is an automated procedure where each pixel or group of pixels in each wavelength is examined by statistical techniques.
Global Positioning System (GPS): The basic idea behind GPS technology is that each satellite broadcasts a constant stream of timing information from highly accurate atomic clocks. The satellite transmits signals that can be decoded by specially designed receivers to determine positions of varying accuracy. The GPS receiver measures a signal's time and range data and converts them to navigation and position data. The receiver reads the timing information from the GPS satellite and compares the signals with their own clock to calculate the distance to each satellite. The receiver calculates the location by triangulation. Consequently at least three satellites must be available at any one time to provide an accurate location fix. A fourth satellite in view makes possible the determination of altitude.

MAP PROJECTION
The part of cartography that deals with the problem of putting a round earth on to a flat paper is called map projection. The earth is thought to be an ellipsoid and when projecting the globe to a flat surface there is always some kind of distortion. One has to select the projection type, which creates minimum distortion. The common projection types are Azimuthal, Cylindrical and Conic type projection.

Secant or Conic projection: If one cuts the earth we would have a secant conic projection. The line on the map where the cut falls on the projection is important, because it is a line along which the earth and the map match exactly, just as in a globe at the same scale with no distortion. The simplest way to evaluate a projection is by how much it distorts the earth's surface during the transformation from an ellipsoid to a flat map.

Projection could be Conformal, where longitudes and latitudes lines meet at right angles. Examples are Lambert Conformal Conic and Mercator projection. In our case we use the Mercator projection, as there is minimum distortion around the equator.

Coordinate System: A computer plotter requires that location be given in (x,y) format that is an east-west followed by north-south distance coordinate points.
There are four geographic coordinate systems:
- Universal transverse mercator (UTM)
• Geographic Coordinates
• Military grid system
• State plane system

Universal Transverse Mercator: The universal transverse Mercator has been in use in the USGS topographic maps since 1950. The Mercator projection distorts areas so much at the poles, produces minimal distortion laterally along the equator. Johann Heinrich Lambert modified the Mercator projection into its transverse form in 1772 in which the equator instead runs north south. The system capitalizes on the fact that the Transverse Mercator is accurate in North-South dividing the earth from pole to pole each 6 degrees of longitude wide. The first zone starts at 180 degrees W at the International Date Line. The last zone starts at 174 degrees east and extends to the date line. Within each zone we draw a Transverse Mercator projection centered on the middle of zone-oriented north south. Thus zone 1 ranges from 180-174 West, the central meridian is at 177 degrees. We work separately from the two hemispheres. From the southern hemisphere, the zero northing is the South Pole and northing is given in meters. The north starts the zero to 10 million in southern hemisphere or 0 meter north in northern hemisphere. As distortion increases towards the poles, it is customary not to use UTM beyond 84 degrees north and 80 degrees south. For the poles stereographic coordinate system is used.

Multi scale resource data: Most maps created prior to the GIS era are only loosely tied to the ground. For most resource applications not knowing exactly where you are on the ground has not been a serious problem. After all a map is understood to be simply an abstraction or representation of which is on the ground. Questions about the soil pit, boundary between vegetation types were not considered economically realistic before GIS and GPS technology.

With the advent of GIS technology not only is it possible to have a very detailed map and a quick analysis of multiple map layers, but it is possible by using GPS on the ground to know the location of anything and to incorporate such locations in a map. With this compatibility and other significant issues arose immediately. These are map scale, accuracy and error. Data at the common scale 1:50000 were sufficient to
Concepts and capabilities of GIS

conduct many large area and regions project and took less effort to collect compared to more detailed information at large scales. However with advent of GPS, development of improved computer speed and disk storage more sophisticated GIS software these scales are not longer adequate for many applications. Larger scale maps and database are required for more detailed mapping for local applications. While it is possible to change the scale of any map in a GIS, making the scale larger is not advised, because the data were collected at a smaller scale and therefore important details may be missing. For example a map of the state of New York collected at a scale of 1:50000 will contain all major roads and highways, but not all the side streets. No matter how much the scale is enlarged, the side streets will not appear because they are not part of the map. Such a map is perfectly acceptable for planning a trip across the state, but will not be adequate for attempting to locate someone’s home in a small town.

**Map Error:** To make effective use of GIS technology understanding the errors associated with the spatial information is important. It is also important to establish data standards and method of documenting GIS data called Metadata.

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INITIAL ENVIRONMENTAL ASSESSMENT
A CASE STUDY OF THE GENALE (GD2) HYDROPOWER PROJECT

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INTRODUCTION

Ministry of Water Resource (MoWR) established important objectives to develop the water sector and some of these are:

- To complete master plan of all major river basins
- To present pre-feasibility and feasibility study of prioritized sub-basins: The pre-feasibility of Baro and Geba (from Baro-Akobo Basin), Genale (Genale Dawa Basin) and Guder (part of Abay Basin) Hydropower Study Projects is completed (see Map 2).
- Integrated watershed development study of degraded areas was started in 1999. The studies have been completed for eight pilot areas.
- The ongoing trans-boundary rivers (particularly the Nile) initiative

Twelve major river basins have been identified and broadly divided as those draining to:

- The Nile
- The Somali lowland
- The dry basins of Afar and Ogaden (see Map 1)

THE STUDY AREA

One of the studies recently undertaken by the Ministry has been the Genale (GD 2) catchment. It is part of the Wabi-Genale River Basin system and draining to the Borena and Somali lowlands. The catchment is located in the southern part of Ethiopia (between 5°15' - 7° 00' N & 38° 30' - 39° 30'E) (see Map 3). It occupies an area of 6,923 km2, which is around 13 times the area of Addis Ababa. The study mainly focused on hydropower development.

Climate: The average monthly temperature of the catchment area is between 17.5 to 20 °C. Precipitation varies between 1000 to 16000mm with two rainy periods. Genale is the major river.
Topography: Elevation ranges from 1000 meter in the south to 3500 meter in the Northwest (see Map 4). Common landforms are mountainous areas in most part, valleys in the center and complex landforms in the Northwest (see Map 5).

Geology: Downstream and center of the sub-basin is dominated by Acidic rocks/Undifferentiated basement system Gneisses/rocks and Basic-Ultra basic Rocks/Pyroclastic Rocks. Undifferentiated Igneous rocks cover upper part of the sub basin (see Map 6).

Soils: According to soil and terrain information of FAO, dominate soils are Chromic Luvisols and Eutric Leptosols in the reservoir and project area. Humic Nitosols and Eutric Vertisols cover Northwestern part of the sub basin (Map 7).

Land use and land cover: The basin is dominated by natural forest and woodland with little cultivated zones in the center and north. The natural vegetation downstream of Genale River is open woodland type (see Map 8).

Farming System: The place where the reservoir and the project site located is agro-pastoral. This covers the largest area of the basin. The other dominant farming system zones are Bale and the Kibre Mengist forest. Enset covers the greater part of the farming systems in the north and northwestern parts. Few cereal cropping is practiced north of the reservoir and project site (see Map 9).

Administration: The basin is within Oromyia and SNNPR. The Oromyia region holds the greater part of the project area and the reservoir (see Map 10).

Infrastructure: Both the asphalt and dry weather roads are distributed in the north and western parts of the basin.

Population and settlement: The northwest highlands of the sub basin are the most densely populated areas with 400-450 persons/sq km (1994 census). Both the reservoir and the project site have the lowest population pressure, i.e. between 30 and 40 persons/sq km (see Map 11). Household: the reservoir and the project site are areas with a very low housing density (5-10 houses/sq km) unlike the northwestern part with the more than 80 houses/sq km (see Map 12).

OBJECTIVES

The Genale Hydropower catchment was one of the sub-basins found under this major basin. It was chosen as a priority area among other basins to conduct the planned pre-feasibility study.

The objectives of the pre-feasibility study were:
- To inventory, analyze and present the resources of the sub-basin
GIS awareness workshop

- To assist in mapping some of the most important resources, particularly environmental resources before full appraisal and implementation of the hydropower project.
- To breakdown different resource planning areas within the sub-basin.
- To support in indicating desired locations for full environmental assessment prior to materializing major infrastructure project.

MATERIALS AND METHODS

Materials:

- 1:50000 topographic map of Ethiopian Mapping Authority (EMA) of 1975 to 1996 was used for digitizing baseline data (towns roads, rivers).
- Auto Cad R 13 and MapInfo Professional 4.1 software.
- A computer, digitizer and plotter to process and present the maps.

Digital data were also used from the following sources:

- 1:250000 land resources data from Woody Biomass Inventory and Strategic Planning Project (WBISPP), 1994.
- MapInfo format 1997's Wereda digital data was imported from World Food Program (WFP). This was originated from of Central Statistical Authority (CSA) 1:50,000 hardcopy maps.
- 1:1000000 Inter Government Authority on Development (IGAD) & Food Agriculture Organization (FAO) land resources information of 1994 and 1996.
- Population data was generated from 1994 Census of CSA.
- Additional data were taken from related sources such as the Abbay River Basin Project (1997), the Oromia Regional State land resources survey project (19980, National Meterological Services Agency (1997) and Disaster Prevention and Preparedness Commission (1997).

Methodology

- The sub-basin boundary was delineated by the survey group and digitized using AutoCAD.
- Baseline data layers were inputted from 1:50,000 topographic maps.
- Appropriate land resources layers were identified and decided.
- The different layers were edited and formatted in MapInfo.
- Land resources, infrastructure and integrated thematic layers were produced. This maps show distribution, area coverage and other aspects of the thematic layers.
- A Map Album was produced using 1:700,000, and the maps were binded in A4-size format.
**Manpower**  
Two geographic information Systems (GIS)/Cartographic Professionals were involved in the project.

**RESULTS AND DISCUSSION**

**Conclusions**

**Secondary Impact Zone (SIZ):** Extensive areas in the upstream Weredas where the project is located covers the broad catchment area. Less impact is anticipated in this zone. This zone can be described from secondary sources.

**Direct Impact Zone (DIZ):** This zone is identified as the center of attention where implementation brings a significant change on physical, ecological and socio-economic circumstances. Both the project area and the main reservoir area are contained within this zone.

**Proposed location and extent of the project area:** As observed in the survey, the hydropower project site follows the regional geological trends of the Wadera Shear Zone (Map 13). The site was proposed to contain the dam, reservoir, powerhouse, intake structure, and contractor's construction compound.

Preliminary design turbine discharge of hydro power is 169 m$^3$/s with a maximum gross head 123 meter at 1360 meter elevation. Based on this preliminary optimization the GD 2 project yields installed capacity 164 MW that is more than 10 times Sor hydropower project (14 MW) that supplies the Gambella and few surroundings town of the power plant. Annual firm energy production of GD 2 is 567 GWh that is 8 times Sor (70.8 GWh).

**Main reservoir area and the dam site:** The reservoir stretched to Chembo and Girjat towns, about 75 km up stream of the dam, having topography of wide and gently sloping area and proposed to inundate 102 km$^2$ areas. The GD 2 dam is found to be located at the intersection of 6° 59’ N and 39° 20’ E, at elevation 1370 m.a.s.l. (Map 13).

**Terrestrial environment**  
*Loss of Acacia woodlands and dense riverine vegetation:* The reservoir is proposed to flood 120 sq km; of this 113 sq km is natural vegetation and the remaining 7 sq km is grazing land (Map 8 and Map 13). Construction of access roads to dam and other sites also affects the natural vegetation and is estimated to cover 1.3 sq km, assuming road width to be 30 meters. (Map 8).

*Soil erosion:* Soil erosion will increase. The physical impact is associated with changes in soil structure and land cover and use change (clearance).
GIS awareness workshop

Aquatic environment: Change in water quality together with erosion and sedimentation obviously lead to disturbances in the aquatic life.

Socio-economic impacts: Certain proportion of people and houses are expected to be affected. Example: Out of the total estimated house holds of the Weredas, which is around 26,000; 850 or 2 to 3%, are affected. This in fact is not significant because the project site has been situated in the low household density areas (42.26 houses per sq km according to CSA 1994 Census result).

ENVIRONMENTAL MITIGATION AND MANAGEMENT

Location of the project site and reservoir demands to combine technical requirements, economic viability and environmental protection. Mitigation should be considered as an integrated packages or process and be combined with other measures too. Thus, measures have to consider also spatial patterns and area coverages of important resources identified by the GIS study. Environmental assessment of different components of the project should be guided by certain principle like the World Bank. See settlement guidelines, project infrastructure (roads, transmission lines, etc) considerations.

Biophysical mitigation and management measures: This should give priority for avoiding disturbances in the areas of pristine (untouched) terrestrial and aquatic environment. Identify in detail the setting and area extent of critical environment before major implementation of the project. This guides careful road construction, water and drainage use and soil erosion control. Moreover, spatial planning could help in designing integrated watershed management for erosion and sedimentation control, replant disturbed areas to prevent soil transport and in controlling minimum flow release during reservoir filling in order to avoid flooding and other problems down stream of the main dam.

Socio-economic mitigation and management measures: The preliminary surveys and field information indicate that there is suitable residential and (potential) agricultural land available in the project vicinity if the resettlement is planned properly. This could be located in extreme southeastern and southwestern parts of the catchments where woodland and grassland are dominant. These are agro-pastoral farming system zones. Take into account the resettlement principles and compensation procedure guidelines of the World Bank that states about people's safely. They should be at least better off after resettlement.

Considering the wide possibilities for hydropower plants in the county, the most competitive ones will be taken into account as reflected in EELPA studies. Spatial planning is required for better economic outcome. Economic analysis should reflect the weight of some established criteria such as cost per Kwhr, operating costs, resettlement, environmental costs and transmission costs. This and other crucial
issues could be addressed during Full Environmental Assessment (FEA). Thus, provisional environmental costs assessed for GD2 is around 8.5 million USD, approximately 5 million USD for 4 years construction phase and 3.5 million USD for 50 years operation phase and need to be refined in the next study phase.

Environmental Monitoring

Monitor whether excavation, land take, construction, etc are done on sites and areas indicated prior to project implementation or not.

Environmental Audit

- Environmental audit required shortly after completion of the project. Auditing indicates gaps, clarifies initial research problems and opens up ways for further study.
- The role of auditing is to identify environmental changes arising from the project to assess the effectiveness of the mitigation measures adopted, and to suggest additional measures where appropriate.

References


Map 2: GENALE-DAWA, GUDER BARO AND GEBA CATCHMENTS

LEGEND
- Major basin boundary
- Sub basins boundary
- Pre-feasibility study areas

1 cm to 72 km
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The delineation of boundaries shown on this map must not be considered authoritative.
Map 5: LANDFORM

Legend
- Towns
- Asphalts
- Dry weather road
- Gorge river
- Wereda boundary
- River boundary
- Wereda name

- Footslopes/Piedmont Plains (F/P)
- Hills, Minor Scarps (H)
- Plateaus (P)
- Mountains, Major Scarps (M)
- Valleys/Minor Valleys (V)
- Complex Landforms (X)

Produced on: Nov 20, 1998
Filename: Landform.png
Source: Inter-Governmental Authority on Development (IGAD), 1996

The delineation of boundaries shown on this map must not be considered authoritative.
Map 6: GEOLOGY
Map 9: FARMING SYSTEMS

Legend:
- Agro-pastoral
- Cereal
- Enset
- Forest
- Data not available

Produced on: Nov 20, 1999
Filename: Firmsys.wor
Source: Woody Biomass Inventory & Strategic Planning Project (WBI/SPP), 1994

Ministry of Water Resources, Ethiopia, Under, Bens and Debre Pre-feasibility Study

The definitions of boundaries shown on this map must not be considered authoritative.
Map 10: ADMINISTRATIVE DIVISIONS

The delineation of boundaries shown on this map must not be considered authoritative.

Produced on: Nov 25, 1998
File name: Admin_div-wor
Source: World Food Programme (WFP), 1997

Ministry of Water Resources, Oromiya, Wolaytta, Borena and Goba Pre-Feasibility Study

1:700,000
Map 11: POPULATION DENSITY

NB: Population information are mapped as actual (total) CSA woredas not as areas of woredas falling inside each basin.
Map 12: HOUSE HOLD DENSITY

NB: Population information are mapped as actual (total) CSA weraias coverages not as areas of weraias falling inside each basin.

Produced on: Nov 20, 1998
Filename: imHideta.wor
Source: Central Statistical Authority (CSA), 1994

The delineation of boundaries shown on this map must not be considered authoritative.
Map 13: APPROXIMATE LOCATION OF THE RESERVOIR AND PROJECT AREA

Data collected by:
Adiapa Achem, ProTech
Sustainability Corp., Ltd.
Addis Ababa, Ethiopia

Produced on: Nov. 20, 1998
Filename: Dmsite.wor
Source: Noiplsa/Norcoisah & AQUATECH, 1998

The delineation of boundaries shown on this map must not be considered authoritative.

Ministry of Water Resources, Genale, Dibek, Bore and Doba Pre-Feasibility Study

Genale 2 Dam
1370 m
APPLICATIONS OF GEOGRAPHICAL INFORMATION SYSTEMS AND REMOTE SENSING IN AGROMETEOROLOGY

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1. INTRODUCTION

In the last thirty years, the role that agro meteorology could play, both in developed and in developing countries has theoretically increased: first, to the traditional subjects of agriculture productivity, we should add the quality of products and the environmental role of agriculture, also in the context of global change. The "rural development" concept launched in the Agenda 2000 of the E.U. underlines an integrated management of land where the exploitation of natural resources, including climate, plays a central role. In this context, agro meteorology can help reduce the inputs, while in the frame of the global change, allows the clarification of the contribution of ecosystems and agriculture to the carbon budget (March, 1991).

Secondly, due to the dramatic increase in world population, which has grown from 3.5 billion in the 1960's, to 8000 billion in the 1990's, there is a need to increase the total production under the constraints of a durable environment.

Nevertheless, the operational application of agro meteorology in the last thirty years has been slowed down due to several constraints that can be summarized as follows:

- The minor role that agro meteorology play in the context of meteorological services with few personnel and scarce resource;
- A declining position of both national and international institutes of research, together with a very weak presence in the agricultural and physical departments.
- The need to diffuse agrometerological information to users very accurately in time and space, because the agricultural activity is related to the very local situation.

Regarding the last point, many new tools are available at the disposal of agrometeorology. These include: local area models, climatic models, satellite and radar measurements, together with the improved crop models. The outputs of all these instruments, together with ancillary information on the land, should allow the downscaling up to a very detailed grid, consistent with the needs of the users. GIS is the main tool, to combine all this information in a systematic way and shift this sector to a modern agrometerology.
2. GIS AND LIS

A geographic Information System (GIS) is a computer-assisted system for acquisition, storage, analysis and display of geographic data. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps (Burrough, 1990).

Maps have traditionally been used to explore the earth and to exploit its resources. GIS technology is an expansion of cartographic science, which takes advantage of computer technologies, enhancing the efficiency and analytic power of traditional methodologies (Coulson et al., 1991; Ballestra et al., 1996).

Nowadays, GIS is becoming an essential tool in the effort to understand complex processes to different scales: local, regional and global. In GIS, the information coming from different disciplines and sources, as traditional or digital maps, databases and remote sensing, can be combined in models that simulate the behavior of complex systems. Some common applications are relative to the control of industrial cycles; simulation of urban and natural systems; evaluation of specific procedures and analysis of environmental impact (Mueksch, 1996; Bouman et al., 1998; Taylor and Burger, 1998).

The next schematic representation (fig. 1) illustrates the main informative sources, the components and the results of the GIS's data processing. Data input can be obtained by means of direct digitalization, scanning or acquisition with compatible sources.

Geographic elements are represented in two ways: using x, y coordinates (vectors) or representing the object as variation of values in a geometric array (raster). The possibility to transform the data from one format to the other allows fast interaction between different informative layers. The other factors may be used directly, with point or values on the territory, or after elaboration, e.g. data spatialisation. Typical operations include overlaying different thematic maps, contributing areas and distance, acquiring statistical information about the attributes, changing the legend, scale and projection of maps, and making three-dimensional prospective view plots using elevation data.

The capability to manage, analyze and process these different information, open incredible new possibilities for the simulation of complex systems. A GIS can be used, not only to produce images or maps, but all the cartographic products, drawings, animations or interactive instruments. These products allow researchers to analyze their subjects in new ways, predicting the natural behavior, explaining events and planning strategies.

For the importance of the agronomic and natural components, in agrometerology these instruments have taken the name of LIS (Land Information Systems).

In each specific system the key components are the same (hardware software, data, techniques and technicians), but in relationship to the information that is required, the importance of every one is quite different.
In particular, LISs requires a series of very detailed information on the environmental elements, such as meteorological parameters, vegetation, soil and water. The final product of a LIS is often the result of a combination of numerous complex informative layers, whose precision is fundamental for the reliability of the whole system. An example of the main information is schematically shown in the Fig. 2.

The next paragraph outlines the importance of each informative layer and provides various examples of application in developed countries.

**The informative layers**

In a GIS, all the information can be linked and processed simultaneously, obtaining a syntactical expression of the changes induced on the system by the variation of a datum parameter. In this way, we have two types of archives: static and dynamic. This technology allows the contemporary updating of geographical data and the own relative attribute; producing a fast adaptation to the real conditions and obtaining answer in considerably near real-time. The system requires preliminary basic information that, in the agro meteorological sector, is often furnished by the historical archives of different disciplines: Geography, meteorology, climatology, agronomy, etc. The importance of this data is delicate and requires time and attention, mainly because this information will provide the basic knowledge of the territory. A recent important improvement is relative to the realization of high resolution Digital Elevation Models (DEMs) (Moore et al., 1991), which are three-dimensional representations of the land, realized starting from quoted contour lines. A realistic reproduction of the morphology, allows a series of considerations on many other parameters, like hydrology, sunshine duration, etc. (Mitasova et al., 1995; Bruneau et al., 1995). Nowadays, we can say that this layer is the base of all the others, especially for the agro meteorologist.

Other informative elements, such as text, photo, film, etc, can be introduced to complete the information, if these don't enter directly in the elaboration. This is important not only for educational purpose, but also for more information in particular aspects. For example, an area characterized by a typical agronomic technique can be linked to an image that explains this technique.

In agrometeorological applications, data collected directly in the field is very important, as it represents ground truth. Meteorological stations and field data collection (eco-physiological observations, agronomic practices, insect attacks, diseases, soil, etc) and direct territorial observations are fundamental for all the possible agro meteorological GIS applications.
All these sources give a picture of the territory and the condition of the elements that it is composed of. The data is used directly or after further elaboration. After the preliminary considerations, only the availability of real-time field data may allow simulations and evaluation of the actual and future scenery.

When there is a lack of information, the models can help the users to complete the information and understand the real situation (Rijks et al., 1998). For instance, it is possible to estimate the soil water deficit of a given area in two ways: direct measurements (very expensive process) or using the estimated values of a model.

Program such as ETRO, computers daily water requirement for the crops, taking into account the different components of water balance (evapotranspiration, rainfall, irrigation and cultural coefficient) and the initial condition of saturation of the soil (Battista et al., 1996). ETRO calculates daily values of different parameters: root development, maximum water supply, easily extractable water supply, effective rainfall and true evapotranspiration (ETr), etc. The software uses three different methods (Integrated model micrometeorological, Penman-Fao and Hargreaves) for the estimation of ETr, according to the available measurement and the accuracy required by the users.

The simulation was made for the culture of corn in the month of June 1997. The chart in the picture shows the trend of water balance and minimal reserve, for one point, suggesting the best moment for the irrigation and the volume of water necessary to restore the water reserve.

In many cases the outputs of the models are introduced as inputs in the GIS, but it is also possible to introduce the models directly. In this way, all the information could be used for new interactions with other informative layers.

The role of remote sensing

A modern and effective agrometeorological weather service, using advanced data collection methods such as remote sensing, should have efficient and trained staff.

Remote sensing provides a series of information, continually improved, which become very reliable and practically irreplaceable (Rijks, 1995).

Remote sensing provides spatial coverage by measurement of reflected and emitted electromagnetic radiation, across a wide range of wavebands, from the earth's surface and the surrounding atmosphere (Cochrane, 1986).

The improvement in technical tools of meteorological observation, during the last twenty years, has created favorable substratum for research and monitoring in many applications of sciences of great economic relevance, such as agriculture and forestry. Each waveband provides different information about the atmosphere and land surface: surface temperature, clouds, solar radiation, processes of photosynthesis and evaporation can affect the reflected and emitted radiation detected by satellites. The challenge to the research is to develop new systems extracting this information from
remotely sensed data, giving to the final users, irreplaceable near-real-time information.

Table 1. Main products of the working satellites.

<table>
<thead>
<tr>
<th>Field</th>
<th>Products</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPOT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lands</td>
<td>Vegetation Index Maps</td>
<td>High resolution land use analysis, biomass and vegetation hydrological conditions</td>
</tr>
<tr>
<td></td>
<td>Land cover and land use</td>
<td></td>
</tr>
<tr>
<td></td>
<td>classification maps</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Digital elevation model Ortho</td>
<td></td>
</tr>
<tr>
<td></td>
<td>photomap</td>
<td></td>
</tr>
<tr>
<td>LANDSAT TM</td>
<td>Cloud cover maps</td>
<td>Meteorological forecasts, numerical models, climatology, floods forecasting</td>
</tr>
<tr>
<td></td>
<td>Albedo maps</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aerosol maps</td>
<td></td>
</tr>
<tr>
<td>Inland and coastal</td>
<td>Water quality monitoring maps</td>
<td>Pollution monitoring environmental impact assessment</td>
</tr>
<tr>
<td>waters</td>
<td>Sea surface temperature maps (SST)</td>
<td></td>
</tr>
<tr>
<td>Lands</td>
<td>Land Surface Temperature maps (LST)</td>
<td>Temperature distribution in urban areas, high resolution land use analysis, biomass, vegetation hydrological conditions, fire risk and damages assessment</td>
</tr>
<tr>
<td></td>
<td>Normalized difference Vegetation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Index Maps (NDVI)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Land cover and land use</td>
<td></td>
</tr>
<tr>
<td></td>
<td>classification maps</td>
<td></td>
</tr>
<tr>
<td>AVHRR-NOAA</td>
<td>Temperature and humidity profile</td>
<td>Meteorological forecasts, numerical models, climatology, floods forecasting</td>
</tr>
<tr>
<td></td>
<td>Precipitation maps</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cloud cover maps</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cloud top height and temperature</td>
<td></td>
</tr>
<tr>
<td>Inland and coastal</td>
<td>Oil slick and monitoring maps</td>
<td>Pollution monitoring environmental impact</td>
</tr>
<tr>
<td>waters</td>
<td>Sea Surface Temperature maps</td>
<td></td>
</tr>
</tbody>
</table>

32
GIS awareness workshop

<table>
<thead>
<tr>
<th>(SST)</th>
<th>assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal zones monitoring coastal streams dynamics, sediments mapping</td>
<td></td>
</tr>
<tr>
<td>Lands</td>
<td>Land Surface Temperature maps (LST)</td>
</tr>
<tr>
<td></td>
<td>Normalized Difference Vegetation Index Maps (NDVI)</td>
</tr>
<tr>
<td></td>
<td>Land cover classification maps</td>
</tr>
<tr>
<td>Lands</td>
<td>Temperature distribution for urban areas, high resolution land use analysis, biomass and vegetation hydrological conditions, fire risk and damages assessment</td>
</tr>
<tr>
<td>Lands</td>
<td>Monitoring of the temporal variation of the coverage</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Field</th>
<th>Parameters/Products</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inland and coastal waters</td>
<td>Oil slick and monitoring maps</td>
<td></td>
</tr>
<tr>
<td>Inland and coastal waters</td>
<td>Ship tracking</td>
<td></td>
</tr>
<tr>
<td>ERS-1 SAR</td>
<td>Monitoring and evaluation of accidental oil slicks, area assessment</td>
<td></td>
</tr>
<tr>
<td>ERS-1 SAR</td>
<td>Temporal evolution forecasting of oil slicks and identification of coastal areas at risk in case of accidental oil slicks</td>
<td></td>
</tr>
<tr>
<td>ERS-1 SAR</td>
<td>Coordination support for anti pollution actions</td>
<td></td>
</tr>
<tr>
<td>ERS-1 SAR</td>
<td>Ship identification in case of illegal polluting slicks</td>
<td></td>
</tr>
<tr>
<td>ERS-1 SAR</td>
<td>Maritime traffic control also in fishing areas</td>
<td></td>
</tr>
<tr>
<td>Lands</td>
<td>Flooded areas maps</td>
<td></td>
</tr>
<tr>
<td>Lands</td>
<td>Emergency actions support in flooded areas</td>
<td></td>
</tr>
<tr>
<td>Lands</td>
<td>Area damage assessment for flooded areas</td>
<td></td>
</tr>
<tr>
<td>Lands</td>
<td>Strong temporal soil moisture variation evaluation</td>
<td></td>
</tr>
</tbody>
</table>

Platform for remote sensing can be either fixed or moving, terrestrial or operating from different altitudes, and can be manned or unmanned. Considering the duration it remains active, the platform can be classified as temporary, semi permanent or virtually permanent. These aspects are important in order to understand the quality and quantity of the information available to the agro meteorological service. The distance of the instruments affects directly the resolution and the precision of the information. The scale of observation can vary from a few square meters, with a scanner mounted on a vehicle, to continental scale, using a meteorological satellite.
The sensors most widely used by environmental scientists are:

- Cameras with quartz lenses for use with ultraviolet film;
- Cameras for use in the visible and photo infrared spectral region;
- Multi band cameras (VIS, NIR);
- Optical mechanical scanners and radiometers for thermal infrared and passive microwave regions;
- Active microwave sensors such as side-looking airborne radar (SLAR) and synthetic aperture radar (SAR), which are not dependent on daylight and possess a near-all weather capability.

Each instrument furnishes different information and a station of detection is generally multipurpose, because it is equipped with different sensors. The most common remote sensing products and applications are reported in the table 1 (Maracchi et al., 1998).

All information produced by the satellite is elaborated for the extraction of the desired information. There are many methods, algorithms and procedures to derive fundamental data for agro meteorological application from remote sensing. Among the existing indices, the most extensively used are:

- The Sea Surface Temperature (SST): index used for meteorological and climatological study and observations.
- The Land Surface Temperature (LST): good indicator of climatic and microclimatic conditions prevailing close to the surface, as well as the frost or the moisture soil.
- The Normalized Difference Vegetation Index (NDVI): optimal index of current plant cover and its variation with time.

The images can be subsequently used as informative layers in the GIS, entering in a quality of analysis or evaluation procedures. One of the simplest methods is the overlapping of these images with DEM, for a realistic representation of the observed phenomenon.

The transfer of the new techniques on processing and interpreting remote sensing data from developed to developing countries, was limited by many factors, such as the cost of receiving equipment, the restrictive or very difficult access to the archives of satellite images and data, the shortage of qualified staff, etc. The situation has changed to the better in recent years, thanks to the availability of long series of satellite data; for example the archive of data from NOAA (USA) and Meteor (Russia), contain information of more than 15 years. In this way, the researcher and user, have the possibility to apply the traditional techniques, approach and procedure and to study the specific case of their own country. The access to the achieves, software and the transfer of information is now simplified, especially with the use of INTERNET tools.

International organizations in particular the WMO also play an active role in coordinating efforts connected with receiving, processing, disseminating and using remotely sensed data. WMO's has recently established a working group on satellites (WG SAT), which will be a good option to handle the above activities.
The goal is the development of common work strategies and the improvement of regional and global management capability of satellite data. For this reason, particular emphasis is placed on data compatibility and integration between different sources of data. The WG SAT has supported a project aimed at developing the receiving station (both hardware and software) at a reasonable cost to be available for developing countries. The WGS has discussed a possible process to improve the use of satellite data from the present global satellite observing system, and has proposed a set of recommended actions.

3. GIS AND REMOTE SENSING APPLICATION IN AGRO METEOROLOGY

Nowadays, public agencies, research laboratories, academic institutions, private and public services, have established their own information system such as GIS. Due to increasing pressure on land water resources, management and forecasting become more essential everyday. GIS is therefore an irreplaceable powerful tool at the disposal of decision-makers.

We have seen in the previous pages that the term GIS is currently applied to computerized storage, processing and retrieval systems that have hardware and software specially designed to cope with geographically referenced spatial data and corresponding informative attribute. Spatial data is commonly in the form of layers that may depict topography or environmental elements or aspects.

In Agrometeorology, to describe a specific situation, we use all the information disposable on the territory: water availability, soil types, forest and grasslands, climatic data, geology, population, land-use, administrative boundaries and infrastructure (highways, railroads, electricity or communications systems). Each informative layer provides to the operator the possibility to consider its influence to the final result. However, often more than the overlap of the different themes, the relationship of the numerous layers is reproduced with simple formulas or with complex models. The final information is extracted using graphical representation or precise descriptive indexes.

Developing countries use agricultural and environmental GIS to plan the time and types of agricultural practices, territorial management activities, and population security, to monitor devastative events and to evaluate damages, etc.

More than the classical applications, like estimation of crops yield, uses for environmental and human security are becoming more and more important. For instance, effective forest fires prevention needs a series of detailed information on an enormous extension. The analysis of data, such as the vegetation coverage with different levels of inflammability, the presence of urban agglomeration, roads and many other aspects, allows the individuation of the areas where risk is greater. The use of other informative layers, such as the position of the control points and resources availability (staff, cars, helicopters, airplanes, fireproof equipment, etc.), can help the decision makers in the management of the territorial systems.
GIS Applications

Monitoring the resources and the meteorological conditions therefore allows the consideration of the dynamics of the system, with more adherences to reality.

In developing countries, GIS are substantially a transfer of the technologies and often of information from the developed ones. Thus the considerations are generalizations of the knowledge and studies carried out on other realities. Frequently in developing countries, data used for the realization of the informative layers are unreliable or even lacking. Besides, the models used in these systems are the results of studies and projects, and studies conducted at different scales.

GIS requires great effort to collect and organize the disposable information on the territory. This important activity requires a period of validation for the operative use of the system.

Many projects have started to highly use GIS for different aspects of environmental and economical systems, mainly using information derived from remote sensing to complete their direct observations. The common advantage is the definition of the state of the art and a first study of the particular problems, with the suggestion of innovative specific solutions. At this level, the products often are already used for practical applications and the operators find it sufficiently powerful and reliable.

The general philosophy of the GIS projects is to realize more and more complex and integrated systems, to answer the needs for users. In developing countries, the approach has to be quite different, realizing in a first phase sufficiently simple systems, which answer specific problems, arriving gradually to complete the different informative layers to realize a fully operative GIS.

An example of preliminary information system to country scale is given by the SISP (Integrated information system for monitoring cropping season by meteorological and satellite data), which allows the monitoring of the cropping season and to provide an early warning system with useful information about evolution of crop conditions (Di Chiara et al., 1994).

4. CONCLUSION

Agrometeorology has to be strengthened in the service, research and training sectors and be equipped with new tools to increase its use and improve its applications both in the developed and developing countries. To meet this objective there are several initiatives that should be undertaken:

- A greater visibility of the sector at both national and international level;
- A larger participation in the international programs;
- A better integration between meteorology and climatology.

All these activities are based on the development of new competencies as in the case of GIS utilization. To prepare this new type of agrometeorologist we can identify three possible ways:

- The reinforcement of training in these new fields;
The promotion of specialized software;

The preparation of multimedia training tools to make learning and the updating of the competencies easier.

The promotion of new specialized softwares should make the applications of the various apparatus easier, bearing in mind the possible combination of several types of inputs such as data coming from standard networks, radar and satellites, meteological and climatological models, digital cartography and crops models based on the scientific acquisition of the last twenty years.

In this perspective, the activity of international agencies such as the WMO and the FAO, in co-operation with the national services and the scientific institutions, is the only way to guarantee the strengthening of the role of agrometeorology at the service of agriculture and of the environment in the world.

REFERENCES


GIS APPLICATION WITHIN AN INTEGRATED FOOD SECURITY PROGRAMME

by
Mathias Reusing
P.O. Box 12631, Addis Ababa, Ethiopia E-mail: atomatthias@hotmail.com

INTRODUCTION

Soil erosion by water has been a serious problem in the Ethiopian Highlands, ever since land was first cultivated more than 2000 years ago. Erosion rates assessed on test plots in different parts of the Ethiopian Highlands are 72 tons/ha per year on the average (Hurni, 1985). It can be assumed that the reduction of soil depth by topsoil erosion will have serious implications on future crop yields.

The intervention area of the 'Integrated Food Security Programme (IFSP) South Gonder', of the German Technical Cooperation (GTZ) lies in the northern part of the Ethiopian Highlands, where droughts and food shortage hit the local population regularly. IFSP is trying to tackle the problem of soil degradation to reduce annual soil loss rates to an acceptable minimum, in order to maintain the soil fertility and its productivity in the long run. In general, the maximum tolerable soil loss that will permit a high level of crop productivity to be sustained economically and indefinitely is indicated in Figure 1.

Apparently, soil loss rates and soil formation rates are not in balance. This is why soil conservation measures have to be undertaken to reduce soil loss rates and to contribute to new soil formation.

This article condenses the results obtained by a consulting mission at the IFSP. It's main objective is to present a methodology on how to produce a soil erosion risk maps using remotely sensed data and GIS techniques. The resulting information products should then serve as a basis for the identification of priority areas for planning of soil conservation measures and the development of land use strategies.
1. DESCRIPTION OF THE PROJECT AREA

The area of investigation was located in the central Ethiopian highlands west of Lake Tana and touches both, the watersheds of Tekeze and Blue Nile River.

The figures of the hillshaded Digital Elevation Model (DEM) and of the altitude range (Figure 3 & 4) give a first impression of the heterogeneous relief and the topography within the area. The topography is characterized by an extremely high relief energy with almost 3000 m altitude difference between the highest elevation (Guna Terara, 4135 m.a.s.l.) and the lowest river beds of the Blue Nile and its tributaries.
GIS awareness workshop

Digital Elevation Model (DEM)

Figure 3: Hillshaded DEM

Figure 4: Relief / Altitude Range
2. METHODOLOGY

Geographical Information System (GIS) is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyse and display all forms of geographically referenced information (Figure 5).

Apart from analogue topographic maps at a scale of 1:250,000, the results of a visual classification of Landsat TM satellite images served as main input data for further processing using GIS. The commercial software products ARC/INFO and ArcView served for the analysis of the vector data, and Idrisi for the raster data analysis.

3. SOIL EROSION MODEL

3.1. The Universal Soil Loss Equation (USLE)

The Universal Soil Loss Equation (USLE) is an erosion model designed to compute long-term average soil losses from sheet and rill erosion (Wischmeier & Smith 42)
1978). It is an empirical model, combining different soil erosion factors as variables by a multiplicative combination.

\[ A = R \times K \times L \times S \times C \times P \quad (\text{Wischmeier & Smith, 1978}) \]

Where:
- \( A \) = average annual soil loss (\( \text{tons/ha*year} \)).
- \( R \) = Rainfall erosivity and runoff factor
- \( K \) = Soil erodibility factor
- \( L \) = Slope length factor.
- \( S \) = Slope gradient factor.
- \( C \) = Land cover and management factor.
- \( P \) = Support or conservation practice factor.

The USLE was adapted to the Ethiopian conditions by Hurni (1985), who established test plots at different locations throughout the country for empirical research and Hellden (1987) came up with regression equations based on Hurni's findings. It has to be mentioned that soil loss rates computed with the USLE are only best available estimates that describe average values but not absolutes.

3.1.1. rainfall erosivity factor

Ethiopia is characterized by high rainfall variability. However, there are only around 200 meteorological stations that regularly deliver reliable data. The rainfall intensity itself is not systematically measured at all. This made it necessary to calculate the mean annual rainfall distribution with a model and use the values as input for the calculation of the R Factor.
GIS application and food security

Eklund performed multiple regression analysis, in order to develop models, which explain the mean annual rainfall pattern of Ethiopia. According to this, the project area is located in the FAO rainfall pattern region A, which is characterized by one short rainy season in summer (Eklund et al., 1990).

After having developed a raster surface, based on the respective multiple regression equation and by incorporating a linear regression factor for the altitudinal effects, the R-Factor values could be calculated, using the following equation:

\[ R \text{ Factor} = -8.12 + 0.562 \times \text{Mean Annual Rainfall [mm]} \quad (r^2 = 1.00) \]

(Helden, 1987)

3.1.2. soil erodibility factor k

The soil properties decide on the susceptible to erosion. The comprehensive legend of the map 'Geomorphology and Soil 1:1.000.000' (FAO/UNDP, 1987) describes dominant soil types within each geomorphologic unit, depending on the slope gradient. Prior to the calculation of a slope gradient layer, a DEM was generated, based on 100 m contour lines. Both, the digitized map and the slope gradient layer were then combined by an overlay analysis, in order to produce a soil type layer.

Finally, an individual K Factor was assigned to each soil type according to the commented legend of the mentioned map.

3.1.3. Slope Length Factor L

According to the conventional approach of the USLE, the slope length is the determining variable of the L Factor. Recent research showed that especially for larger areas, an alternative way could be followed in order to derive L Factor values. In the case of raster image analysis, it is being recommended to calculate the flow accumulation for each pixel of the surface. Each pixel value then represents an approximation of the total water run-off length, which can be described as the catchment area for an individual raster cell.
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$$ R \text{ Factor} = -8.12 + 0.562 \times \frac{\text{Mean Annual Rainfall in mm}}{(r^2 = 1.00)} $$

(Helden, 1987)

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The flow accumulation layer was calculated based on a flow direction surface that was derived through the slope gradient information. The flow direction generally corresponds to the aspect of slopes in the eight main compass directions. It then serves as input for the calculation of a flow accumulation image by accumulating the weight for all cells that flow into each down slope cell. Output cells with a high flow accumulation are areas of concentrated flow and may be used to identify the stream network by applying a threshold value. Output cells with a flow accumulation of 0 are local topographic highs and may be used to identify ridges. In general, the flow accumulation is an indicator for the catchment area of each individual raster cell. Last but not least, the L Factor was calculated for each pixel applying the following regression equation, which describes the L Factor as a function of the slope length.

\[ L \text{ Factor} = 0.799 + 0.0101 \times \text{Slope Length} \text{ [m]} \quad (r^2 = 0.95) \quad (He/den, 1987) \]

3.1.4. Slope Gradient Factor S
The slope gradient was derived from the DEM by calculating the maximum rate of change in value around each pixel to its neighbours. After having calculated a continuous slope gradient surface, the following equation, expressing a linear regression, could be applied to develop an S Factor surface.

\[ S \text{ Factor} = 0.344 + 0.0798 \times \text{Slope Gradient} \text{ [%]} \quad (r^2 = 0.97) \quad (He/den, 1987) \]

3.1.5. Land Cover Factor C
The most time and cost-effective way to derive an accurate land cover data for larger areas is to interpret satellite remote sensed data. Thus the project purchased hardcopy prints of a current Landsat TM scene (185km x 185 km) that covered the entire IFSP project area.
GIS application and food security

A ground check serves to compare image signatures to real field condition and for the definition of land cover classes. Within two weeks, all prevailing agro-ecological zones of the project area were visited except inaccessible valley bottoms. Detailed notes and photographs were taken from all occurring land cover classes and compared with their signatures in the image. Based on the experience from the fieldwork, a visual land cover classification was performed in a working scale of 1:100,000.

Assigning respective values to all land cover classes based on experience and references generated the C Factor image.

Table 1: Area Statistics of the land cover Types with IFSP S.G. Project Area

<table>
<thead>
<tr>
<th>ID</th>
<th>Land Cover</th>
<th>C-Factor</th>
<th>Area [sqkm]</th>
<th>Area [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Forest Land, Eucalyptus Plantation</td>
<td>0.001</td>
<td>30</td>
<td>0.54</td>
</tr>
<tr>
<td>2</td>
<td>Woodland</td>
<td>0.010</td>
<td>96</td>
<td>1.75</td>
</tr>
<tr>
<td>3</td>
<td>Bushland, Shrubland</td>
<td>0.038</td>
<td>570</td>
<td>10.44</td>
</tr>
<tr>
<td>4</td>
<td>Grassland</td>
<td>0.013</td>
<td>101</td>
<td>1.85</td>
</tr>
<tr>
<td>5</td>
<td>Afro-alpine Vegetation</td>
<td>0.042</td>
<td>50</td>
<td>0.92</td>
</tr>
<tr>
<td>6</td>
<td>Cultivated Land (Highland)</td>
<td>0.250</td>
<td>562</td>
<td>10.29</td>
</tr>
<tr>
<td>7</td>
<td>Cultivated Land (Highland)/slightly degraded</td>
<td>0.250</td>
<td>798</td>
<td>14.60</td>
</tr>
<tr>
<td>8</td>
<td>Cultivated Land (Highland)/heavily degraded</td>
<td>0.250</td>
<td>114</td>
<td>2.08</td>
</tr>
<tr>
<td>9</td>
<td>Cultivated Land (Escarpmment), Settlement, Bushland</td>
<td>0.150</td>
<td>2449</td>
<td>44.83</td>
</tr>
<tr>
<td>10</td>
<td>Settlement, Eucalyptus Plantation</td>
<td>-</td>
<td>255</td>
<td>4.67</td>
</tr>
<tr>
<td>11</td>
<td>Bareland, Rock Outcrops</td>
<td>1.00</td>
<td>27</td>
<td>0.50</td>
</tr>
<tr>
<td>12</td>
<td>Cultivated Land (Lowland)</td>
<td>0.100</td>
<td>408</td>
<td>7.46</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5463</td>
<td>100.00</td>
</tr>
</tbody>
</table>

3.1.6. Support Practice Factor P

For the entire area, it was assumed that contour ploughing is a common soil conservation practice, which is applied throughout the entire area. According to ratio tables, the p Factor varies with the slope steepness according to the following table.

Although further erosion-control practices exist within the project area, it was not possible to incorporate them into the model. Intensive field-inventories would be necessary in advance, in order to map the spatial distribution of soil conservation measurements.
Table 2: P-factor values for the USLE (modified: Morgan, 1995)

<table>
<thead>
<tr>
<th>Management practice</th>
<th>Slope Gradient [°]</th>
<th>P-factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contouring</td>
<td>&lt;1</td>
<td>0.60</td>
</tr>
<tr>
<td>Contouring</td>
<td>2 to 5</td>
<td>0.50</td>
</tr>
<tr>
<td>Contouring</td>
<td>6 to 7</td>
<td>0.60</td>
</tr>
<tr>
<td>Contouring</td>
<td>8 to 9</td>
<td>0.70</td>
</tr>
<tr>
<td>Contouring</td>
<td>10 to 11</td>
<td>0.80</td>
</tr>
<tr>
<td>Contouring</td>
<td>12 to 14</td>
<td>0.90</td>
</tr>
<tr>
<td>Contouring</td>
<td>&gt;14</td>
<td>1.00</td>
</tr>
</tbody>
</table>
3.2. CALCULATION OF THE MEAN ANNUAL SOIL LOSS RATES

The final assessment of mean annual soil loss rates could be performed by simply multiplying all developed factor images using overlay analysis.

It has to be underlined that the absolute figures of soil loss rates [tons/ha*year] might vary considerably from year to year. Nevertheless, the overall message and qualitative assessments, which are visually and statistically documented, are highly reliable. This means that in areas where soil loss rates of more than 400 tons/ha*year were calculated, the risk for further erosion is in fact extremely high, even if the actual amounts might be slightly lower. However, if it comes to planning soil conservation measures, minor errors of the absolute soil loss rates can be neglected.
Mean Annual Soil Loss

- Sheet Erosion damage
  - < 12.5 (tons/ha-year)
  - 12.5 to 24.9
  - 25.0 to 49.9
  - 50.0 to 99.9
  - 100.0 to 199.9
  - > 200.0
- Linear Erosion damage
  - > 400.0

Figure 8: Mean Annual Soil Loss, Detail 1

Figure 9: Mean Annual Soil Loss, Detail 2

<table>
<thead>
<tr>
<th>ID</th>
<th>Soil Loss [tons/ha-year]</th>
<th>Area [sq km]</th>
<th>Area [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt; 12.5</td>
<td>193</td>
<td>3.53</td>
</tr>
<tr>
<td>2</td>
<td>12.5 to 24.9</td>
<td>393</td>
<td>7.20</td>
</tr>
<tr>
<td>3</td>
<td>25.0 to 49.9</td>
<td>744</td>
<td>13.61</td>
</tr>
<tr>
<td>4</td>
<td>50.0 to 99.9</td>
<td>1030</td>
<td>18.84</td>
</tr>
<tr>
<td>5</td>
<td>100.0 to 199.9</td>
<td>1029</td>
<td>18.82</td>
</tr>
<tr>
<td>6</td>
<td>200.0 to 400.0</td>
<td>876</td>
<td>15.72</td>
</tr>
<tr>
<td>7</td>
<td>&gt; 400.0</td>
<td>509</td>
<td>9.50</td>
</tr>
<tr>
<td></td>
<td>Linear Erosion</td>
<td>489</td>
<td>8.94</td>
</tr>
<tr>
<td></td>
<td>Linear Erosion, Settlement</td>
<td>12</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>Settlement</td>
<td>243</td>
<td>4.44</td>
</tr>
<tr>
<td></td>
<td>5467</td>
<td>100.00</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Area Statistics of the Mean Annual Soil Loss within IFSP S.G. Project Area
CONCLUSION
The results show that it is possible to perform detailed assessments of soil erosion susceptibility, based on high-resolution satellite images and GIS techniques.

With an on-going population growth, more land than ever will have to be cultivated to feed more people.

Although the Ethiopian Government and the Bureau of Agriculture in Bahir Dar are aware of the soil erosion problem, the efforts will have to be increased considerably, in order to reverse the current situation in future. However, the greatest resources are the farmers themselves, who have to be motivated and whose workforce will have to be utilised in order to tackle the problem of soil conservation.

Land degradation by soil erosion can never be stopped, but only be reduced to an acceptable minimum. This can be achieved by the application of appropriate and well-adapted soil conservation measures and by farming practices, which sustain the fertility and productivity of the soil.

The study results, the developed statistics and maps will help identify potential intervention areas where immediate measures have to be undertaken and can support planners and decision-makers to apply suitable conservation techniques.

5. REFERENCES


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GLOBAL POSITIONING SYSTEMS (GPS):

HISTORICAL DEVELOPMENT AND PRACTICAL UTILIZATION FOR LAND USE AND LAND RESOURCE SURVEYS

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GTZ - LUPO, Addis Ababa

INTRODUCTION

Global positioning Systems (GPS) are increasingly used for navigation and capturing global geographic coordinates for various purposes. Accuracy levels depend on the purpose the receivers are employed for, communication efficiencies with remotely placed satellite platforms, and the technological qualities of the receivers.

Today, GPS provide wider ranges of geographic data and facilitate prominent data acquisition methods for Geographic Information Systems. They also support geometric rectifications for images generated via resource surveying space satellites. Due to their inherent technical and economic advantages, the small hand-held receives generate volatile services especially in land use/land cover and land resource surveys for large-scale mapping and spatial data analysis purposes in community-based development projects.

This note provides an introductory understanding on the concept, history, development and practical uses of GPS in the context of acquiring existing land use/land cover and land resource data at local levels.

The note consists of two main parts. The first part is a compilation from different Internet sources; and gives informative remarks on the meaning, history and developments in GPS applications. The second part explains the practical utilization, strengths and weaknesses of the system in the light of surveying existing land use and land resources for land use planning at GTZ-LUPO.
CONCEPTS, HISTORY AND GENERAL USES OF GLOBAL POSITIONING SYSTEMS

GPS, stands for Global positioning System. It is the only system today that enables us to show our exact position on the Earth anytime, in any weather condition. GPS satellites, twenty four in all, orbit at 11,000 nautical miles above the Earth. Ground stations located worldwide continuously monitor them. The satellites transmit signals that can be detected by anyone with a GPS receiver. Using the receiver, we can determine our location with great precision.

GPS is one of history's most exciting and revolutionary developments, and new uses for it are constantly being discovered. But before we learn more about GPS, it's important to understand a bit more about navigation.

The fist GPS satellite was called GPS Block I. Launched in 1978, it was a developmental satellite. Another nine Block I satellites were launched through 1988.

NAVIGATION

Since prehistoric times, people have been trying to figure out a reliable way to tell where they are, to help guide them to where they are going, and to get them back home again. Cavemen probably used stones and twigs to mark a trial when they set out hunting for food. The earliest mariners followed the coast closely to keep from
getting lost. When navigators first sailed into the open ocean, they discovered they could chart their course by following the stars. The ancient Phoenicians used the North Star to journey from Egypt and Crete. According to Homer, the goddess Athena told Odysseus to "keep the Great Bear on his left" during his travels from Calypso's Island. Unfortunately for Odysseus and all the other mariners, the stars are only visible at night-and only on clear nights.

The next major developments in the quest for the perfect method of navigation were the magnetic compass and the sextant. The needle of a compass always points north, so it is always possible to know which direction one is going. The sextant uses adjustable mirrors to measure the exact angle of the stars, moon, and sun above the horizon. However, in the early days of its use, it was only possible to determine latitude (the location on the earth measured north or south from the equator) from the sextant observations. Sailors were still unable to determine their longitude (the location on the Earth measured east or west). This was such a serious problem that in the 17th century, that the British formed a special board of longitude consisting of well-known scientists. This group offered $20,000, equal to about a million of today's dollars, to anybody who could find a way to determine a ship's longitude within 30 nautical miles.

The generous offer paid off. In 1761, a cabinetmaker named John Harrison developed a shipboard timepiece called a chronometer, which lost or gained only about one second a day-incredibly accurate for the period. For the next two centuries, sextants and chronometers were used in combination to provide latitude and longitude information.

In the early 20th century several radio-based navigation systems were developed, which were used widely during World War II. Both allied and enemy ships and airplanes used ground-based radio-navigation systems as the technology advanced.

A few ground-based radio-navigation systems are still in use today. One drawback of using radio waves generated on the ground is that one must choose between a system that is very accurate but doesn't cover a wide area, or one that covers a wide area but is not very accurate. High-frequency radio waves (like UHF TV) can provide accurate position location but can only be picked up in a small, localized area. Lower frequency radio waves (like AM radio) can cover a larger area, but are not a good yardstick to tell you exactly where you are.

Scientists, therefore, decided that the only way to provide coverage for the entire world was to place high-frequency radio transmitters in space. A transmitter high above the Earth sending a high-frequency radio wave with a special coded signal can cover a large area and still overcome much of the "notice" encountered on the way to the ground. This is one of the main principles behind the GPS system.
GPS ELEMENTS

GPS has three parts: the space segment, the user segment, and the control segment. The space segment consists of 24 satellites, each in its own orbit 11,000 nautical miles above the Earth. The user segment consists of receivers, which you can hold in your hand or mount in your car. The control segment consists of ground stations (five of them, located around the world) that make sure the satellites are working properly.

One trip around the earth in space equals one orbit. The GPS satellites, each take 12 hours to orbit the Earth. Each satellite is equipped with an accurate clock to let it broadcast signals coupled with a precise time message. The ground unit receives the satellites signal, which travels at the speed of light. Even at this speed, the signal takes a measurable amount of time to reach the receiver. The difference between the times the signal is sent and received, multiplied by the speed of light, enabled the receiver to calculate the distance to the satellite. To measure precise latitude, longitude, and altitude, the receiver measures the time it took for the signals from four separate satellites to get to the receiver.

The GPS system can tell us our location anywhere on or above the earth to an accuracy of about 300 feet. Even greater accuracy, usually less than three feet, can be obtained with corrections calculated by a GPS receiver at a known fixed location.

To help us understand the GPS system, let's take the three parts of the system—the satellites, the receivers, and the ground control—and discuss them in more detail to help us look more closely at how GPS works.
GPS consists of three major segments: the space segment, the user segment, and the control segment.

SATELLITES IN SPACE

As we’ve said, the complete GPS space system includes 24 satellites, 11,000 nautical miles above the Earth, which take 12 hours each to go around the Earth once (one orbit). They are positioned so that we can receive signals from six of them nearly 100 percent of the time at any point on earth. We need as many signals as possible to get the best position information. Satellites are equipped with very precise clocks that keep accurate time to within three nanoseconds (that is three billionths, or a second) or 0.000000003. This precision timing is important because the receiver must determine exactly how long it takes for signals to travel from each GPS satellite. The receiver uses this information to calculate its position.
GPS Block II is a production satellite first launched in 1989. Block II consists of 24 satellites, the last one launched in 1994.

The first GPS satellite was launched in 1978, and the first 10 were developmental satellites, called Block I. From 1989 to 1993, 22 production satellites, called Block II, were launched. The launch of the 24th satellite in 1994 completed the system.

GROUND CONTROL STATIONS AND RECEIVERS

Ground Control Stations

The GPS control, or ground, segment consists of unmanned monitor stations located around the world (Hawaii and Kwajalein in the Pacific Ocean; Diego Garcia in the Indian Ocean; Ascension Island in the Atlantic Ocean; and Colorado Springs, Colorado); a master ground station at Schriever (Falcon) Air Force Base in Colorado Springs, Colorado; and four large ground antenna stations that broadcast signals to the satellites. The stations also track and monitor the GPS satellites.
GPS is used by surveyors, utility companies, and oil and gas explorers for precise positioning.

**RECEIVERS**

GPS receivers can be hand carried or installed on aircraft, ships, tanks, submarines, cars, and trucks. These receivers detect, decode, and process GPS satellite signals. More than 100 different receiver models are already in use. The typical hand-held receiver is about the size of a cellular telephone, and the newer models are even smaller. The hand-held units distributed to U.S. armed forces personnel during the Persian Gulf War weighed only 28 ounces (0.8kg).

We know that the GPS system consists of satellites whose paths are monitored by ground stations. Each satellite generates radio signals that allow a receiver to estimate the satellite location and distance between the satellite and the receiver. The receiver uses the measurements to calculate where on or above the earth the user is located.

Now that we have an idea about how the GPS functions, let's see how we can put it to work for us. As we might imagine, GPS has many uses in both military and civilian life.
GPS FOR MILITARY USES

Although the GPS satellite constellation was completed only recently, it has already proved to be the most valuable aid to U.S. military forces. Without a reliable navigation system, U.S. forces could not have performed the maneuvers of Operation Desert Storm. With GPS, the soldiers were able to go places and maneuver in sandstorms or at night when even the troops who lived there couldn't. Initially, more than 1,000 portable commercial receivers were purchased for use. The demand was so great that, before the end of the conflict, more than 9,000 commercial receivers were in use in the Gulf region. They were carried by troops, soldiers and attached to vehicles, helicopters, and aircraft instrument panels. GPS receivers were used in several aircraft, including F-16 fighters, KC-135 aerial refuelers, and B-2 bombers; Navy ships used them for rendezvous, minesweeping, and aircraft operations.

GPS has become important for nearly all military operations and weapons systems. In addition, it is used on satellites to obtain highly accurate orbit data and to control spacecraft orientation.

GPS is based on a system of coordinates called the World Geodetic System 1984 (WGS 84), similar to the latitude and longitude lines we see on wall maps in school.
The WGS 84 system provides a built-in frame of reference for all military activities, so units can synchronize their maneuvers. More than 9,000 GPS receivers were used by U.S. and coalition forces during Operation Desert Storm.

**GPSUSES IN EVERYDAY LIFE**

The GPS system was developed to meet military needs of the department of defense, but new ways to use its capabilities are continually being found. As we have read, the system has been used in aircraft and ships, but there are many other ways to benefit from GPS. Just a few can be mentioned.

During construction of the tunnel under the English Channel, British and French crews started digging from opposite ends: one from Dover, England, one from Calais, France. They relied on GPS receivers outside the tunnel to check their positions along the way and to make sure they met exactly in the middle. Otherwise, the tunnel might have been crooked.

Remember the example of the car with a video display in the dashboard? Vehicle tracking is one of the fastest-growing GPS applications. GPS-equipped fleet vehicles, public transportation systems, delivery trucks, and courier services use receivers to monitor their locations at all times.

GPS is also helping to save lives. Many police, fire, and emergency medical service units are using GPS receivers to determine the police car, fire truck, or ambulance nearest to an emergency, enabling the quickest possible response in life-or-death situations.

Automobile manufacturers are offering moving-map displays guided by GPS receivers as an option on new vehicles. The displays can be removed and taken into a home to plan a trip. Several Florida rental car companies are demonstrating GPS-equipped vehicles that give directions to drivers on display screens and through synthesized voice instructions. No more getting lost on the way to Disney World!

Mapping and surveying companies use GPS extensively. In the field of wildlife management, threatened species such as the Mojave Desert tortoise are being fitted with GPS receivers and tiny transmitters to help determine population distribution patterns and possible sources of disease. GPS-equipped balloons are monitoring holes in the ozone layer over the Polar Regions, and air quality is being monitored using GPS receivers.

Archaeologists and explorers are using the system. Anyone equipped with a GPS receiver can use it as a reference point to find another location. With a basic knowledge of math and science, plus a hand-held GPS receiver, one could be an instant hero if he/she and friends got lost on a camping trip.
The future of GPS is as unlimited as our imagination. New applications will continue to be created as the technology evolves. The GPS satellites, like handmade stars in the sky, will be guiding us well into the 21st century.

The Aerospace Corporation was one of the GPS team members honored with the 1992 Robert J. Collier Trophy, awarded by the National Aeronautic Association for the greatest achievement in aeronautics in America.

**GPS TECHNIQUES AND PROJECT COSTS**

Receiver costs vary depending on capabilities. Small civil receivers can be purchased for under $200, some can accept differential corrections. Receivers that can store files for post-processing with base station filed cost more ($2,000-5,000). Receivers that can act as GPS reference receivers (computing and providing correction data) and carrier phase tracking receivers (and two are often required) can cost many thousands of dollars ($5,000 to 40,000). Military receivers may cost more or be difficult to obtain.

Other costs include the cost of multiple receivers when needed, post-processing software, and the cost of specially trained personnel.

Project tasks can often be categorized by required accuracies, which will determine equipment cost.

- Low-cost, single-receiver projects (100 meter accuracy)
- Medium-cost, differential positioning (1-10 meter accuracy)
- High-cost, single-receiver projects (20 meter accuracy)
- High-cost, differential carrier phase surveys (1 mm to 1 cm accuracy)

**HOW GPS WORKS**

So we can more easily understand some of the scientific principles that make GPS work, let's discuss the basic features of the system. The principle behind GPS is the measurement of distance (or "range") between the receiver and the satellites. The satellites also tell us exactly where they are in their orbits above the Earth. It works something like this: if we know our exact distance from a satellite in space, we know we are somewhere on the surface of an imaginary sphere with radius equal to the distance to the satellite radius. If we know our exact distance from two satellites, we know that we are located somewhere on the line where the two spheres intersect. And, if we take a third measurement, there are only two possible points where we could be located. One of these is usually impossible, and the GPS receivers have mathematical methods of eliminating the impossible location.
GPS UTILIZATION

In order to be put in use, the GPS has to be switched on. When switched on, it automatically starts to find or contact the different satellite constellations. By contacting more than three or four of the satellites, the position page (screen) appears. Subsequently, it starts receiving enough information from satellites if it is oriented to do so. After the appearance of the position page, one has to go to the place where he/she wants to record a ground (true) position. The 'MARK' button has to be pressed for taking the northing and easting positions of that point. Next, the 'SAVE' button has to be pressed for storing the acquired position. This procedure is repetitively done until the intended tasks are completed.

Since the system relies on satellite signals, the receiver should not be obstructed. GPS signals are relatively weak and do not travel through rocks, buildings, metal and materials such as thick canvas (Garmin; GPS 45 personal Navigator Reference Manual; 1996). A clear view of the sky generates the best performance.

WAY POINT STORAGE CAPACITIES OF SMALL CIVIL RECEIVERS

Like all the automated devices, GPSs have got different data storage capacities. In the case of LUPO, 45 XL GARM IN GPS stores a maximum of 250 positions/way points in a single-complete surveying session. The later model (GARM IN 12) stores exactly double of that amount. During the subsequent rounds, the GPS becomes full and downloading the data becomes imperative. Depending on the referencing system, the coordinate values referring to each position on the actual ground can be flexibly converted. Measurements in meters (UTM projection) can be altered to degrees of latitude and longitude, or vice versa. The coordinate reference values are, therefore, used either to directly and automatically make maps by appropriate computer programs or prepare manual sketches.

PART TWO: PRACTICAL USES IN THE CASE OF GTZ-LUPO

Uses in Land Use/Land Cover Surveys

Despite their importance for navigation and other military purposes, GPSs are being increasingly used for land use and resource inventory surveys. Accuracy levels for ground coordinate registrations mostly vary from 1 meter for urban cadastral surveys to 15 meters in rural surveys. Currently, the accuracy level for special-purpose GPSs has reached as high as 1 centimeter, i.e., ten times those used for urban cadastral surveys.

In many rural land use surveys, GPS is used for land use/land cover mapping at scales ranging from 1:10,000 to 1:5,000. Initial data are limited to coordinate pairs representing the Northing and Easting values for each reference point. Each reference point in GPS is given a discrete number known as way point. In the
mapping process, there are two ways of using the coordinate values, namely: direct downloading and manual sketching.

Direct downloading is an action by which digital GPS coordinates are directly transferred to a digital data processing environment of computer systems. The process requires the availability of hardware and software interfaces and application programs that assist data conversion, manipulation and analysis. Software interfaces facilitate the importing of positional data in the vector formats for point and line files, and putting respective points into value files.

In manual sketching, these values are used differently for objects represented by points, line and area. For point features, values are directly transferred to the appropriately referenced locations. In the case of lines, each coordinate pair has to be connected to the adjoining value. This also applies for objects representing area features. In both cases, the shapes of line and area features are manually oriented to resemble the physical realities in the field. Sketches are usually made on stable and grided-tracing papers. Grids help the accurate and appropriate tracing of values within the maximum and minimum extents of the survey area.
Background

The decision to use GPS for land use/land cover and land resource survey at the project came as the result of the problems faced to acquire up-to-date and scale-appropriate aerial photographs for the intervention areas of the project. At the sole provider agency (EMA), over 75.0 percent of the available aerial photographs of the project's intervention areas were taken before 17-20 years. In the light of investigating the existing land use/land cover and land resource situations, old photographs seldom provide appropriate information for planning and decision-making. The importance of such photographs would also become too marginal for areas largely characterized by high intensity and dynamism of the human and natural factors.

With the aim to utilizing up-to-date aerial photographs, the project approached the Sewed Survey for contractual exposures across the intervention areas. However, cloud cover created serious hindrance to the survey due to unexpected weather changes of the normal dry season. For a phased-project like LUPO, further tolerance meant unnecessary lagging in the production of information necessary for planning and decision-making.

LUPO, therefore, opted for the use of GPS for land use/land cover and land resources surveys. For the project, data acquisition through GPS provided an invaluable quality of spatial data particularly in the case of four areas (sub watersheds and pilot Kebeles) in Kuyu, Degem, and Abote Woredas in North Shewa Zone of Oromiz Region. The GPS-assisted surveys conducted so far in all pilot kebeles (West and North Shewa Zones) involved the three geographical features: points, lines and areas.

Area features include:

- Water points (protected and unprotected springs, stream eyes, etc);
- Social facilities (schools, clinics, churches, P.A. offices, flour mills, etc.);
- Individual tukuls (huts);
- D.A houses;
- Soil pits;
- Auger points for soil depth, textures, types, organic composition, etc.);
- Single standing trees;
- Agricultural diversification measures (Apple trees, Enset, and other fruit trees);
- Ponds.

Lines involve:

- Roads (tramac, all-weather, seasonal, footpath);
- Drainage (perennial main rivers, perennial tributary, seasonal);
- Gullies (linearly stretched);
GIS awareness workshop

- Administrative boundaries;
- Ridge (cliffs);
- Land use boundaries;
- Irrigation water channels;
- Lined trees;
- Soil and water conservation bunds;
- Biological conservation (SWC) strips (Vetiver, Susbania, trilucern, etc.);

Area features:

- **Land use/land cover consisting:**
  - Cultivated land (stable, stony, non-stony, degraded);
  - Grazing land (degraded and non-degraded);
  - Big tree plots;
  - Fallow land;
  - Shrub;
  - Rock outcrop;
  - Settlement area;
  - Nursery site;
  - Bare land (degraded);
  - Gully;
  - Scattered tree plots;
  - Forest land;
  - Conserved plots.

- **Land capability factors:**
  - Slope;
  - Waterlog;
  - Stoniness;
  - Effective soil depth;
  - Past erosions;
  - Rockiness.

The use of data from differing sources did not pass without posing problems of bringing all data sets to a common geographical reference. The mismatch had particularly been observed in integrating the digital topographic data (EMA) with that of the GPS-surveyed data set.

As can be observed from the following map, the differential coordinate revealed a mismatched average distance of 280 meters between the two data sources. The data unconformity portrayed not only distance differentials but also resulted in directional differences.

However, the mismatch can be resolved by geometrically orienting the GPS data to that of the Ethiopian Mapping Authority, although the work would consume
considerable time. For quality reasons, the adjustment function is much easier in Arc/Info where all spatial features of the GPS data have to be moved to the correct geometric positions and direction of the topographic data sets. In this regard, permanent topographic features like peaks, rivers and roads can be used as special aides of accuracy. Referencing to the EMA’s map data is justified mainly in the light of maintaining the data accuracy, consistency and maintaining official standards as most of the modeling functions will have to be performed on those grounds. The mismatch between the different data sources could likely results from:

- Differences in the techniques employed;
- Inherent differences in the technical accuracies of the platforms;
- Measurement accuracy of both data sources at times of acquisition; and
- Resulting human errors in the process of data collection, input and editing.

Practical Sequences in the Use of GPS

From the practical point of view, a successful GPS-assisted land use and land resource surveys at the local levels should follow the following logical orders:

- Setting the survey objectives;
- Preparing survey materials;
- Delineating the survey area;
- Conducting reconnaissance survey;
- Determining data defining the land use classes;
- Conducting field surveys;
- Tracing (transferring) the survey data onto tracing material;
- Verifying data completeness and accuracy;
- Preparing final base map;
- Digitizing base map (optional);
- Preparing final land use map.
GEOMETRIC MISMATCH BETWEEN DATA FROM DIFFERENT ORIENATIONS:
EXAMPLE OF YAYA MICHAEL LAND USE POLYGONS

LEGEND

GPS-surveyed data
Rectified according to EMA's topo map coords
Data collected using GPS can be quantified and displayed in graphical forms.

**Strengths and Limitations**

There are a number of known strengths and limitations in using GPS for land use and land resource surveys.

**Strengths**

- GPS can help avail detailed and up-to-date land use and land resource data in the absence also of up-to-date large-scale photographs;
- It is easy to use; and higher expert knowledge is not always necessary;
- Easy for handling in the field;
- Optional unit of measurement are available, flexible and conversion is automatic.
- There is enough flexibility in the scale of survey data;
- Three-dimensional measurement is possible;
- Survey costs are relatively cheaper even for large scale mapping;

**Limitations**

- There is high distortion for calculating areas in irregular terrains;
- Object representation for line and area features I relatively imperfect and always requires manual orientations;
- Digital conversion of coordinates needs computer skill;
- Obliteration can possible result in poor data quality;
- No easy maintenance;
- Reference incompatibility with other data sources (e.g., topography) requires additional geometric corrections.
REMOTE SENSING TECHNOLOGIES IN AGRICULTURE
PROCESSES, APPLICATION POTENTIALS AND
CONSTRAINTS

By
Demeke Nigussie

INTRODUCTION

Lack of appropriate decision making techniques for agricultural land use and resource management is one of the reasons for the low agricultural productivity in the country. Sustainable use and development is possible through wise utilization of resources based on their potentials and limitations. Population growth, migration, consumption of resources, proliferating crises and globalization of the economy create the need for more timely, accurate, cost-effective information products to meet these challenges (Neer, 1999).

In studying land resource potentials and constraints, there is a need to perform surveys with a view to discover their spatial distribution, structure and type. For a proper management and use, resources need to be inventoried, monitored, and then mapped to understand their extent and nature. Continuous inventory and mapping of resources of interest will enable one to assess and monitor periodic changes and trends. This information is indispensable for the purpose of management in agriculture, and forestry for informed decision-making in planning, for feasibility studies in land development projects and many engineering works (Lo, 1986). However, in Ethiopia, the potentials and constraints of land resources for agriculture are not well studied, quantified and documented and disseminated for appropriate decision-making. Even if there exists limited information, it is not documented in an easily accessible form.

Therefore, we need to give emphasis for collecting geo information about our ample natural resources so as to plan, manage and use them effectively. Geographic Information System (GIS), Remote Sensing (RS) and Global Positioning System (GPS) will have significant contribution for the collection and processing of geo information relevant to the agricultural sector of Ethiopia. The main use of RS is to enable acquire data on the environment and natural resources using a sensor system onboard a platform and extracting information through further processing and interpretation of that image. Though remote sensing has been introduced in Ethiopia a decade ago, it has shown no significant development in the country. With this viewpoint, this paper attempted to provide basic insight on the processes, potential uses and limitations of Remote Sensing Systems in agriculture.
1.1. Remote sensing terms and definitions
Remote sensing is the acquisition of data using remotely located sensor, and then the interpretation of that data to extract information by viewing the image and/or photographs and presented in map or statistical form (Aronoff, 1995, McCloy, 1995, Jenson, 1986 and Meaden and Keptesky 1991). Before going into the detail discussion of remote sensing it seems important to provide definitions for most common remote sensing terms.

- Spatial resolution - the minimum size of feature that can be differentiated by a sensor
- Temporal resolution: how often a satellite revisits a location.
- Spectral resolution - refers to the ability of a sensor to record the amount of energy reflected within specific segment of the electromagnetic spectrum.
- Radiometric resolution - the sensitivity of a detector to differences in signal strength to record the reflected or emitted radiant from the object.
- Multispectral - refers to remote sensing recording in two or more spectral bands.
- Sensor - a device that collects electromagnetic radiation and converts it to a signal (e.g. TM, MSS, HRV).
- Platform - is a stage that carries the sensor (e.g. aircraft, satellite).
- Pixel - a picture element of an image having spatial and spectral properties.

1.2. Historical Development
Historical development of the science of remote sensing began with the development of photography and photo-interpretation (McCloy, 1995; Aronoff, 1995). Since it is beyond the scope of this paper to provide the whole development process, it is advisable that readers of this paper refer Aronoff (1995), McCloy (1995), Allan (1990) and Meaden and Kaptesky (1991) for the detailed development of this technological history. The summarized development of RS starting from photography is illustrated in Table 2. These days, several remote sensing satellites with wide varieties of capabilities are launched and planned for launching. For instance IKONOS and Orb View are launched carrying high spatial resolution sensors. The earlier series of SPOT and LANDSAT are recently launched (SPOT 5 and LANDSAT 7) with extra capabilities in addition to the previous series.
Table 2: Historical development of remote sensing

<table>
<thead>
<tr>
<th>Year</th>
<th>Invention/operation</th>
<th>Responsible</th>
</tr>
</thead>
<tbody>
<tr>
<td>1822</td>
<td>The 1st photograph was taken</td>
<td>Daguerre and Niepce</td>
</tr>
<tr>
<td>1852</td>
<td>Demonstrated that photographs could be taken from a balloon</td>
<td>Touran Chon</td>
</tr>
<tr>
<td>1909</td>
<td>The 1st aerial photograph was taken</td>
<td>Wilbur Wright</td>
</tr>
<tr>
<td>1935</td>
<td>The first color separation film developed</td>
<td>Hauron</td>
</tr>
<tr>
<td>1935</td>
<td>Kodachrome evolved</td>
<td>Hauron and others</td>
</tr>
<tr>
<td>1935</td>
<td>Color film was 1st used from an aircraft</td>
<td>-</td>
</tr>
<tr>
<td>During WW I</td>
<td>The 1st radar was developed</td>
<td>U.K.</td>
</tr>
<tr>
<td>During WW II</td>
<td>The idea of thermal sensing to detect human and machine was 1st proposed</td>
<td>-</td>
</tr>
<tr>
<td>1950s</td>
<td>Devices to detect thermal radiation led to the development of scanners to satisfactory level</td>
<td>-</td>
</tr>
<tr>
<td>1950s</td>
<td>The 1st imaging radar was developed</td>
<td>U.S.A.</td>
</tr>
<tr>
<td>1960</td>
<td>The 1st meteorological satellite TIROS 1 launched</td>
<td>U.S.A.</td>
</tr>
<tr>
<td>1972</td>
<td>Satellite-born scanners were used for resource related purposes with the launch of ERTS-1 (Landsat-1)</td>
<td>U.S.A.</td>
</tr>
<tr>
<td>1978</td>
<td>The 1st satellite-born radar accessible to civilian community</td>
<td>U.S.A.</td>
</tr>
<tr>
<td>1986</td>
<td>SPOT satellite launched</td>
<td>French</td>
</tr>
</tbody>
</table>

2. PROCESSES

The remote sensing processes extend beyond data acquisition and analysis steps. The principal steps used to analyze all remotely sensed data are as:

1. Definition of information needs;
2. Collection of data using remote sensing and other techniques;
3. Data analysis;
4. Verification of analysis results;
5. Reporting of results to those who will use the information;

The information needs should be defined considering accuracy needed, how quickly it is needed, when the information should have been collect (e.g. within the past year or in a particular season.), the cost to produce it, and the form (e.g. electronic, paper map, tabulated) in which it is needed (Aronoff, 1995).
2.1. Basic Concepts of Remotely Sensed Data Collection

Remote sensing uses electromagnetic energy to acquire data about the Earth. The electromagnetic radiation reflected or emitted from the earth is detected and recorded by sensors carried by a platform (Satellite, air craft, spectro-radiometer, etc). Then, the data recorded by the sensors will be transmitted via telemeter to ground stations. Using the available facility relevant and understandable information (digital or analog) is extracted and disseminated potential users. From this process one can see the required components for the job: namely, energy source, sensor/platform, data, digital and/or analog facilities for image processing; experienced personnel for information extraction and users. In the data collection, the spectral response difference of various Earth's features to the different wavelengths of electromagnetic radiation (EMR) is important aspect.

2.1.1. Electromagnetic Radiation and Spectral Characteristics of Vegetation, Soil and Water

The electromagnetic wavelengths most important in remote sensing systems are the Visible, Near Infrared (NIR), Mid-infrared (MIR) and Thermal Regions. Electromagnetic radiation incident to a surface is reflected, absorbed or transmitted. The nature of the reflection at the interface depends upon:
- the angle of incidence of energy
- surface roughness, and
- The materials on either side of the interface as they will affect the angle of refraction and the percentages that are reflected, absorbed and transmitted at the interface (McCloy, 1995).

![Figure 1: The Electromagnetic Spectrum](image)

Remote sensor systems record the amount of energy reflected or emitted by targets (earth's feature) on selected wave bands. The identification of earth's features by using multi-spectral data is primarily dependent on the spectral response of the various earth's features. So, it is important to know about the characteristics of electromagnetic waves in relation with the different responses of various earth's features.
The discrimination of earth's features is possible due to the spectral response differences of various earth's surface features in space and time at different wavelengths. Figure 2 shows the general pattern of responses of soil, vegetation and water at different wavelengths.

Land cover types most important in agriculture are vegetation, soil and water. In this section, a brief description of the reflectance characteristics these important features are provided.

Figure 2a and 2b. Reflectance spectra of typical features

**Vegetation**

The spectral response of a vegetation depends on the anatomical structure of the leaves, age, pigment, leaf type, leaf moisture content, mineral deficiencies, pest and disease attacks stress conditions, etc. Though all plants respond generally in the same way to incident radiation, there are small and important differences in the reflectance of different species that may eventually be used to obtain better information out of remotely sensed data (McCloy, 1995). The major differences in reflectance between species are dependent upon leaf thickness that affects both pigment and physiological structure (Curran, 1985). Figure 2, illustrates the reflectance property of typical healthy green vegetation. In the visible region, the pigmentation of leaves is the dominant factor in the spectral behavior of the vegetation; most of the incoming radiation is absorbed and the remainder is reflected. The internal structure of leaves determines the amount of reflectance of the NIR region. The moisture content of a plant is also the dominant factor affecting the spectral properties in the MIR region of EMR. Because of this, healthy green leaves
have low reflectance in red and blue, medium reflectance in green and high reflectance in NIR.

It is obvious that it is not the individual plant, which is detectable, but the surrounding soil-background and plant canopy planted with the same or different species. The nature of canopy and soil background also controls the nature of reflectance. Fundamentally, canopy reflectance is due to:

- Optical properties (reflectance and transmittance) of leaves
- Reflectance of soil background
- Canopy geometry-leaf angle, distribution and leaf area index
- Illumination angle, atmosphere, etc (Myers et al 1983).

In addition, transmittance of leaves, amount and arrangement of leaves characteristics of other components of the vegetation canopy (stalks, trunks, limbs), characteristics of the background (soil reflectance, amount of leaf litter solar zenith angle, look angle; and azimuth angle may be very important in determining the image tone (reflectance) of a vegetation canopy (Myers et al 1983).

Table 2: Sources of variation in multi-spectral signatures of vegetation (Barry and Curtis 1986)

<table>
<thead>
<tr>
<th>Illumination condition</th>
<th>Physiological conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illumination geometry (sun angle, cloud distribution)</td>
<td>Turgidity</td>
</tr>
<tr>
<td>Spectral distribution of radiation</td>
<td>Nutrient levels</td>
</tr>
<tr>
<td></td>
<td>Disease</td>
</tr>
<tr>
<td></td>
<td>Heat-exchange process</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site environmental condition</th>
<th>Atmospheric conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meteorologic</td>
<td>Water vapor</td>
</tr>
<tr>
<td>Micrometeorologic</td>
<td>Aerosols</td>
</tr>
<tr>
<td>Hydrologic</td>
<td>etc.</td>
</tr>
<tr>
<td>Edaphic</td>
<td>Absorption, scattering, emission</td>
</tr>
<tr>
<td>Geomorphologic</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reflective and emissive properties</th>
<th>Viewpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>spatial properties (geometrical forms, density of plants &amp; pattern of distribution)</td>
<td>observation geometry (scan angle, heading relative to sun)</td>
</tr>
<tr>
<td>spectral properties (e.g. reflectance or color)</td>
<td>time of observation</td>
</tr>
<tr>
<td>thermal properties (emittance and temperature)</td>
<td>altitude</td>
</tr>
</tbody>
</table>
Plant conditions
- Maturity
- variety

Multi-channel sensor parameters
- electronic noise, drift, gain change
- Accuracy and precision of measurements on calibration reference and standards.
- Differences in spectral responses of systems.

Soil

The spectral response of soil is controlled by factors such as texture, organic matter content, color, moisture contents, etc. Several studies have shown that an increase in moisture content (Figure 3), particle size, iron oxide and organic matter content of soil caused a decrease in reflectance of the electromagnetic spectrum; whereas a decrease in surface roughness caused an increase in the reflectance of EMR. One of the most important remote sensing data collection problems is disentangling the contribution of these constituents to the remote sensing spectra (http://info.er.usgs.gov/research/GIS, after Jensen and Cowen, 1997; 1999; Cowen and Jensen, 1998). So, to identify which factor contributed to the level of reflectance and accurately identify the soil characteristics, there is a need to carry out ground check and may need to use two data or higher resolution multi-date data.

Figure 3. Reflectance spectra of silty loam soil for different moisture contents (Allan 1990 after Bowers and Hanks, 1965)
Water
The reflectance of water is affected by the varying condition of the water. As illustrated in figure 3, the water absorbs most of all incident NIR and MIR regions of EMR. The reflectance from the clear and deep water decreases with an increase in the wavelength of EMR. Suspended materials, chlorophyll, etc. in the water are important factors affecting the spectral response of water. Some studies have shown that an increase in suspended materials increases the reflectance and an increase in chlorophyll concentration in the water significantly decreases in the blue and increase in the green bands. Such properties assist to clearly locate and identify water bodies from the surrounding using remote sensing systems.

2.1.2 Development of Remote Sensing Satellites and Sensor Systems
Among resource satellites, SPOT and LANDSAT satellites are most commonly used. These brought about satellite RS into operation. There are other resource and meteorological satellites launched in various years by different countries. ERS (Europe), IRS (India), JERS (Japan), IKONOS, Orb View (1-4) and RADARSAT (Canadian) are among some. Sensors systems onboard like satellites vary in capabilities such as:

- Spatial and temporal, resolution;
- Spectral resolutions (spectral band width) and radiometric resolutions;
- Spectral coverage (spectral band location);
- Spectral dimension (No. of bands)
- The scanning method (Push broom; or swivel scanning);
- Altitude of operating;
- The swath width (or scene size);
- Presence or absence of stereoscopic viewing capability, etc.

Figure 4. Multistage Remote sensing platforms
Several resource satellites are launched and will be launched with enhanced capabilities like, Orb view (acquiring, 1mX1m pan and 4mX4m hyperspectral imagery which will be useful for classifying material types on the Earth's surface—beneficial in agriculture and forest management, mineral exploration, environmental
monitoring and national security activities); LANDSAT 7 (with 15m, 5m and 10m imagery over large scene areas, normally 60x60 km, but also up to 120 km wide, and will also carry the vegetation sensor with 1 km resolution daily Earth coverage (ERDAS, 20000, QuickBird, etc. Some satellites systems have the capability tailored image acquisition program to suit users data requirements. Such systems such s SPOT can be programmed to collect the type of image data needed, with the geographic coverage users need, in the time users need it. When ordering, there is a possibility of ordering full or sub-scenes of satellite images to fit into the interest area of study (ERDAS, 2000).

2.2 Information Extraction Process

There are several steps to be carried out to convert remote sensing data into meaningful information. Information extraction from the raw data could be through visual interpretation, computer assisted processing or both. In this process, it is advantageous to exploit both visual and digital image processing. Before visual or digital information extraction, there is a need to perform geometric and radiometric corrections using ephemeris or ancillary data (Jensen 1986).

Visual interpretation

Visual interpretation is one of the important methods of information extraction from satellite imageries and aerial photographs. It can be done with using analogue equipments such as stereoscopes, Zoom-transferscopes, Optical projectors, light, tables, etc. Size, color/tone, shape, shadow, texture and patterns of objects are important interpretation elements to identify objects from the imagery or aerial photograph.

Digital image processing:

Before the actual information extraction, there are some tasks that need to be done depending on the nature of the data. The most common steps in digital image processing of remotely sensed data are: preprocessing, image enhancement, image correction (geometric and radiometric), image (supervised and unsupervised) classification, and accuracy assessment.

Digital image processing is a system designed for the radiometric and geometric correction, enhancement, and computer-assisted interpretation (Classification) of digital remotely sensed data.
**Preprocessing**
Satellite images are not free of errors. There are a number of internal and external errors in remote sensing data collection. So to successfully extract information, a preprocessing step are needed to correct the raw data both radiometrically and spatially.

**Enhancement:**
To improve the visual interpretability, image enhancement process is also an important step in remote sensing. The enhancement technique includes: contrast stretching, edge enhancement, spatial filtering, principal component analysis, ratios and various indexes, etc.

**Classification**
In the digital image classification, there are two main techniques, unsupervised and supervised image classification.

In the supervised classification technique, the analyst needs to select homogenous, representative sites called training sites from the image to train the computer to look for surface features with similar reflectance characteristics. Based on these training sites, the computer classifies the whole image. In contrast, unsupervised classification technique requires only a minimum initial input from the analyst. The computer program does this by identifying typical patterns in the reflectance data. These patterns are then, identified by undertaking site visits to a few selected examples to determine their class types.

Accuracy assessment (Validation) of the extracted information is also an important step in the whole process or remote sensing.
3. APPLICATION POTENTIALS AND LIMITATIONS OF REMOTE SENSING

3.1 Applications Vs Resolution

Resolution parameters (spatial, spectral, temporal and radiometric of the sensor system is very important in remote sensing as it has effect on the detail of the recorded data. The application of the remote sensing system depends on the resolution of a sensor system. Davis and Simonett et al (1991) suggest that for low contrast targets, the effective resolution of sensors required for analysis may be as much as 10 times less than that for identification and 30 times less than that for detection. Table 3 below illustrates the relationship of various applications or attributes and the resolutions (temporal, spatial and spectral). The agricultural area should be sufficiently large to enable the resolving power of observing system to be relevant; i.e., the agricultural parcel must be at least four times the normal area of the recording pixel to be sure that there is no effect from the mixed pixel boundaries (Allan, 1990). Jenson (1986) also stated that classification accuracies become acceptable for most RS in agriculture and forestry applications when the field sizes are greater that 60 IFOV’s in size.

The spatial resolution of a remote sensor varies with the task to which the data are applied, specifically:

1. Detection-determining the presence of an object;
2. Identification-labeling of an object and
3. Analysis - where information is obtained about an object beyond its initial detection and identification (Davis and Simonett, 1991).

Table 3: Relationship between Biophysical Attributes and the minimum remote sensing resolutions required (http://info.er.usgs.gov/research/GIS)

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Minimum resolution requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Temporal</td>
</tr>
<tr>
<td><strong>Vegetation</strong></td>
<td></td>
</tr>
<tr>
<td>V1 - Type and biomass-level I (continental)</td>
<td>Daily</td>
</tr>
<tr>
<td>V2 - level ** (regional)</td>
<td>1-5 years</td>
</tr>
<tr>
<td>V3 - Species (local)</td>
<td>1-10 years</td>
</tr>
<tr>
<td>V4 - Stress</td>
<td>1-2 weeks</td>
</tr>
<tr>
<td>V5 - Moisture content</td>
<td>1-2 weeks</td>
</tr>
<tr>
<td>V6 -Landscape ecology metrics (patch)</td>
<td>1-2 years</td>
</tr>
<tr>
<td>V7 - Surface roughness</td>
<td>1-2 years</td>
</tr>
<tr>
<td>V8 - Canopy structure (stems, branches)</td>
<td>1-2 months</td>
</tr>
<tr>
<td><strong>Water</strong></td>
<td></td>
</tr>
<tr>
<td>W1 - Land surface water extent</td>
<td>1-2 years</td>
</tr>
<tr>
<td>W2 - Ocean water extent</td>
<td>Daily</td>
</tr>
<tr>
<td>W3 - Depth (bathymetry)</td>
<td>1-10 years</td>
</tr>
<tr>
<td>W4 - inorganic matter -Suspended sediment</td>
<td>1-10 days</td>
</tr>
<tr>
<td>W5 - Organic matter-phutoplankton, Chl a</td>
<td>1-10 days</td>
</tr>
<tr>
<td>W6 - Dissolved organic matter</td>
<td>1-10 days</td>
</tr>
<tr>
<td>W7 - Temperature</td>
<td>1-2 days</td>
</tr>
<tr>
<td><strong>Soils and Rocks</strong></td>
<td></td>
</tr>
<tr>
<td>SR1 - Inorganic matter-mineral content</td>
<td>1 - 10 years</td>
</tr>
<tr>
<td>SR2 - Organic matter-humus</td>
<td>1 - 10 years</td>
</tr>
<tr>
<td>SR3 - Hydrothermal alteration (clay, mica)</td>
<td>Monthly</td>
</tr>
<tr>
<td>SR4 - Soil moisture</td>
<td>20-30 m</td>
</tr>
<tr>
<td><strong>Atmosphere</strong></td>
<td></td>
</tr>
<tr>
<td>A1 - Cloud extent daytime</td>
<td>Hourly</td>
</tr>
<tr>
<td>A2 - Cloud extent nighttime</td>
<td>Hourly</td>
</tr>
<tr>
<td>A3 - Cloud temperature</td>
<td>Hourly</td>
</tr>
<tr>
<td>A4 - Water vapor</td>
<td>Hourly</td>
</tr>
<tr>
<td>A5 - Ozone</td>
<td>Monthly</td>
</tr>
</tbody>
</table>
Remote Sensing

Remote sensing satellites have collected over 7 million images (ERDAS, 2000) and more than 120,000 gigabytes of data from LANDSAT, 12,000 gigabytes of data from AVHRR, and more than 880,000 declassified intelligence satellite photographs are held at the EROS data Center (http://info.er.usgs.gov/research/GIS). Landsat 7 alone collects 250 scenes per day (Medias, December 1999, No 11). The total holdings by the year 2005 will come to some 2,400,000 gigabytes of data – an ocean of information stored as bits and bytes on computer media (http://info.er.usgs.gov/research/GIS). Provided that there is enough and skilled manpower, data and appropriate facility, remote sensing has the promising potential to be applied in several fields of agriculture (management and scientific application) (Table 4).

RS is time and cost effective as a result of the following comparative advantages.

- The swath width of satellites is larger, consequently it covers wider area at a single scene.
- Being a digital, it reduces the need for digitalization cost and time.
- Compared with aerial Photograph and ground surveying methods, satellite system data collection is significantly cheaper.
- The spectral resolution of most resource satellite is good. This enables the detection and discrimination of different land features. This is so because the spectral response of land features varies with wavelength. This is one of the best advantages of satellite data, which enable us to apply a single imagery to various application areas.
- Most resource satellites have less than 26 days revisit capability of an area. The data, which is obtained repeatedly, is good for spatial and temporal change analysis and monitoring.

Table 4. Agricultural applications of remote sensing (Allan, 19900)

<table>
<thead>
<tr>
<th>Management applications of remote sensing</th>
<th>Scientific applications of relevance in agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Agriculture</td>
<td>• Crop science</td>
</tr>
<tr>
<td>▪ Agro-ecology</td>
<td>▪ Vegetation indices</td>
</tr>
<tr>
<td>▪ Crop damage</td>
<td>▪ Stress detection</td>
</tr>
<tr>
<td>▪ Crop condition</td>
<td>▪ Agro-climatology</td>
</tr>
<tr>
<td>▪ Crop inventory</td>
<td>▪ Agro-ecology</td>
</tr>
<tr>
<td>▪ Crop classification</td>
<td>▪ Hydrology</td>
</tr>
<tr>
<td>▪ Livestock inventory</td>
<td>▪ Surface run-off</td>
</tr>
<tr>
<td>▪ Yield estimation</td>
<td>▪ Ground water</td>
</tr>
<tr>
<td>▪ Yield prediction</td>
<td>▪ Land surface</td>
</tr>
<tr>
<td>▪ Degraded land studies</td>
<td>▪ Terrestrial ecosystems</td>
</tr>
<tr>
<td>▪ Environmental impact studies</td>
<td>▪ Soil science</td>
</tr>
<tr>
<td>▪ Of agricultural development</td>
<td>▪ Vegetation</td>
</tr>
<tr>
<td>▪ Of urban development</td>
<td>▪ Rangeland management</td>
</tr>
<tr>
<td>▪ GIS contributions to regional</td>
<td>▪ Range land</td>
</tr>
<tr>
<td>agricultural information</td>
<td></td>
</tr>
</tbody>
</table>

82
Management applications of remote sensing | Scientific applications of relevance in agriculture
--- | ---
- Irrigated lands  
  - Inventory  
  - Monitoring extent  
  - Crop condition  
  - Water utilization  
  - Regulation of water use  | - Range land condition  
  - Range land classification  
  - Range production  
  - Soil survey  
  - Vegetation science, including forestry

The actual potential and limitations of remotely sensed imageries depend on several factors. Some of these are:

- The application scale
- The purpose
- The details needed
- The timeliness and
- The cost effectiveness

The availability of satellite data from existing and future high resolution satellites helps in generating information in greater details and in facilitating updating of existing records. These data also serve as useful inputs in prioritizing implementation of area development plans and effective monitoring (Perumal, et al. 1997).

The potential advantages of remote sensing for agriculture and resource management are numerous. Myers Et al (1983) provided a good summary of the main potentials of remote sensing which include:

- accelerated surveys;
- Capability to achieve a synoptic view under relatively uniform lighting conditions;
- Availability of multi-spectral data providing increased information;
- Capability of repetitive coverage to depict seasonal and long-term changes;
- relative inexpensive cost of monitoring from space;
- The opportunity of integrating existing surveys into unupdated monitoring system;
- Change detection capabilities needed by the regulatory programs for updating information of vegetation/terrain conditions;
- Availability of imagery with minimum distortion, thereby permitting direct measurements of agro-physical parameters; and
- Provision of a permanent record
Aspects contributing for the growing potential of application of RS

Changing world dynamics and associated geographical landscapes, rapidly advancing high speed, low cost, commercial computer technology; and the ever-increasing demand for content rich, digital earth information has encouraged entering the domain of commercial high-resolution earth imaging from space (Neer, 1999). The following are some of the contributing factorsto the dynamic growth of remote sensing.

1. **Computer technology**: The continuing and rapid decline in the cost of storage and the computer processes. Is a key economic factor in the commercialization of remote sensing. (Neer, 1999).

2. **Communication technology**: Now a days, one can browse using the Internet to:
   - Identify available image coverage of interest area.
   - Types of products available for various sensors
   - And order images.

3. **GPS technology**: is important device that can be used in the training sample location and accuracy assessments of image classification. It also facilitated the ground control point collection process for image rectification.

4. **Satellite technology**: rapid advancement of satellite technology in type, capability and number (see section 2.1.2).

5. **Media of data exchange**: data transition costs have been dropping rapidly over the decades as both electronic dissemination costs and media (tape, disks) costs have dropped from $1000’s per gigabyte in the 1970s to today about $1-10 per gigabyte for media recordings and surface ‘transmission’ costs (Neer, 1999).

6. **Software programs**: the parallel development of software programs for processing such complex data: In the erdas imagine release, for instance, hyperspectral capabilities are to be included as a core part of the software, which will use wizard-based interfaces (GEOEurope, May 2001, page 31-32).

7. **Data analysis**: development of various data analysis and integration techniques: various models and programs with wide capabilities of data integration and analysis are rapidly being developed.

### 3.3. LIMITATIONS

**3.3.1. Limitations of remote sensing (general)**

Although remote sensing is cost effective, there is a problem of comparing input and output costs when the monetary values for the benefits cannot be determined
adequately. The benefits cannot be quantified without extensive cost-benefit analysis. The cost-effectiveness depends on inputs, which comprise data type, equipment type, personnel qualification, and method of data analysis (RCSSMRS, 1993).

The following are some of the general drawbacks for introducing and using remote sensing techniques.

- It needs technically skilled personnel
- Accessibility to the data:
  - the need for near receiving stations
- Spatial resolution of most of satellites sensors is relatively low
- It needs sophisticated processing facilities (establishment cost is higher)
- It needs could free condition except satellites with active sensors
- It needs intensive field work (ground truthing)
- The need for high storage capacity (Figure 5).
3.3.2. Challenges in the Application of RS for Agriculture in Ethiopia

The agricultural system of Ethiopia is based on traditional smallholders. This resulted in a very small and fragmented size of fields with almost homogenous coverage. So, the detection and identification of such small fields will not be easy using low-resolution satellite. In addition, the cropping season most of the time is covered by cloud, which hinders data acquisition using passive sensor systems. For such conditions, radar satellites systems are appropriate since they can work in any weather condition any time (day and night time). The other challenge in Ethiopia is that since there is no defined land information system to supplement the identification and classification of satellite images, using such variables as land use, land cover, and land holding information, becomes difficult to identify permanent and seasonal vegetation covers, using a single scene. It is not also easy to discriminate between cropped and grass and related covers using low-resolution satellite images. This implies that there is a need for multi-date for appropriate identification of a particular feature in most cases. But there is still a challenge for acquiring multi-date data due to cost of satellite images. Even though they are relatively inexpensive, it is not still affordable to purchase multi-date data for such a large country. The application of remote sensing in the country is limited due to:

- Lack of awareness
- Lack of budget allocation for data purchasing
- Lack of timely data
- Lack of trained manpower
- Lack of facilities
- Lack of ancillary data and lack of appropriate information on land use, land cover,

Fragmented nature of land holdings

4. SYNERGISTIC APPROACH TO IMPROVE RS APPLICATION

Remote sensing should not be considered as a sole data source. Data from available GIS-database, field data, GPS data collection and other relevant ancillary data should be incorporated in the analysis process. GIS and remote sensing in combination with GPS are dynamic tools used to collect analyze and report information for appropriate spatial decision-making. GIS and remote sensing have complementary capabilities. Now a days, GIS/RS software developers are producing software that can handle image (raster) and vector data referred as hybrid types. This development has simplified data integration for extracting more reliable information. Even though some software enables us displaying and superimposing various raster and vector data, some lack image-processing capabilities.
Analysis capabilities of remote sensing can be improved by the verification of data retrieved from a GIS, and GIS applications can benefit from the information remote sensing can generate. The integrated use of remote sensing and GIS methods and technology cannot only improve the quality of geographic information, but also enable information to be economically produced (Aronoff, 1995).

Sustainable land management technologies require repetitive information on current status and utilization potential of natural resources. Satellite remote sensing data in conjunction with collateral data proved to be very effective in meeting these requirements. Geographic Information System (GIS) served as a very effective tool in the storage, manipulation, analysis, integration and retrieval of information. The synergistic use of these front line technologies helped to evolve an 'action plan' which was quite useful in planning for sustainable management of land resources (Perumal, A. Et al, 1997).

5. OVERVIEW OF REMOTE SENSING APPLICATIONS AND EXISTING REMOTE SENSING DATA ON ETHIOPIA

Remote sensing and GIS facilities and applications are inadequate in the country. This is partly due to the lack of capacity of institutions in identification and purchasing of appropriate hardware, software, and data; and due to lack of human resource development through local and abroad training.

Even if there are some organizations with GIS/RS capacity, the existences of such capacity are not easily known. This is because; most of the data they hold and study results are not announced or distributed for potential users and are located in a fragmented state. Though it is not easy to provide a comprehensive listing, since it is beyond the scope of this paper, the potential remote sensing data holders and users are stated in the sections to follow. This listing is expected to help to improve awareness on studies conducted using remote sensing, the potential facility, manpower availability and sources of remotely sensed data and study results. This section gives special emphasis to the experiences of EMA for many reasons. First, EMA is mandated for such responsibility, and second the present while working in EMA participated and experienced most of the application constraints and successes and different applications. Third, EMA has undertaken many researches using Remote Sensing, GIS and GPS.

5.1. Existing remotely sensed data and institutions possessing and are expected to possess such data (partial listing)

* **Ethiopian Mapping Authority:**

  * **Aerial photographs**
    * Aerial photographs of 1950s and 960s covering 95% of the country;
Remote Sensing

- Aerial photographs since 1970s for 1:50,000 Topo-map preparations covering is almost 75% of the country.
- Up to 1:2000 scale Aerial photographs of urban and rural development areas—major town, large-scale farms, mineral exploration areas, etc.

Satellite imageries

1. LANDSAT MSS of 1973—covering the whole country;
2. LANDSAT TM since 1988—Benishangul Gumuz, Afar and Somali (fully covered), Oromiya (most), SNNPR (partly), and Amhara (small) are covered;
3. SPOT-XS—since 1986 covering the whole Gambela and few areas in SNNPR;
4. Kate 1985/84 covering the whole country.

Several Federal and Regional Bureaus, NGOs and international organizations are expected to possess satellite images. Unpublished work by Gobel and Thomas (1999) overviewed and identified a number of projects and offices and documented the existing land-resource data in the form of digital or paper maps on Ethiopia. According to this source, the following are some of the institutions holding remotely sensed data.

1. Woody Biomass Inventory and Strategic Planning Project (WBISPP): used LANDST-TN and ERS imageries. WBISPP possesses LANDSAT image coverage of about 30% of the country (the Central and South Western parts). Since the project continues until 2003, the coverage of satellite images is expected to be much higher than this.
2. Ministry of Water Resources: used satellite image interpretation of LANDSAT for the entire areas of each basin, and SPOT images for selected sites. But it was not ascertained whether the imagery is in the form of digital or paper print.
3. National Meteorological service Agency (NMSA); operates a satellite receiving station for meteorological satellites (Meteosat and NOAA).

5.2. Applications of Remote Sensing Technology in Agricultural Resource (some example from Ethiopia)

*Ethiopian Mapping Authority*

a) Pilot project studies

- Land use land cover and change detection of Lake Aba Samuel and its surroundings.
- Land use/cover classification of Addis Ababa using LANDSAT-TM
- Environmental impact assessment of areas of Lakes Ziway, Koka, Abaya and Chamo
b) **Researches in cooperation with science and technology**

- Human impact on physical environment of Tana-Beles area
- Land cover and soil study of Ziway area
- Liminological study of Abijata and Shala lakes
- Topographic mapping with the aid of SPOT stereoscopic images.

c) **Researches by users' requests**

The projects from users' request estimated to be about 40. Some of such studies include:

- Refugee related environmental impact assessment of Western Ethiopia (Bonga, Pugnido, Dimma and Sherkole); and Eastern Ethiopia.
- 1:250,000 scale national topographic map revision
- Land use/cover study of Afar and Benishangul-Gumuz Regions using satellite images
- Natural resource assessment of Somali Region
- Multi-temporal data analysis of River Chemoga Watershed (E.Gojam); etc.

**CONCLUSION**

For sustainable land management and use, consistent, appropriate and use, consistent, appropriate and timely information on the potential and constraints of natural resources is essential. In meeting the information acquisition and processing requirements, remote sensing and GIS are very effective tools. Remote sensing is very efficient for data collection, analysis and integration of information. So, considering the comparative advantages, it is advisable to use satellite imageries whenever it is found appropriate to save time and money. Various institutions in the country should also collaborate in the information exchange to avoid duplication of effort and data.

**REFERENCES**


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