The Use of Geographic Information Systems for Disaster Risk Reduction Programmes in Africa

-User Manual-

Paola Rosa Fava, Steffen Fritz, Alexandre Castellano

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The manual aims to provide support to Aid Agencies working in Disaster Risk Reduction contests.

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ACRONYMOUS

CBO	-	**Community based Organization**
COOPI	-	**Cooperazione Internazionale**
CPC	-	**Civil Protection Committee**
DRM	-	**Disaster Risk Management**
DRR	-	**Disaster Risk Reduction**
GDB	-	**Geographical Database**
GE	-	**Google Earth**
GFDRR	-	**Global Facility for Disaster Reduction and Recovery**
GIS	-	**Geographic Information System**
GPS	-	**Global Positioning System**
GVH	-	**Group Village Head**
HFA	-	**Hyogo Framework of Action**
KML	-	**Keyhole Mark-up Language**
ISDR	-	**International Strategy for Disaster Reduction**
M&E	-	**Monitoring and Evaluation**
NSO	-	**National Statistic Office**
NGO	-	**Non Governmental Organization**
PGIS	-	**Participatory Geographic Information System**
PRA	-	**Participatory Rural Appraisal**
RAM	-	**Random Access Memory**
RDBMS	-	**Relational Database Management System**
ROM	-	**Read Only Memory**
RS	-	**Remote Sensing**
SDMS	-	**Spatial Database Management Systems**
SI	-	**Satellite Images**
TA	-	**Traditional Authorities**
TEK	-	**Traditional Ecological Knowledge**
UN	-	**United Nations**
UNITAR	-	**United Nations Institute for Training and Research**
UNOSAT	-	**UNITAR Operational Satellite Applications Programme**
UNSPIDER		**United Nation Platform for Space-based Information for Disaster Management and Emergency Response**
WB	-	**World Bank**

SUMMARY

The development of this manual is part of one of the activities of a Disaster Risk Reduction project in Malawi, funded by DIPECHO and implemented by COOPERAZIONE INTERNAZIONALE (COOPI), an Italian Non Governmental Organization

Since the ‘80s, the interest for Geographic Information Systems (GIS) has been rising both in the private and the no-profit/humanitarian sectors, as a tool to monitor land use changes, rivers patterns, evolution of disaster risk areas, etc. The great advantage of GIS is the possibility to merge different information from several sources and visualize them on a unique map thanks to a georeferencing process.

The purpose of this manual is to provide useful information, practical solutions and advices in the implementation of Geographic Information System and other remote sensing instruments (RS), such as satellite images and Global Positioning System (GPS), with reference to specific web sites, on line sources, books, tutorials and other documents.
Specific focus is given to the use of GIS in Disaster Risk Reduction activities. GIS has been considered a fundamental tool in order to act promptly in case of floods, earthquakes or other natural disasters by enabling to use available spatial information. This information can be gathered through the combination of traditional knowledge at ground level and remote sensing techniques. This could be particularly useful in projects run by governments, NGOs and other International Organizations.

This manual is divided into four chapters.

Chapter 1 introduces the reader to GIS and its components. Other remote sensing tools, such as satellite images and GPS, are also described including some useful links and information about data sources, satellites properties and purchasing details. A short paragraph describes Google Earth as a powerful and user-friendly tool that is significantly influencing the future of geographical information systems.

Chapter 2 focuses on the implementation of GIS. Technical requirements, including hardware and software specifications, human resources required and recommended steps are described in this

chapter, as well as, related constraints that would eventually limit the application of GIS in developing countries, such as political instability, slow internet connection to obtain data, etc.

In Chapter 3, the use of GIS in Disaster Risk Reduction project management is described. The importance of GIS system in DRR has been continuously growing as it provides immediate and up to date information during emergency. Particular attention has been given to flood cases, with some specific case studies of GIS applications in Africa and Asia.

Finally, Chapter 4 is dedicated to the specific case study of GIS tools applied to a disaster risk reduction project in Salima district in Malawi, implemented by COOPI and funded by DIPECHO. The project describes the integration of several GIS tools: from National geographic data, Participatory Rural Appraisal (PRA) maps and satellite images, to GPS mapping process, providing a significant example of an effective methodology for GIS in DRR.

1. Introduction to GIS and Remote Sensing in developing countries

1.1 What are GIS and its components?

A **Geographic Information System (GIS)** or **Geographical Information System** is any system that integrates, captures, stores, analyzes shares, manages, and displays data that is linked to location or so called geographic data. GIS merges computer database technology with geo-referenced and cartographic information, resulting in digital maps and databases with fundamental applications in areas such as natural resource management, ecosystem conservation, environmental studies, utility management, infrastructures and transportation planning, town and regional planning, municipal government and also commercial applications. It is an ideal tool for integrating data from the land itself (e.g. data gathered from satellites) and socio-economic data (e.g. tax records).

Although there are several definitions of GIS, ranging from the technologically-based to those focusing on organizational aspects, GIS is about evaluating geographical relationships through spatial analysis, database management and graphical display (*Dunn, 1997*).

In developing countries there is a growing interest in these tools, both in the public and private sector. GIS offer a wide range of possibilities in the fields of planning and decision making. With GIS one can store and manage geographical data, integrate different types and analyze relations between data themes and perform spatial analysis. The results are displayed visually on maps to help decision-makers better understand and solve problems.

GIS is an interdisciplinary tool: it receives attention from various disciplines such as agricultural engineering, civil engineering, computer science, sociology, etc. This is an advantage as it helps to bring different disciplines together and become partners in the process of implementing the GIS; however it can also complicate the situation as different expertise have to be interpreted together: a sociologist does not worry about projection systems, an agricultural engineer does not see the need of a neatly structured database, a computer scientist is more focused on technical aspects rather than the interpretation of the final goal of his new toy but each one of them wants to have or to be himself "the" GIS specialist (*Jonathan Deckmyn, 1998*).

At first, GIS were developed to address specific problems, such as large-scale land use planning concerns. These systems were unique, expensive, difficult to use and allowed only limited data transfer. As the GIS market expanded throughout the 1980s and 1990s, commercial companies developed generic systems which can be bought for less costs, are easy to use, and allow the incorporation of data from a wide variety of sources.

In order to make use of a GIS system, its different components have to be considered. **GIS** is made of the following **components:**

HARDWARE - from centralized servers to desktop application. In terms of hardware, a modern PC with at least 128 MB RAM and several GB of space on the hard disk is the basic requirement. Using Web services for your GIS needs requires minimal investment in infrastructure, while an enterprise GIS implementation requires careful planning and a fairly significant investment in computer equipment, network technology, database connectivity, and other required tools.

SOFTWARE - GIS software elaborate and analyze field data, maps or satellite imagery; it also allows to create new data to be viewed and eventually integrated with existing data and to answer particular queries. However, some specific analysis tasks may require data transformation and manipulation before any analysis can take place. The query and analysis results can finally be displayed on a map. There are two types of commonly used GIS software: Desktop GIS and Web Map Server. The former usually serves all GIS tasks of geographical analysis such as viewing (GIS Viewer), edit (GIS Editor), and analyze (GIS Analyst) data while Web Map Servers are used to distribute maps and data over the internet. Spatial Database Management Systems (SDMS) are mainly used to store the data, but often also provide (limited) analysis and data manipulation functionality (*Weibel, 2009*). Details and suggestion on the choice of GIS Software are reported in the second chapter of this manual.

DATA - this is a very important component and there are two data types in GIS: *raster and vector data*. **Raster data** type is any type of digital image represented in grids and consists of rows and columns of cells, with each cell storing a single value. Additional values recorded for each cell may be a discrete value, such as land use, a continuous value, such as temperature, or a null value if no data is available. The resolution of the raster data set is its cell width in ground units. Raster data can be stored in various formats; from a standard file-based structure of Tagged Image Files (TIF), Joint

Photographic Expert Group (JPEG), etc. to Binary Large Object (BLOB) data stored directly in a Relational Database Management System (RDBMS).

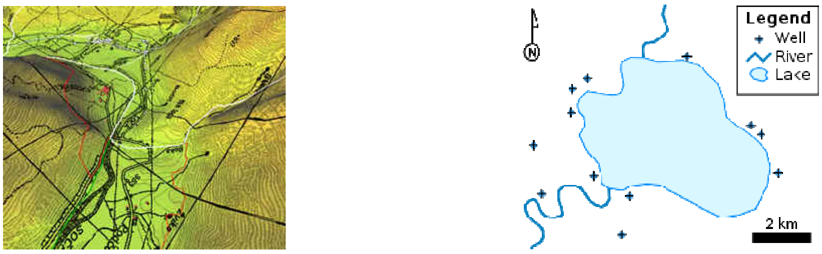


Figure 1: Raster (left) and Vector (right) Data

Vector Data type is any geographical feature considered as a geometrical shape. Different geographical features are expressed by different types of geometry: points (for single location), lines (for rivers, roads, railroads, trails, etc…) and polygons (for lakes, park boundaries, buildings, city boundaries, etc). Polygons convey the most amount of information of the file types. Linear figures can measure distances and polygon features can measure perimeter and area. Each of these geometries is linked to a row in a database that describes their attributes. For example, a database that describes lakes may contain a lake's depth, water quality and pollution level. This information can be used to make a map to describe a particular attribute of the dataset. For example, lakes could be colored depending on level of pollution. Different geometries can also be compared**;** GIS could be used to identify all wells (point geometry) that are within one kilometer of a lake (polygon geometry) that has a high level of pollution.

HUMAN RESOURCE COMPONENT - the continued growth of increasingly powerful GIS systems has increased the amount of practical applications for this field, and created a demand for skilled GIS-trained employees. Therefore, GIS requires expert and skilled people, but especially willing to learn and confront their knowledge with the local and indigenous ones in order to have a real impact on development issues. We refer to Chapter 2 for more details about skills required for GIS experts.

METHODS AND PROCEDURES - the geographic information process consists of three stages: data acquisition, data processing through Geographic Database (GDB) and data dissemination. Geospatial technologies are used in three stages as shown in Figure 2: GPS and satellite imagery, among others, are useful tools for geographic data collection; GIS have demonstrated their powerful capacities to enable data integration, analysis, display and dissemination. Hence, remote sensing techniques, GPS and GIS have become ubiquitous in developing policies for integrated management (*United Nation Statistic Division, 2004*).

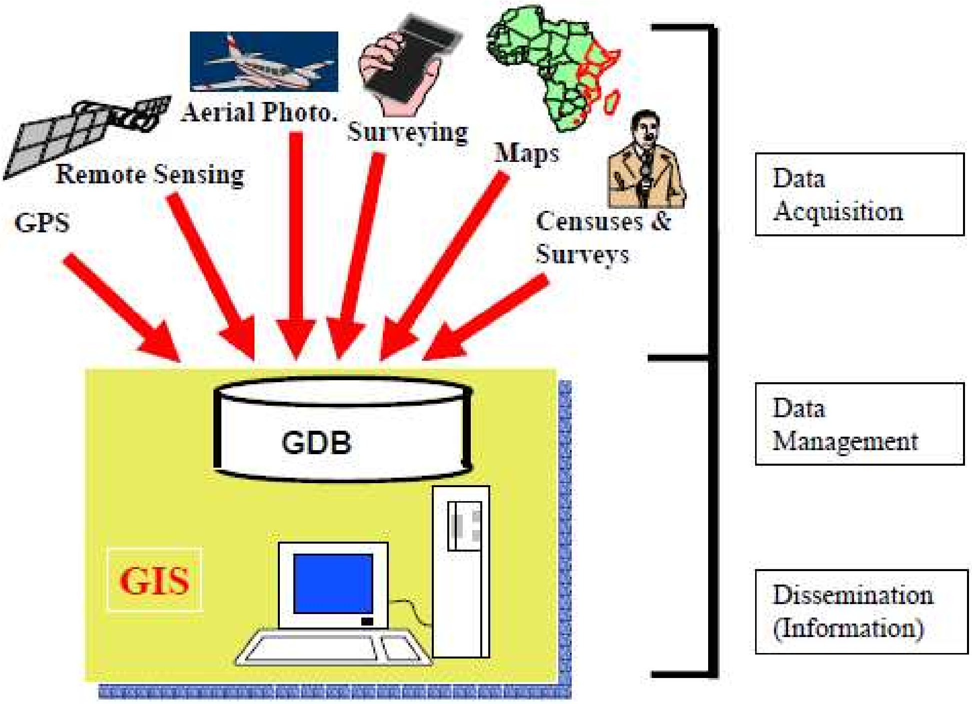


Figure 2: Geographic Information Process *(United Nation Statistic Division, 2004)*

1.2 How and why do we use GIS?

As said before, GIS applications enable the storage, management, and analysis of large quantities of spatially distributed data and can manage different data types occupying the same geographic space. For example, a biological control agent and its prey may be distributed in different abundances across a variety of plant types in an experimental plot. Although predator, prey, and plants occupy the same geographic region, they can be mapped as distinct and separate features.

The ability to depict different, spatially coincident features is not unique to a GIS, as various computer aided drafting (CAD) applications can achieve the same result. The power of a GIS lies in its ability to analyze relationships between features and their associated data. This analytical ability results in the generation of new information, as patterns and spatial relationships are revealed (*Milla, 2005*).

Although, at first, GIS was primarily used in developed countries, many actual and potential applications for GIS have become widespread in developing countries too, ranging from resource inventory and monitoring through to land use planning, land evaluation, biological control and health studies, irrigation and drainage, social and economic planning, disaster avoidance, management of conservation areas and parks to tourism. In most cases the uses of GIS in developing countries and developed countries are the same (*Zeller, 2002*).

Beside GIS, also Remote Sensing technology, most notably aerial photography and satellite imagery, have been introduced in developing countries. As an example, satellite imagery is used extensively in developing countries owing to the partial or complete absence or unavailability of topographic and thematic mapping needed for development projects. The range of applications has diversified over the past twenty years from simple cartography to cover such topics as land use, forestry, coastal zones, planning, route location, agriculture, hazard mapping, and others. GIS has played important roles in integrating the various datasets.

Up to now, remote sensing technology has been scarcely exploited in developing countries because of its high costs. However, some RS data (at least 30 meter type of Landsat resolution data) is free and other data is becoming also cheaper and going down in costs. This and open source GIS systems contribute to make the GIS and RS system more easily affordable for developing countries. It has however to be pointed out that the technology itself is not sufficient as appropriate skilled personnel is also essential to get the required information (*G. Di Martino, 2005*).

1.3 Remote Sensing Information: GPS and Satellite Images

It is important and useful to deeply analyze the potential of some geographic tools such as GPS and remote sensing products, as part of the GIS. Some definitions are reported below.

1.3.1 Global Positioning System (GPS)

The Global Positioning System (GPS) was initially developed by the U.S. Department of Defense for military applications and it was made available for civilian use in the 1980's. It consists of a network of 24 satellites that circle the earth twice a day in a very precise orbit and transmit low power radio signals. GPS is a satellite- and ground-based radio navigation and location system that enables the user to determine very accurate locations on the surface of the Earth. GPS technology has provided an indispensable tool for management of agricultural and natural resources. Although GPS is a complex and sophisticated technology, user interfaces have evolved to become very accessible to the non-technical user.

The type of GPS equipment selected depends on a number of considerations, including the degree of accuracy required by the user, budget considerations, ease of use, and working conditions (e.g., waterproof equipment required).

The issue of instrument accuracy is one that appears to cause some concern among new users. Many users seem to assume that an inexpensive ($100-$200) handheld unit is not able to deliver the necessary accuracy and precision. The fact is that even inexpensive units are capable of attaining good accuracies. Studies have demonstrated that accuracies on the order of 10-20 m can be obtained from inexpensive typical stand-alone GPS units (*Ochieng, 2002*). If accuracies less than 10 meters are needed, other methods are available, such as taking several tracks at the same place and then averaging over these points, therefore increasing precision, or using Differential GPS (DGPS). A differential corrections method requires a base station receiver or beacon placed at a known location, which then transmits corrections in real time to a roving receiver via a ground- or satellite-based radio signal. Another method is to obtain pre-recorded correction files for post processing. Files can be obtained from commercial and governmental agencies. The increased accuracy of DGPS data comes at an increased cost, and the user can expect to pay significantly more for the equipment (*Milla, 2005*).

A good overview of GPS can be found on The Geographer's Craft Web site (http://www.colorado.edu/geography/gcraft/contents.html), developed by the University of Colorado at Boulder.

GARMIN is one of the most important GPS manufacturing companies. GARMIN GPS are available at different prices accordingly to technical specifics, starting from 100$ up to 500$ or more. Those GPS can be purchased from the following web site: http://www.gpsnow.com/gmgen.htm and detailed information on how to use it can be found in the website http://www.gpsinformation.org/dale/wgarmin.htm or by consulting the Garmin GPS guide at http://www8.garmin.com/manuals/GPSGuideforBeginners_Manual.pdf . GARMIN GPS also provide MAPSOURCE software to visualize and georeference data with the possibilities to record waypoints, tracks and routs data.

Other GPS manufacture companies are: TomTom (http://www.tomtom.com/), Magellan (http://www.magellangps.com/) and Lowrance Electronics (http://www.lowrance.com/).

An accurate hands-on guide on the use of GPS and GIS application is given by the University of Mississippi GeoInformatic Center and it can be found at the following webpage: http://umgc.olemiss.edu/pdf/workshop/umgc_gps_gis.pdf. Also it is possible to find many advices and blogs about GPS use on the web. Particularly, an interesting GPS tutorial is the TRUMBLE GPS Tutorial, http://www.trimble.com/gps/index.shtml

Once data has been recorded by a GPS unit, GPS coordinates (waypoints), tracks and routs can be displayed in a GIS software as shape files. Particularly, ExpertGPS is a good software, available at a low price (50$) and able to convert GPS data in shape file and therefore directly exportable in GIS system. It is possible to download a month free trial ExpertGPS version on the website: http://www.expertgps.com/download.asp

1.3.1.1 GPS in Mobile phones

An alternative to GPS unit is also mobile phone or PDA. Now many mobile phones have GPS and they are getting cheaper and cheaper. Mobile phone GPS unit identifies user's position information with details including latitude, longitude with maximum accuracy up to 15 meters in radius.

GPS on smart phones or PDA is no longer an emerging trend. It's almost a must-have feature nowadays, and more and more handsets are offering it. With the embedded GPS receiver and a mapping service, real-time position tracking, text- and voice-guided directions, and points of interest are available. Some concerns about GPS in mobile phones are only related to data processing as limited analysis can be developed.

Sometimes it can be costly to take advantage of GPS and the navigation power that comes with it. However, Google and Nokia are shaking things up by offering the premium features for free on such devices as the Motorola Droid, Nexus One, and Nokia 5800 Navigation Edition. Here are six of the most recent smart phones with built-in GPS and related details.

Product name	 Motorola Droid (Verizon Wireless)	 HTC Nexus One by Google (unlocked)	 Nokia 5800 Navigation Edition (Unlocked)	 Palm Pre (Sprint)	 RIM BlackBerry Bold 9700 (T-Mobile)	 Apple iPhone 3GS - 32GB - black (AT&T)
Price	$199.99 to $599.99	As shown: **$529.00**	$289.99 to $319.99	$149.99 to $749.99	$129.99	$299.00 to $299.99
Review date	October 28, 2009	January 06, 2010	February 03, 2010	June 03, 2009	November 04, 2009	June 17, 2009
The Bottom Line	Despite some design issues and a couple of missing features, the Motorola Droid is the most powerful and fastest Google Android device to date. It fully embraces the openness of the Android platform and offers Verizon customers a smartphone that certainly rivals the other touch-screen devices on the market.	It doesn't have all the features we'd like, but the Nexus One greatly enhances the Google Android family with a fast processor, good call quality, and improved voice control features. What's more, we love that all versions of the phone will be unlocked.	As one of the more affordably priced handsets from the company, the Nokia 5800 Navigation Edition is a good value, offering road warriors a midlevel device with decent navigation skills and the freedom of an unlocked phone.	Despite some missing features and performance issues that make it less than ideal for on-the-go professionals, the Palm Pre offers well-integrated features and unparalleled multitasking capabilities. The hardware could be better, but more importantly, Palm has developed a solid OS that not only rivals the competition but also sets a new standard in the way smartphones handle tasks and manage information.	The RIM BlackBerry Bold 9700 brings T-Mobile its first 3G BlackBerry and improves on its predecessor with a sleeker design and more power. We only wish it had a better browser to complete the package.	The iPhone 3GS doesn't make the same grand leap that the iPhone 3G made from the first-generation model, but the latest Apple handset is still a compelling upgrade for some users. The iPhone 3GS is faster and we appreciate the new features and extended battery life, but call quality and 3G reception still need improvement.

Table 1: List of the most recent smart phones with GPS (source: http://reviews.cnet.com/1770-5_7-0.html?query=smartphones+with+GPS&tag=srch)

As shown in Table 1 referring to the US market, prices of smart phones with GPS, can be comparable with GPS devices prices in it and in some cases can be even cheaper. Second hand smart phones can be usually purchased at lower prices although not many models are available at the moment.

Also Google Maps for mobile phones are available on the web and they can be downloaded from the following link: http://www.google.com/mobile/maps/

1.3.2 Remote Sensing

In parallel with the development of GIS, has been the development of Remote Sensing technology, most notably aerial photography and satellite imagery. Remote sensing is the science and art of acquiring information (spectral, special, temporal) about material objects, area or phenomenon, without coming into physical contact with them and by using some mean of transferring information through space. In remote sensing, information transfer is accomplished by use of Electromagnetic Radiation (EMR). EMR is a form of energy that reveals its presence by the observable effects it produces when it strikes the matter; therefore remotely sensed data is based on the property that materials absorb and reflect Electromagnetic Radiation. Two types of remote sensing technology exist depending on the source of radiation: passive remote sensing and active remote sensing. The former is based on the use of sensors that detect the reflected or emitted EMR from natural sources, the latter uses sensors that detect the reflected or emitted EMR from natural sources irradiated from artificially-generated energy sources, such as radar (*GIS Development Pvt Ltd*). The EMR emission spectrum has been captured and analyzed by proper sensors projecting the geological properties of the materials. Therefore most remotely sensed data used for mapping and spatial analysis is collected as reflected electromagnetic radiation, which is processed into a digital image that can be overlaid with other spatial data (*Milla, 2005*). As an example, the spectral properties of vegetation in different parts of the spectrum can be interpreted to reveal information about the health and status of crops, rangelands, forests and other types of vegetation.

Satellite images are given by single or constellation of satellites. In Table 2, a list of the most common satellites sensors providing images is reported, with related images characteristics and websites.

SATELLITE NAMES	IMAGE TYPE	LINK
ASTER	L1B Imagery	http://www.landcover.org/data/aster/
IKONOS	Fine Resolution Imagery	http://www.landcover.org/data/ikonos/index.shtml
Landsat	GeoCover,. Landsat ETM+,.Landsat MSS,.Landsat TM	http://www.landcover.org/data/landsat/
MODIS	16 and 32-day Composites	http://www.landcover.org/data/modis/
QuickBird	Fine Resolution Imagery	http://www.digitalglobe.com/index.php/85/QuickBird
OrbView	Fine Resolution Imagery	http://www.landcover.org/data/quickbird/
SRTM, Shuttle Radar Topography Mission	30, 90m and 1km Elevation Imagery	http://www.landcover.org/data/srtm/

Table 2: Satellite images types

Satellite images and remote sending products can be purchased from several websites, such as:

Digital Globe: (http://www.digitalglobe.com/) DigitalGlobe is a global provider of commercial, high-resolution, world imagery products and services. Sourced from an advanced satellite constellation, imagery solutions support mapping, analysis and navigation technology. They also offer advanced collection sources, a comprehensive Image Library and a range of online and offline products and services.

Terra Server: (http://www.terraserver.com/) has assembled a large variety of aerial photos, satellite images on the Internet. From the website, it is possible to search and view online imagery and then purchase digital image downloads and high quality prints/posters.

USGS (http://www.usgs.gov/) is specialized in providing biology, geography, geology and geospatial information. Satellite images are also available.

Earth Sat (http://www.earthsat.com/) recently renamed MDA, provides remote sensing products and applications for GIS.

In recent years, remote sensing data has been available relatively cheaply and easily via the internet that is a key source of data which can be used in a GIS. Moreover, some remote sensing products are freely available, such as the Landsat archive, http://www.landcover.org/index.shtml or RESMAP website http://www.resmap.com/ .

The Land Processes Distributed Active Archive Center (LP DAAC) is a data center within the NASA Earth Observing System Data and Information System (EOSDIS) (https://lpdaac.usgs.gov/). Here it is possible to find and purchase the image types accordingly to the satellite used, as described in the previous table.

GPS and Remote sensing information can be both easily integrated in the GIS system.

1.3.2.1 Google Maps and Google Earth

Google Maps is a basic web mapping service application and technology provided by Google. It offers street maps, a route planner for traveling by foot, car, or public transport and an urban business locator for numerous countries around the world. According to Lars Rasmussen, one of its creators, Google Maps is "a way of organizing the world's information geographically". The big advantages of using Google are: it is free, generally up to date, easy to learn, developer/programmer friendly, independently platformed and open to a large user community. Users can freely view data, images or geographical information on the Google Earth platform.

Google Earth (GE) is a virtual globe, map and geographic information program that maps the Earth by the superimposition of images obtained from satellite imagery, aerial photography and GIS 3D globe. It is available under three different licenses: Google Earth, a free version with limited functionality; Google Earth Plus (discontinued), which included additional features; and Google Earth Pro ($400 per year), which is intended for commercial use.

Google Earth displays satellite images of varying resolution of the Earth's surface, allowing users to see things like cities and houses looking perpendicularly down or at an oblique angle, with perspective. The degree of resolution available is based somewhat on the points of interest and popularity (Wikipedia). For example, it can vary from less than 15m in countrysite to less than 1-2 feet (20-40 cm) in major US cities and up to 10 cm in some parts of Manhattan (up to 10cm). Satellite and Airborne Imagery are 1-3 years old (*Freemantle, 2006*).

Examples of low and high resolution images are shown in Figures 3 and 4.

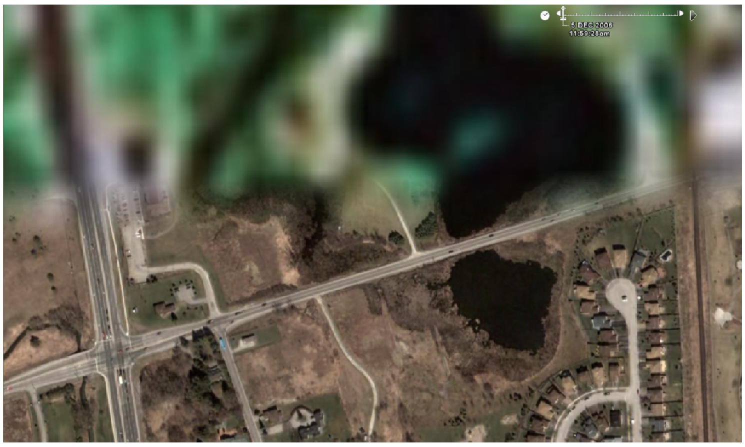


Figure 3: Top section: low resolution data, details are not clearly defined; bottom section: high resolution data, details are clearly defined (Freemantle 2006)

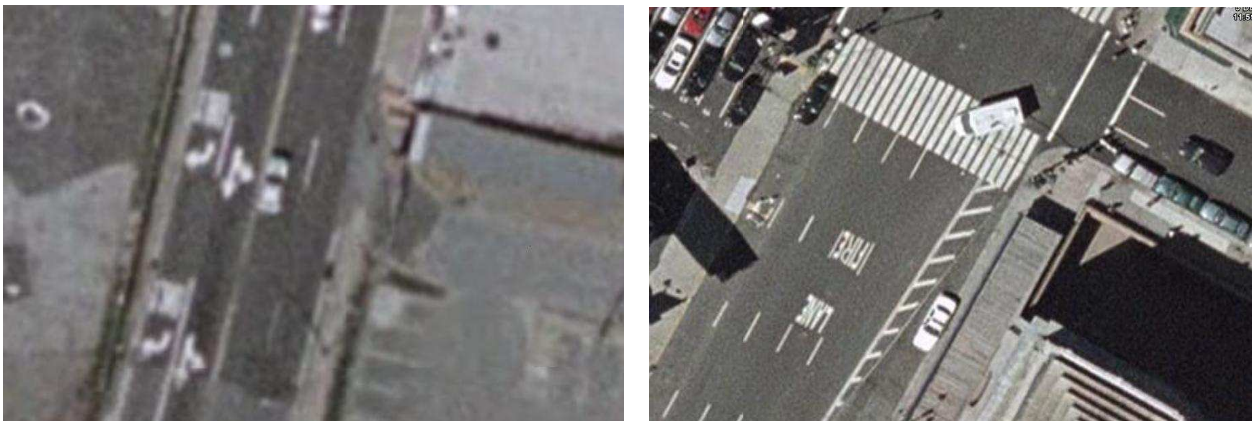


Figure 4: 20 cm (left) vs 10 cm (right) resolution images (Freemantle 2006)

The whole of Europe and North America have been already coverd with high resolution satellite images in Google Earth. Though it has already been planned to extend the coverage of very high resolution images to developing countries, only few locations are covered with high resoultion in Africa. As an example, in Malawi, about 20% of the total surface is covered by high resolution satellite images.

The internal coordinate system of Google Earth is geographic coordinates (latitude/longitude) on the World Geodetic System of 1984 (WGS84)[1] datum. This same coordinate system is used by the GPS and it will be valid up to 2010.

Google maps cannot be used in any GIS but the other way around is possible. GIS data can be exported into Keyhole Markup Language (KML) file format and viewed on Google Earth. Kml is a computer language applied to Google Earth similar to Hyper Text Markup Language (HTML) applied to Web Server. Alternatively, Google Earth derived .tiff, .jpeg and other graphic files can be geo-referenced using some reference points and then can be also used as background layer in an ordinary GIS.

KML is computer language schema to express a geographic annotation and visualization on web-based and Earth browsers. KML was developed for use with GE and it specifies a set of figures for each represented point (placemarks, polygons, images, etc…).

The potential of Google Earth is also to monitor environmental changes such as deforestation and land use. To this purpose, the Google Earth Outreach program supports not-for-profit organizations. As an example, it uses Google Earth three-dimensional images to show Tanzanian villagers that forests are the source of their water and to enlist the villagers in identifying chimpanzee habitats and elephant paths. Also, one of the first Google Earth Outreach projects involved indigenous tribes in the Amazon rain forest. The tribes were using GPS to map their lands, plot rivers, sites of spiritual significance, and their resources, including medicinal plants and rich hunting grounds (*Butler, 2009*).

[1] As of the latest revision, the WGS 84 datum surface is a pole-flattened (*oblate*) spheroid, with major (*transverse*) radius *a* = 6,378,137 m at the equator, and minor (*conjugate*) radius *b* = 6,356,752.3 m at the poles.

2. Implementing a GIS System

In order to implement a GIS system to accomplish our purpose, some important considerations about software, hardware and human resources in terms of needs and cost effectiveness have to be carried out particularly in order to avoid unnecessary expenditure for the intended purpose.

2.1 Where to start?

To uninitiated GIS users, the complexity and vast array of potential applications can be confusing and intimidating. Because the applications of GIS-GPS-RS involve a wide range of disciplines, how do potential users with little prior knowledge identify specific ways in which they can be useful in their own work?

The decision must begin with a process of self-education. This includes gaining an understanding of the basic concepts of the technologies and doing a careful evaluation of your own needs and the needs of your clientele. A good place to start is at http:www.digitalgrove.net/. This Web site is a mapping gateway for resource managers and provides information on the fundamentals of GIS-GPS-RS technologies and data and provides numerous links to other sources of information, tools, utilities, data, and software applications. Another useful resource is ESRI's Virtual Campus online education and training web site (http://campus.esri.com). This site offers courses both free and inexpensive modules on the use of ESRI's GIS software, as well as courses on how to go about planning and implementing a GIS. However it has to be pointed out that the educational tools provided by ESRI mainly use demonstration material of their own software (e.g. ArcGIS) which is not free.

An Internet search on uses of GIS, GPS, and RS in your field is a good way to start. Many agencies already use these methods, post project reports, research results, and information on specific applications. Good sources include the USDA-ARS Hydrology and Remote Sensing Laboratory at the Beltsville Agricultural Research Center (http://hydrolab.arsusda.gov/) and the U.S. Fish and Wildlife Service GIS home page (http://www.fws.gov/data/gishome.html). Many online tutorials and educational materials are also accessible through the worldwide web. Two excellent tutorials are the National Center for Geographic Information and Analysis GIS Core Curriculum (http://www.ncgia.ucsb.edu/pubs/core.html) and the Remote Sensing Core Curriculum (http://www.r-s-c-c.org/).

Once you have researched the potential for GIS-GPS-RS technologies in your field, it is important to become familiar with the workings and capabilities of different software applications and equipment technologies before a decision is made about its implementation. A number of software companies have free data readers and browsers that provide an opportunity to examine and use some of the functionality of their software packages. Some examples include ESRI's Arcexplorer (http://www.esri.com/) and Leica Geosystems' ViewFinder (http:www.leica-geosystems.com). Many software companies will also provide time-limited trial copies of software packages to allow the user to evaluate the applications before purchasing. If your needs are limited to obtaining and viewing images and GIS data layers and performing simple analysis functions, then one or several of these free data viewer programs may be sufficient for your purposes. Using ESRI's ArcExplorer, for example, you can view, identify, locate and query geographic and attribute data; create thematic maps; and perform basic statistical analysis.

If it is needed to create or edit new data layers, or perform some analysis and data conversion functions, several freeware applications are available that may fulfill the requirements. Freeware applications will be discussed in the following sections of this manual. However freeware are usually less user friendly and the learning curve is not as fast as with commercial packages.

A number of different GIS and RS software packages are commercially available, each with different features and functionality. Some of these applications can be expensive for organizations with a limited budget. However if the organization is affiliated with an educational institution, then a special educational price may be available. Although ESRI GIS software products and file formats are probably the most common for manipulating and distributing GIS data, most other GIS software applications can translate data from and to these file types. For reviews and discussions and downloads of different GIS software products, see http://software.geocomm.com/ (*Milla, 2005*).

2.2 Technical Requirements: Software and Hardware

Before describing details about software and hardware requirements, it is important to report some general considerations. For both hardware and software, the key requirements are: (i) user friendliness, with minimum system management and a user interface written to reduce users' initial unfamiliarity (perhaps using menus and windows); (ii) low costs, since financial support for expensive systems may be impossible to justify. An investment in GIS still represents a considerable initial financial outlay, even if the system eventually proves cost-effective. Furthermore, GIS requires a certain minimum of hardware, usually peripheral equipment (printer, plotter, digitizer or scanner etc) in addition to a basic micro-computer.

The purchase of hardware and software encompasses only a small part of the financial cost, but it is also the one that is most likely to be controlled (*Teefelen, Gustavson, & Verkoren, 1992*).

The goal for developing countries should be to establish a basic system as soon as possible and not to try competing with the most modern systems. The private sector, which designed the hardware and wrote the software for GIS in the West, is partly responsible for this in its eagerness to sell it as a quick techno fix for development.

2.2.1 Software

In order to define the appropriate software, at least three important aspects need to be considered:

1. purpose of using that specific software;
2. training required;
3. technical requirements of the available hardware; it has to be able to support the selected software.

Once these three points have been satisfied, further considerations can be developed.

The appropriate technology should be low in capital costs and utilize as many local resources as possible and can be maintained without a high level of expertise (*Burrough, 1992*). ESRI for example offers its latest Version ArcView 9.3.1 Single Use Licence at a Price of $1500, (http://store.esri.com/esri/showdetl.cfm?SID=2&Product_ID=29&Category_ID=121). Also the range of applications should only include the ones that are efficient and entail low risk. Examples of such applications are: automated mapping, cadastral systems, natural resource management and location planning of public services. Also some other important factors to be considered are:

- software must be upgraded over time, and hardware maintained and serviced. Introduction of equipment in a rapid or uncontrolled way inevitably creates problems and specialized hardware may be unfamiliar. Systems must be introduced slowly to allow time not only for technical training but also for networks of spare parts to be developed.
- help from software vendors is needed. In western countries this is acquired through established networks by telephone, fax or e-mail, which may be unavailable elsewhere. Informal support networks are effective, but local software support groups or centers may take time to become established.
- after training, people need to maintain and extend knowledge and skills through, for example, adequate library facilities or conferences (*Dunn, 1997*).

The key players in the GIS software market today are Autodesk, Bentley, ESRI Inc., GE (Smallworld), Pitney Bowes (MapInfo), and Intergraph. GIS software companies tend to target specific application domains. For instance, ESRI's ArcGIS product tends to be mainly used for business analysis, planning, and environmental applications, while Autodesk, GE and Bentley products are rather used in utility and facility management.

Two main GIS technologies are available: the Desktop GIS applications, so called GISystems and the Web based GIS software, called GIServices. The major difference between the two is that GISystems works on wired, while GIServices work both through wired and wireless networks. Additional software tools are Spatial Database Management Systems (SDMS) and Software Development Frameworks and Libraries (web and non-web).

2.2.2 Free Software

As one of the main concerns in GIS application is costs, it is important to individuate sources of free software. In fact, GIS software is not only provided by companies but increasingly also by free and open source software projects. The development of open source GIS software has - in terms of software history - a long tradition from 1978. Numerous systems are nowadays available which cover all sectors of geospatial data handling. While commercial vendors usually offer products for various software categories, open software projects often concentrate on a single category, e.g. Desktop GIS or WebMap server. Competitive GIS software that is developed by free software projects exists especially with respect to server applications (MapServer, GeoServer) and spatial DBMS (PostGIS). Free desktop GIS projects, such as Quantum GIS and gvSIG, currently experience growing user communities. Such free GIS software rather complements the set of proprietary software instead of competing with it. Table 3 and 4 provide a list and description of the most common open source GIS, also available at the webpage: http://www.freegis.org/. Particularly, Table 3 refers to Desktop GIS applications.

Free Desktop-GIS software name	Software link	Description	Comments
GRASS GIS, (Geographic Resources Analysis Support System)	http://grass.osgeo.org/	Geospatial data management and analysis, image processing, graphics/maps production, spatial modeling and visualization.	GRASS is currently used in academic and commercial settings around the world, as well as by many governmental agencies and environmental consulting companies.
MapWindow	www.mapwindow.com	The MapWindow GIS open source project includes a Microsoft Windows compatible desktop application capable of viewing shapefiles, and raster data in many formats. It can reproject data, clip, merge, and perform other geoprocessing through a "GIS Tools" plug-in.	Developer-users can extend the application by writing plug-ins using any .NET Framework compatible language, or developers can write GIS enabled software using the MapWinGIS ActiveX control
Quantum GIS	www.qgis-org	Quantum GIS (QGIS) is a Geographic Information System (GIS) that runs on Linux, Unix, Mac OSX, and Windows.	QGIS supports vector, raster, and database formats. It also can display tracks from GPS. It is also available in a web server version
GvSIG	http://gvsig.gva.es/	gvSIG is an tool for handling geographic information. It has a friendly interface and it can access to several data format (raster or vector).	
SAGA	http://geosun1.uni-geog.gwdg.de/saga/html/index.php	SAGA is a geographic information system, with a unique 'Application Programming Interface' (API) for geographic data processing.	This API makes it easy to implement new algorithms- The SAGA API supports grid data like digital terrain models and satellite images, vector data, and tables."
uDig	http://udig.refractions.net/	uDig is an open source spatial data viewer/editor, with special emphasis on the OpenGIS standards for internet GIS, the Web Map Server and Web Feature Server standards.	uDig will provide a common Java platform for building spatial applications with open source components." It is also available in a webserver version
Map Maker	http://www.mapmaker.com/	Map Maker is e**ase of use,** you do not have to be a GIS expert. Within hours you can learn how to draw, edit and print basic maps, and link them to databases. It has a simple and clean user interface (UI).	Upgraded versions and professional mapping programs are for free to not-for-profit organizations, educational establishments, and students.

Table 3: Free Desktop GIS software and applications

In addition to the Desktop GIS software, there are also Web GIS software and additional components, such as Database and Libraries. These are listed in Table 4.

Free Web-GIS software name	Software link	Description	Comments
Map Server	http://www.mapserver.com/	Application to deliver dynamic GIS and image processing via Web. It also contains stand alone application for building maps, scalebars and legends offline.	Access to the development environment of MapServer is possible with several programming languages.
Cartoweb	http://cartoweb.org/	Comprehensive and ready-to-use Web-GIS as well as a convenient framework for building advanced and customized applications.	
GeoServer	http://geoserver.org	open source software server written in Java that allows users to share and edit geospatial data.	
MapFish	http://mapfish.org/	It is an easy-to-use and extensible web 2.0 mapping application framework. It is made of two parts: MapFish Client and Server	MapFish can be used as a self alone application or as an add on to an already existing web application.
PostGIS	www.postgis.refractions.net/	PostGIS adds support for geographic objects to the PostgreSQL object-relational database.	PostGIS can be used as a backend spatial database for geographic information systems (GIS)
OpenLayers	www.openlayers.org/	open source AJAX library for accessing all kinds of geographic data layers, originally developed and sponsored by MetaCarta	GIS Library
GeoTool	http://www.geotools.org/	Open source GIS toolkit written in Java, using Open Geospatial Consortium specifications	GIS Database

Table 4: Free Web GIS software and applications

2.2.3 Hardware

The hardware selection is also a very important step and an accurate analysis has to be done in order to take the right decision.

Although some basic GIS software versions can also be handled with older hardware, as discussed in a case study in Uruguay where a full GIS has been established with 486/66 PCs (*Zeller, 2002*); this is not the routine and a general rule does not exist as hardware specifications depend on the chosen software.

Therefore, once the software specifications are clearly identified, then it is possible to define the minimum requirements for the hardware, such as: RAM, ROM, Processor etc… As an example, ArcView 9.3 requires a minimum of 1 GB RAM.

Also housing and infrastructure such as printers and plotters often require big investment but for the protection of the sensitive and expensive hardware saving too much at this point can be dangerous.

2.3 Human Resources in GIS: requirements and skills needed

Cost of required human resources is another important element to be taken into consideration. Skilled labor is rare and therefore wages for such workers are quite high. Unfortunately this is a factor, which cannot be changed easily.

2.3.1 Technical Skills requiered

There are many GIS position with different expertise and competences. The following is a summary of skills the "ideal" candidate for a GIS Analyst position should hold:

- strong GIS skills with two or more GIS packages;
- strong Macro / C / C++ / Visual Basic programming skills;
- understanding of and/or willing to learn math and statistical analysis;
- strong Oracle or related RDBMS skills including development skills;
- excellent verbal / written communication skills;
- genuinely excited and enthusiastic about learning and pushing technical limits / finding new solutions;
- good writing skills - for documentation, training, processes;

- formal training (eg. Degree) or high level of experience with GIS;
- "hands-on" experience;
- good analytical / problem solving skills;
- a basic understanding of the concepts behind data management in a relational database;
- good IT technical skills;
- problems solving abilities;
- good knowledge of Cartography /Geography and projection properties;
- good candidates have travelled outside of their own country, even better if they have worked outside their own country;
- think outside of the box;
- clear understanding of the specific area of GIS use, i.e. DRR, Environment Conservation, Climate Change, etc…

2.3.2 How to get a good consultant?

For many GIS projects, people will hire a consultant to implement technology, provide a total solution, or help manage an internal development project. Common GIS consulting projects will start out as needs assessment, cost benefit analysis, implementation plan or application design.

There is literally a sea of GIS consultants and consulting firms, so how do you choose the "right" one? First of all, you need to understand the many types of consultants and services they provide. Consulting firms will range from a person working out of their house to small firms to large corporations. Some firms specialize while others offer diverse services. Some are software vendors that offer consulting services centered on their products.

In order to choose a good consultant, skills, experience, costs and references as well as "trustworthiness" "dedication," "creativity", "honesty" and "hard working." have to be considered. The consultant should mesh well with the organization staff and dedicate to see the organization successful. Also GIS is becoming more and more important in organizations and plays more of an integral part in enterprise and mission critical business systems. Having a consultant that not only has excellent GIS experience but also has experience with database and internet applications as well as network and security skills will be valuable. Many firms are specialized and don't have these skills so it is important to choose wisely depending on your needs.

Perhaps the best advices to select a good GIS consultant are:

- to find one that you like to work with and can trust;
- to find a GIS consulting firm that is professional, performs well, and has a great skilled and innovative staff;
- to find a GIS consulting firm that has a good record of accomplishment and has been in business for a while, consultants have also to be able to demonstrate results from previous works;
- to find a GIS firm that is willing to listen and spend time working with you to solve problems, build solutions, and make you successful;
- to find a GIS firm that provides the best possible value and service for your budget (*Payne*).

2.4 Costs analysis for GIS

The cost estimation is a vital link in the success or failure of the GIS project/purchase. Cost Benefit Analysis appears to be the best tool to monitor the costs and advantages of GIS. The objective is to understand the costs incurred for the user when adopting a GIS. The resulting estimate takes all monetary costs into account, based on objective estimates. In order to identify these costs, it is necessary to:

a) define user groups and usage scenarios;
b) select the GIS alternative which offers the best value to the customer.

For each usage scenario, the following steps are suggested:

1. identify the components that the GIS project and therefore GIS purchase consists off;
2. understand the relevant cost and benefit factors. These are all factors which may influence the decision of the user during the lifetime of a GIS application (e.g. purchase and customization costs, integration of legacy systems, introduction cost, maintenance and cost of migration to new technology);

3. make up the balance sheets for each GIS alternative. This should include relevant cost items and other relevant factors (cost estimates for purchase, customization, user training, operating and maintenance, and also estimates of the time spent for learning how to use the GIS application and for using it, and of the cost of this time). The sum of all costs for the GIS application lifetime is therefore calculated. There may be different results for different usage scenarios (*ESPRIT/ESSI project no. 21580*).

In relation to the point 1, GIS costs can be divided into the following components:

1. hardware,
2. software (basic GIS and additional modules such as libraries and database),
3. maintenance,
4. services (resources to fulfill the GIS project, i.e. customization),
5. training,
6. data acquisition (if obtained from elsewhere).

According to the authors of ESPRIT/ESSI project no. 21580 the costs related to each of these components contribute to the overall GIS costs as described in the following chart (Figure 5).

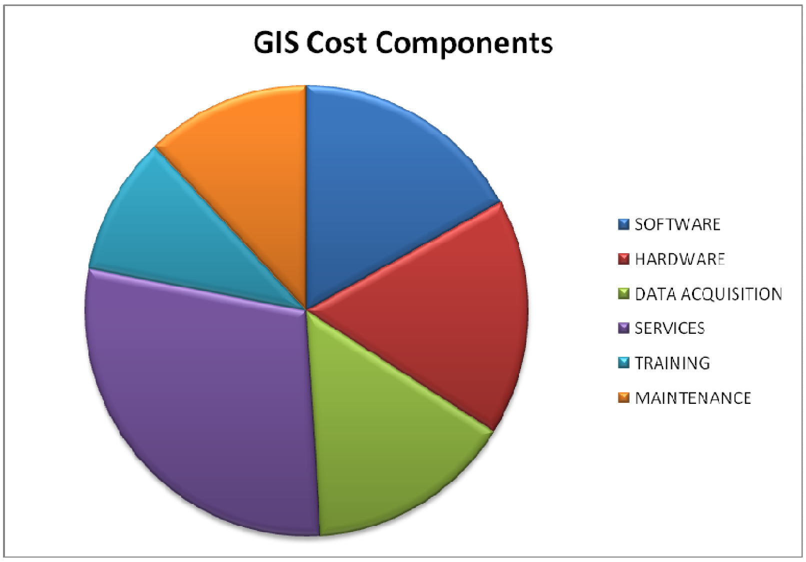


Figure 5: Costs details for GIS System, (ESPRIT/ESSI project no. 21580)

As shown in Figure 5, the price of a GIS (hardware and software) is not the most important cost factor. Issues such as usability (maintenance), learning and training cost, services as well as data acquisition also affect the decision for a specific GIS project.

Also, the cost of a GIS installation and customization for whatever purpose varies very much per application area and the job or project that the GIS is needed for. Therefore, it is very difficult to define a general price list for GIS as each GIS project requires different tools and expertise and related costs can vary significantly. For example, as human resource costs concern, hourly billing rates can fluctuate between $25 and $250 per hour. Such a variety is due to different levels of expertise of the consultant, also based on his/her annual salary.

However, an example of price list for GIS from the department of GIS in Crook County in Oregon USA for town planning is shown in Table 5.

2009-2010 Price Structure	
GIS Services	
Standard Hourly Rate	$75.00/hr (1 hr min.)
Map Printing	
Stock Maps: Roads, Parcels, Animal Ranges, UGB-City, City Boundary, Zoning (County & City), Enterprise Zone, Subdivisions, Destination Resort, FEMA 100 Yr & 500 Yr Flood Maps, Prineville Water & Sewer	
24x24	$10.00
24x36	$10.00
36x36	$10.00
Copies	
Color 8.5x11	$1.00
Color 11x17	$2.00
Color 24x36	$10.00
Color 36x36	$15.00
Color 42x42	$20.00
B&W plat copy	$4.00
Aerial Photography	
Digital Orthophoto Quads (color)	$100.00
Digital Orthophoto Quads (b&w)	$50.00
Multiple quads 20% discount per quad from posted price	
Custom Services	
1- Mile Study and Report (Includes 2 8.5x11 aerial photo maps)	$170.00
Soil Survey 1	$25.00
Soil Survey 2	$75.00
GIS database analysis	$75.00/hr (1 hr min.)
GIS Data	
CD Creation	$5.00
GIS Data CD (one-time CD)	$250.00
Parcels or Roads GIS layers	$150.00
All other GIS & DXF (CAD) layers	$50.00
Assessors Tables	$75.00 (per table)
Internet Applications	
Annual GIS FTP Subscription (inc. all base County & City layers & Assessors tables)	$450.00
Roads or Parcels layer for web applications	$450 plus base cost of layer
Annual County Subscription Map Service Single User – Assessment, Community Development, GIS (Title Companies & Realtors)	$700.00
2-10 users, per user per year	$175.00
11-50 users, per user per year	$70.00

Table 5: GIS price list Crook County GIS Dep. Oregon USA
http://gis.co.crook.or.us/Resources/GISPrices/tabid/91/Default.aspx

Another general example of GIS costs breakdown (in $1000s) for two typical client server GIS implementation is also provided by Longley et al. in Table 6:

	10 seats		100 seats	
	$	%	$	%
Hardware	30	3.4	250	8.6
Software	25	2.8	200	6.9
Data	400	44.7	450	15.5
Staff	440	49.1	2000	69.0
Total	895	100	2900	100

Table 6: Breakdown GIS costs, (*Longley 2001*)

In the two case studies, GIS data costs are ranking around $500 and human resource expenditures are very significant in both examples: $75 per hour or $2000 for 100 seats.

However, the examples reported above are relative to GIS applications in United States for town planning and environmental conservation projects. Prices of other GIS applications can be significantly different, especially in developing countries. Moreover different types of maps and therefore different prices are required for Disaster Risk Reduction rather than environmental conservation purpose. Unfortunately, there is not much information available for GIS application in DRR, especially in Africa, but some data, developed by the authors of this guide, about an area of 300 Km^2 in the Salima case study is reported in Chapter 4.

Important factors to be consider while analyzing GIS costs:

- Size of the mapping area,
- Map scale required,
- Type of GIS (desktop or web applications),
- Database and data sources (where is the data source?),
- Maps have to be available in soft or hard copies?
-Type of services and maintenance.

2.5 Limitation of GIS and the use of GIS as an appropriate technology

GIS has been proven to be a very powerful and useful tool in the past recent years, however some critics have been developed recently about its application and role in the social context. Particularly, the type and source of information chosen is an important issue among GIS users as GIS is often defined as a techno-representation readily controlled by the powerful. A GIS may be of spurious authority and map people into co-ordinates of control. Like all geographical information, GIS has the potential to reduce social inequities or to exacerbate them, both within countries and in terms of a wider North/South divide. On one hand, GIS can be subversive or it can empower a techno-elite. On the other hand, GIS may also be an instrument for 'discovering' local resources contextually. Local knowledge of the region (and the ability of the GIS to enhance this knowledge) makes appropriate technology a viable alternative to the current modes of development. GIS could become a tool in the service of the poor rather than a further technological instrument for their control; all depends on who constructs and analyzes the information and who controls the GIS (*Dunn, 1997*).

'*Ground Truth'* by John Pickles (1995) is the first book to explicitly address the role of geographic information systems (GIS) in their social context. (*Pickles 1995*) Contributing authors consider the ideas and practices that have emerged among GIS users, demonstrating how they reflect the material and political interests of certain groups that will open up an important debate.

A new approach to GIS is the recently developed Participatory GIS (PGIS) that implies making Geographic Information Technology available to disadvantaged groups in society in order to enhance their capacity in generating, managing, analyzing and communicating spatial information. If appropriately utilized, the practice could exert profound impacts on community empowerment, innovation and social change. More importantly, by placing control of access and use of culturally sensitive spatial information in the hands of those who generated them, PGIS practice could protect traditional knowledge and wisdom from external exploitation. However, for PGIS to be effective, it has to be based on the proactive collaboration between local and traditional knowledge and facilitators skilled in applying PGIS and transferring know-how to local actors (*Rambaldi, 2006*).

As an example, the International Council for Science defines Traditional Ecological Knowledge (TEK) as ‘‘a cumulative body of knowledge, know-how, practices and representation maintained and developed by peoples with extended histories of interaction with the natural environment. TEK—if interpreted carefully and assessed appropriately—can provide important data on ecosystem conditions and trends. The most promising methods of data collection are participatory approaches, in particular Participatory Rural Appraisal (PRA). PRA is an alternative to unstructured visits to communities, which may be biased toward more accessible areas, and to costly, time-consuming questionnaire surveys (*Chambers, 2006*). PRA was developed in the ‘90s by allowing recipients control of problem definition and solution design and by carrying out research over a longer period. Activities such as interviewing, transects, mapping, measuring, analysis, and planning are done jointly with local people. Participatory methods have their limitations. First, they only produce certain types of information, which can be brief and superficial. Second, the information collected may reflect peoples' own priorities and interests. Third, there might be an unequal power relation among participants and between participants and researchers. A rush to obtain traditional knowledge can be biased toward pre-existing stereotypes and attention to vocal individuals who do not necessarily reflect consensus (*Millennium Ecosystem Assessment, 2005*).

The use of this PRA knowledge integrated with the GIS system can provide an interesting combination of information where local and rural communities play an active and fundamental role. Taking into account that GIS must be part of an organization's overall, long-term activities and goals not just a quick fix for a single issue.

2.6 Limitation and Contraints of the use of Remote Sensing and GIS in Developing Countries

The ability to store and retrieve data about special aspects of the earth and the way people live on it and the potential to use this data in models of environmental and socioeconomic process in order to learn more about the possible outcomes of natural trends, planning decisions or disaster is not only very important for industrialized countries but also for the developing world. There are many actual and potential applications for GIS in developing countries ranging from resource inventory and monitoring through land use planning, land evaluation, biological control and health studies, irrigation and drainage, social and economic planning, disaster avoidance, management of conservation areas and parks to tourism. In most cases the uses of GIS in developing countries and developed countries are the same but still there are some differences (*Zeller, 2002*).

As information about physical and socioeconomic phenomena is scarce in developing countries, data from remote sensing, mostly through aerial pictures, is very important to supply information efficiently. As an example, explicit information about the total and the density of population is available in developed countries. As field surveys take a lot of time and cost a lot of money, the easier (but also more approximately) way to get this data for developing countries is by aerial imagery. The use of GIS facilitates easier, quicker solutions for technically complicated, time- absorbing geographical problems. GIS are rapidly becoming a key technology for the automated capture, management, analysis and presentation of location- referred data all over the world.

The application of a GIS is a very time consuming process, even in industrialized countries, to introduce and to consolidate new ways of working. Furthermore, in developing countries, the use of GIS and remote sensing is characterized by other major constraints, such as cost, skills and education required, but also infrastructure and data constraints. Some of them have been analyzed below:

- Cost constraints: Software and Hardware
- Infrastructures constraints
- Educational constraints
- Data constraints: Existence and Accessibility of data

2.6.1 Cost Constraints

Some extra attention has to be paid to the financial situations of developing countries, since they do not allow expensive projects to be carried out. GIS Tools are mostly programs which are developed and sold by developed countries. As currency exchange rates for developing countries are mostly bad, these products are often very expensive. The selection of the appropriate hard and software for a GIS is a delicate matter. In the initial state it is often difficult to assess the exact functionalities required for the GIS to be used. In order to avoid unnecessary investments it would be unwise to tie the project to a completely determined GIS environment. Starting with a very basic system is usually the cheapest and most efficient way (*Teefelen, Gustavson, & Verkoren, 1992*).

2.6.2 Infrastructure constraints

A particularly significant issue in developing countries is the slow internet connection that limits the downloading of free data and makes developing countries more dependent on developed ones also to get the proper information. In some African countries, the future looks more promising and fiber optics have been currently put into place allowing a fast internet connection and faster data downloads but much still has to be done.

Also, an issue related to operational constraints is that many areas in developing countries are very hard to access or many of those areas are too far away from commercial support services. When problems occur with the hardware or software, the companies are mostly too far away to give appropriate technical support.

2.6.3 Educational Constraints

Most of the problems in developing countries also occur in developed countries but become more critical in these economically weak countries. In developing countries there is still a high level of illiteracy especially concerning IT issues that can highly limit the use of GIS. Therefore the reduction of the technology gap is crucial particularly in improving access to education and transfer of knowledge. Some examples of the major educational constraints are listed below:

- basic knowledge of mathematics, statistics, geography and other base sciences due at various level of education, from primary, secondary, high school and sometimes not yet addressed at university level;
- knowledge of English is also quite basic and prevents often reading GIS related literature and obtaining fellowships;
- low wages for university professors sometimes cause a competition for the knowledge in the new "high-tech" fields and are in some cases the reason why the transfer of knowledge to colleagues or students is limited;

- in many developing countries, companies are not yet aware of the full possibilities of GIS technology and therefore did not create the corresponding job positions. The main possibilities at this moment are governmental institutions and universities. Also employment opportunities in universities are usually not very attractive because of the low appreciations and salaries and the limited resources for research;
- GIS equipment for education is still very expensive, especially with reference to wage levels Universities are also subject to the national economic pressures. However some online and accessible courses have been developed in recent years.

One further problem about the workforce is the brain drain effect. Enough educated people often immigrate to developed countries in order to get higher salaries. Paying high wages in developing countries is not only a problem because there are not enough resources; it also provides social tensions and crime. This is a problem which cannot be solved easily. While selecting the workforce it must be considered that the workers will stay long enough with the team before investing big sums of money.

Beyond the difficulties to find GIS expertise and the unbalanced demand-supply of GIS professionals in developing countries there are also the following factors: universities lag behind the technology, primary focus on research, migration of students to the West, GIS not seen as a career, GIS is unrecognized in the government and vendors deemphasize training issues (*Prof. Sahay, 2009*).

Some possible, although very expensive, solutions are: to select local staff and send them abroad to learn about GIS in developing countries or run trainings on the spot involving specialists from developed countries. The best option so far seems to be ‘online seminaries’. ESRI offer many basic modules for free or at low or anyway affordable rates, http://training.esri.com/gateway/index.cfm?fa=catalog.gateway.

In a case study in Senegal, a set of web-based training modules have been developed allowing researchers and students to use simple spatial analysis techniques and Arc View software to map and analyze local indicator data on a range of scales (*Huxhold, 2002*).

2.6.4 Data Constraints

Very often an effective implication is hampered by the limited availability of useful data. There are two aspects to this problem. The first is the pure existence of data; the second is the accessibility of existing data (*Teefelen, Gustavson, & Verkoren, 1992*).

Existence of data

Making maps as well as updating them is a costly and time consuming activity, therefore detailed and current maps are scarce. Often many field surveys have to be done to cover the whole area for at least a detailed topographical map. But also information about natural resources, soils and vegetation, climate and geology are often not available. In this case it is important to know the most important information influencing decision in the country. Again it is better to start with a minimal solution for a GIS than waiting for an alternative if available. Moreover, socioeconomic phenomena like population density, growth, and movement tend to be much more variable and harder to predict than in developed countries. This means that also the maintenance of a GIS might involve more work. In addition, many of those countries are or were not democratically ruled. This means that especially information about the economy, literacy and poverty might be faked, so data has to be scrutinized if there is any possibility that data is not trustworthy (*Teefelen, Gustavson, & Verkoren, 1992*).

Accessibility of data

In many countries that are ruled by a military dictatorship, good information is available, but is often considered as military secrets. Satellite imagery seems to help in this case, but as those countries mostly do not have their own satellites, remote sensing data can only be purchased from developed countries, once more increasing the dependency. Also the latest imagery is often not available for public use. Often, a decision has to be taken between purchasing either cheap and old or new but expensive data. As data is the most important thing about a GIS, it has to be paid attention that the cost for things like soft and hardware and the availability of data stand in an appropriate relation (*Teefelen, Gustavson, & Verkoren, 1992*).

IKONOS high resolution images is an example of very costly but high quality data, The IKONOS-2 satellite is a high resolution craft operated by GeoEye, (formerly Space Imaging). IKONOS is used to obtain both urban and rural mapping of natural resources and of natural disasters, tax mapping, agriculture and forestry analysis, mining, engineering, construction, and change detection. IKONOS provides relevant data for nearly all aspects of environmental study. The cost of IKONOS images varies between 20 and 40 USD per 1 square Kilometer (price list 2009).

2.6.5 Political Stability

The idea of building a database of a country's resources and using that information to help plan and direct the future development of the country concerned is only possible within the context of collective commitment and political stability" (*Burrough, 1992*). Not only that the financing of a project over a long period is very difficult; it is also hard to predict how stable the political system of the country and its neighbors will be. As the installation of a fully functioning GIS takes a lot of time, there is a risk, that the project cannot be accomplished.

Using GIS in developing countries is something that seems very unusual for many people, and the number of constraints shows that it is still a problem. However, nowadays there are a big number of GIS projects taking place in developing countries. Several standard PC packages have proven to be very useful in western organizations. These packages can also be used in developing countries for prototype purposes (*Zeller, 2002*).

Many of the constraints seem very inhibiting in the first instant, but in many cases there is a way to solve most of them. The important thing about a GIS is that it is not only a nice thing to make countries look more modern, it is a very good investment in the future of a country. GIS can be a cheap and effective way to improve decision making processes in developing countries, as long as one always keep the goal in mind: the installment of an appropriate GIS, not the competition with the latest technology GIS in developing countries.

But can GIS really support change for the better in poorer countries and avoid the trap of putting the powerless seriously at risk from GIS in top-down planning? Many doubt it (Dunn, 1997).

2.7 Things to Keep in Mind

In this section a list of guidelines that may be helpful when considering or implementing spatial technologies has been developed.

- *Educate Yourself:* GIS-GPS-RS technologies have rapidly become more accessible, less expensive, and more sophisticated. As a result of the relatively fast evolution of geospatial technologies, many professionals may either be unaware of their capabilities or may have an obsolete understanding of their potential and current implementation. It is important for potential users to educate themselves before investing in equipment and software.
- *Clarify Your Needs:* Make sure there is a clear need for GIS-GPS-RS technologies. Lack of understanding can lead users to overestimate the usefulness of geospatial technologies. Using these technologies requires a broad understanding of many different concepts, including map projections and coordinate systems, data types and formats, computer literacy, and proper documentation of data. If all you require is the ability to make maps or locate features, and don't need sophisticated spatial analysis capabilities, then you may not need a full-featured GIS package. In many instances, conventional methods of data collection, analysis, and presentation are more appropriate and efficient.
- *Know Your Users:* Carefully consider the needs of the intended users. Do you need technical support for your own staff, or do you want to create deliverables for your clientele? Do the intended users have a high or low degree of technical savvy? Are they teachable or not? Applications should be kept as simple as possible for your needs.
- *Be Realistic in Your Expectations:* experience assures that it is impractical to expect all members of your staff or faculty to learn to use GIS-GPS-RS technologies. Workshops held for this purpose have usually been poorly attended, despite enthusiasm expressed by the would-be attendees. Before investing in infrastructure, it may be wise to consider if your work could be farmed out to a consulting agency. There are now many commercial and independent contractors doing geospatial consulting work. In the long run, hiring a consultant may be more cost efficient.
- *Maintain Spatial Integrity of Your Data:* One of the most frustrating aspects of working with geospatial data is dealing with different geographic coordinate systems and map projections.

Because the Earth is not a perfect spheroid, numerous different projection systems have been devised to transfer points from an irregular curved surface to a plane surface. Different projections and coordinate systems are used for different purposes. For example, the State Plane coordinate system is used for many surveying applications, whereas a Transverse Mercator projection is useful for showing equatorial and mid-latitude continental regions. When data is stored and distributed in different projections, it must be re-projected so that all layers will plot in the same coordinate space. It is extremely important to carefully keep track of both the original and re-projected systems.

- *Document Your Data:* Developing metadata documentation of your spatial data cannot be emphasized enough. Without proper documentation of coordinate and projection systems your data may be useless to both you and others. A commonly used method for preparing metadata documentation has been developed by the Federal Geographic Data Committee (FGDC) and is described in the Content Standard for Digital Geospatial Metadata (http://www.fgdc.gov/). It is very important that users of GIS data understand the documentation procedure before using and creating data.
- *Organization is Key:* Another important point to keep in mind before establishing and working with a GIS database is that your data can quickly become disorganized. You will find that you will accumulate a large number of files as well as different versions of the same data (for example, in different projections systems). It is vitally important to establish a system for organizing data from the beginning (*Milla, 2005*).

2.8 Recommended steps for a GIS project

Up to now in this chapter, many important details and references have been described in order to develop a successful GIS project. However, after several considerations about technical requirements, such as hardware and software, human resources skills, etc, it is still not easy to define how to proceed. Whenever a GIS project has to be implemented, several steps can be recommended in order to make the right decision without wasting time and resources. Although some of those steps can be obvious, many times they have not been taken into proper consideration, leading to misunderstandings and mistakes. The authors of this guide summarize this suggested procedure in Figure 6 on the next page.

Imagine you were a GIS project planner: follow the steps…

1. **Clarify your needs. Before the baseline define the purpose of the maps.**

This is a crucial point for the future development of the GIS project. Planning a GIS project is not an easy task but it is necessary in order to avoid future errors or misunderstandings. At this stage, you have to ask yourself who the targets and beneficiaries of the produced maps are, what types of maps are required at different level of intervention, what is the level of accuracy of the planned maps. What additional data or database do you require in order to satisfy your purpose?

2. **Identify available existing GIS data and sources.**

Once your objective has been identified in step 1, it is time for you to do some research, by using all the available sources such as the Web, Government Ministries, NGOs reports, Universities, Survey Departments, etc This research will help you to check what is already available out there in order to satisfy your purposes. Also it will fatherly clarify your needs by learning from others' experiences. Finally it will save you a lot of time in the future steps.

3. **Identify whether already available GIS suits your needs.**

During your research in step 2 you will find out if some data, GIS data (e.g. shapefiles), are already available that can suit your purpose. If this data is not available you may need to adjust your research by going back to step 2 or proceed to step 4.

4. **Define additional needed information, the methodology to collect it and the associated costs (money and time).**

At this stage, it should be clear what additional information you need to produce. Identify tools and instruments required to get it and define the related costs. Ask yourself: do I need remote sensing images at high resolution? Do I need further demographic data /assets or infrastructures? Do I need other data at ground level?

5. **Collect needed data with appropriate tools (PRA, GPS, RS)**

Now it is time for you to collect data by using the correct tools as identified in step 4. This step will provide you with the missing data but it will also allow you to test your methodology and verify your information thorough cross checking from different sources.

6. **Integrate the information in a GIS Database**

Up to now, you have been able to collect all your data. It is time for you to integrate it in the GIS by using the appropriate software and GIS modules.

7. **Make your GIS project available to others according to their needs.**

Now you have completed your GIS project. It is time for you to make it available to the target group defined in step 1. i.e.: develop printed laminated maps for communities and provide complete IT packages to trained National Authorities. Make sure your maps include all the necessary cartographic elements, please refer to Annex 2 for more details.

2.9 Useful links and Further Reading

Some useful links about GIS and related applications are here reported:

ESRI GIS and Mapping Software http://www.esri.com

Federal Emergency Management Agency (FEMA) http://www.fema.gov/

Arkansas GIS Users Forum http://eciolist.state.ar.us/mailman/listinfo/gisusersforum

Federal Geographic Data Committee (FGDC) http://www.fgdc.gov

GeoWorld Magazine http://www.geoplace.com/gw/

GIS.com http://www.gis.com

GIS Data Depot http://data.geocomm.com/

GIS Discussion Groups and Lists http://home.earthlink.net/~rpminfonet/gislist.html

GIS User Groups http://gislounge.com/ll/usergroups.shtml

Software package R http://www.r-project.org/ - mainly used for statistical purpose but it has some spatial analysis modules

Intergraph Corporation http://www.intergraph.com/dynamicdefault.asp

Land Information Board News and Updates http://eciolist.state.ar.us/mailman/listinfo/libnews

MapInfo http://www.mapinfo.com

MidAmerica GIS Consortium (MAGIC) http://magicweb.kgs.ku.edu/

National Emergency Number Association (NENA) http://www.nena.org

Networking in GIS http://gislounge.com/features/aa031401a.shtml

Office of Homeland Security http://www.whitehouse.gov/homeland/

Open GIS Consortium, Inc. http://www.opengis.org/

Urban and Regional Information Systems Association (URISA) http://www.urisa.org

3. The use of GIS and Remote Sensing for disaster Risk Reduction

3.1 Disaster Risk Reduction: risk, vulnerability and hazard assessment

Until a few decades ago, disasters were seen as one-off events. Governments and relief agencies were reacting to them without considering the social and economic causes and consequences of those events. In the last few decades, this trend has been shifting towards a more comprehensive approach and deeper analysis defined as **Disaster Risk Management**. This approach aims to consider disasters no longer as extreme and unpredictable events but as unresolved problems of development.

Accordingly to some authors, the definition for disaster risk is a combination of three elements: **hazard**, **vulnerability** and **capacity** and they are related according to Equation 1.

$$\text{DisasterRisk} = \frac{\text{Hazard} \times \text{Vulnerability}}{\text{Capacity}}$$

Equation 1: Disaster Risk Assessment Equation

Hazard is a potential dangerous situation and it does not dependent on human intervention. Vulnerability is a characteristic of certain communities to be more or less exposed to hazard. Finally, capacity indicates the degree to which a community can intervene and manage a hazard in order to reduce its potential impact. This implies that, based on people's perception of their disaster risk, they are able to make decisions to adapt to, modify or ignore the risk (*Yodmani s.d.*).

Other authors (*Chricton 1999*) define risk by using the risk triangle, through hazard, vulnerability and exposure components and reported in Figure 6.

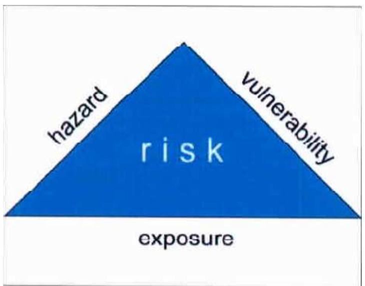


Figure 6: Risk Triangle (Chricton 1999)

Accordingly to those authors, *risk is the probability of harmful consequences or expected losses resulting from a given hazard to a given element at danger or peril, over a specified time period. Hazard is a potential damaging physical event, phenomenon, and or human activity, which may cause loss of lives or injuries, property damage, social and economic disruption or environmental degradation. Hazards can be single sequential or combined in their origin and effect. Vulnerability is a characteristic of person or a group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural or man-made disaster –noting that vulnerability is made up of many political-institutional economic and social-cultural factors*. Finally, *exposure is the probability of occurrence of an extreme physical event*. Risk is here defined as hazard * vulnerability * exposure. (*Ehrlich 2004*)

Disaster Risk Management (DRM) is the organization of resources and responsibilities for dealing with aspects of emergencies (including disaster prevention and mitigation), but especially disaster preparedness, response and rehabilitation/recovery.

The "disaster management cycle" is a formalized body of knowledge that originated in the late 1980s and is reflected in a global UN "Disaster Management Training Programme", carried out in many developing countries in the early-mid 1990s.

Key components in Disaster management cycle are: prevention, mitigation, preparedness, response and recovery/rehabilitation" as show in Figure 7.

An interesting work has been developed by Stefan Kienberger and the Salzburg University in relation to spatial modeling and vulnerability assessment.

Kienberger focuses particularly on the different factors (such as climatic characteristics, lack of coordination among institutions, reliance on subsistence agriculture, the issue of access etc…) and people's perception that are modeling the complex issue of vulnerability.

He also produced the 'Mapping the vulnerability of communities'
Manual& Toolbox referring to a case study in Mozambique. It is a useful tool for those implementing DRR programmes and need to conduct vulnerability mapping. The manual is available at the following web page: http://projects.stefankienberger.at/vulmoz/

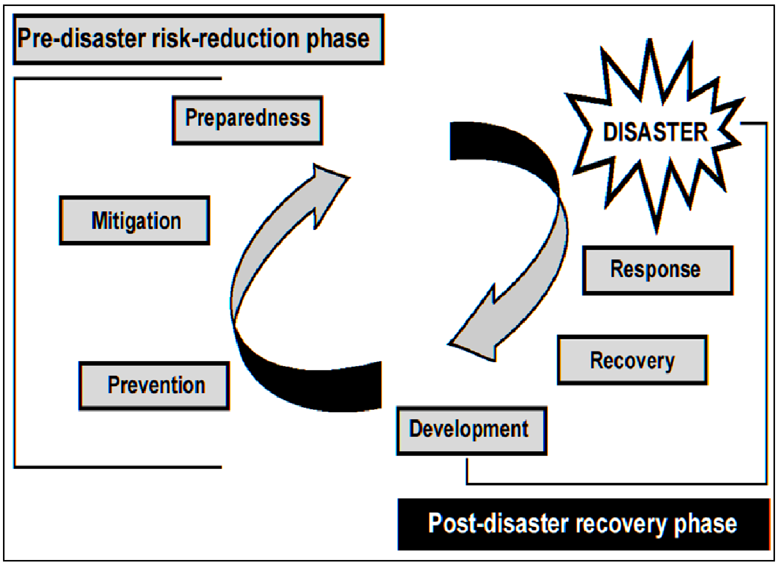


Figure 7: Disaster Management Cycle (Holloway 2003)

Prevention: activities to avoid the adverse impact of hazards and related environmental, technological and biological disasters.

Mitigation: ongoing structural and non-structural measures undertaken to limit the adverse impact of natural hazards, environmental degradation and technological hazards.

Preparedness: activities and measures to ensure effective response in an emergency and its impacts, including timely and effective early warnings and the temporary removal of people and property from a threatened location.

Relief/response: provision of assistance and/or intervention during or immediately after a disaster to meet the life preservation and basic subsistence needs of those affected.

Recovery: decisions and actions taken after a disaster in order to restore living conditions of affected communities, while encouraging and facilitating adjustments to reduce disaster risk.

While the concepts of prevention, mitigation, preparedness, relief/response and recovery continue to be viewed as useful operational terms, the "disaster management cycle" is less favored today, than it was ten years ago. This is due to the fact that the described steps can occur concurrently as well as sequentially (*Holloway 2003*).

Disaster Risk Assessment is an integral component of the process by which individuals, communities and societies cope with hazards. Risk Assessment has been usually done by economist, scientists or experts in insurance companies, government agencies on agriculture, environmental management, health, public work and highways who are concern with estimating probable damages and proposing mitigation measures based on cost-benefit analysis (*Yodmani s.d.*). Whithin the risk assessment framework, the community based risk assessment is a participatory process of determining the nature, scope, magnitude of the negative effect of hazards to the communities and to households.

In January 2005 and for the first time, 168 countries, UN and WB met in Hyogo, Japan, to define a common strategy to face disaster risks and develop disaster risk reduction policies. They produced the Hyogo Framework of Action.

In 2007, the Global Facility for Disaster Reduction and Recovery (GFDRR) was established. This is a parternship of the International Strategy for Disaster Risk Reduction (ISDR) system to support the HFA implentation.

> ***Hyogo Framework of Action (HFA)*** *is the primary international Agreement for Disaster Reduction between 168 countries and multilateral organizations (WB, UN). HFA goal is to integrate disaster risk consideration in development policies, planning, programming and financing at all levels of government.*
> *(ISDR and WB, 2007)*

3.2 Use of satellite images in DRR

Space tools have given a significant contribution in prevention, early warning, disaster reduction, rescue and rehabilitation. Particularly earth observation satellites provide accurate, timely and detailed data for several aspects of DRM: analysis of risk and mapping of potentially dangerous zones before disasters; early warning, cyclone location, drought surveillance, oil spill, forest fire and progress of desertification, disaster assessment including surveillance and assessment of flooding, post disaster assessment of damage. Satellite images combined with other GIS data helps producing analysing and modelling risks in specific areas.

In the field of flooding, prevention and anticipation of floods require global and fine modelling of basins of risk, by integrating information from several disciplines such as geography, geology, meteorology and hydrology. Satellite images can provide all these types of information.

Satellite technology is particularly important also in restoring communications in a post disaster contest when ground communications and infrastructures have often broken down.

In a disaster contest, it is very important to coordinate affords from different space agencies and using different space tools. In Africa, some of those initiatives are: the Space and Major Disaster International Charter, described later on in this chapter (3.2); the Disaster Monitor Constellation (DMC), able to provide multi spectral images; the Real-Time Emergency Management via Satellite (REMSAT), providing real time communications, remote sensing data and positioning system in emergency situations; the Constellation of Small Satellites for Mediterranean Basin Observation (COSMO-SkyMed), providing useful information on floods, droughts, landslides, volcanic/seismic events, forest fire, industrial hazard and water pollution and the Global Monitoring for Environment and Security (GMES), with the aim to facilitate the relationship between information providers and data users (*ISDR and WB 2007*).

3.3 Overview of Approaches

One of the main and most important applications of GIS and remote sensing in developing countries is related to Disaster Risk Reduction (DRR) and disaster risk preparedness. Particularly natural disasters such as floods, earthquakes, tsunami and volcanic eruption can be monitored and analyzed through satellite images and policies and measurements can be identified in order to limit damage or promptly intervene.

Also it is a key element to provide good coordination between different organizations, governments and international institutions and this is not an easy target especially in developing countries. In fact, all phases of emergency management depend on data from a variety of sources. The appropriate data has to be gathered, organized, and displayed logically to determine the size and scope of emergency management programs. Emergencies can impact on all or some government departments.

Emergency personnel often need detailed information concerning pipelines, building layout, electrical distribution, sewer systems, and so forth. By utilizing a GIS, all departments can share information through databases on computer-generated maps in one location. Without this capability, emergency workers must gain access to a number of department managers, their unique maps, and their unique data. Most emergencies do not allow enough time to gather these resources. This results in emergency responders having to guess, estimate, or make decisions without adequate information. This costs time, money, and—in some cases—lives. GIS provides a mechanism to centralize and visually display critical information during an emergency (*Jhonson, 2000*).

As said by the Minister of Science and Technology, Mrs. Grace Ekpiwhre, during a flood in Nigeria in August 2008, space-based technology such as Remote Sensing, Geographic Information system and Global positioning system are very reliable as they provide faster, cheaper, accurate and reliable data to address flood and other environmental disasters. The Geographic Information System provides the enabling environment for combining remote sensing data, Digital Elevation Models, hydrological data and attributes datasets to delineate flood affected areas under different magnitudes of floods or flood scenarios (*Muhammad, 2008*).

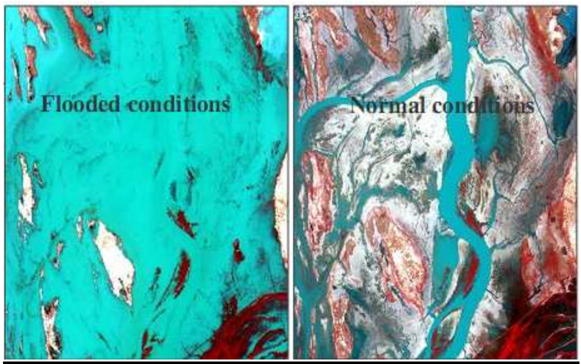


Figure 8: Satellite Images during floods in Senegal, 1999 (Aliou Dia s.d.)

Particularly in Africa, in recent years, several workshops have been organized in order to prioritize the use of satellite images and GIS for disaster prevention. Visualization and data consolidation capabilities allow GIS to convey large amounts of information to a large number of people in a brief period of time, exactly what is needed in the immediate aftermath of disaster. Satellite technology can also be a powerful tool for communications within hours of a crisis, helping to coordinate relief efforts and give reassurance to family and friends. One satellite beam could cover

Europe and Africa to provide emergency communications when land-based infrastructure is lost. When a disaster strikes, communication systems are usually affected as terrestrial and cellular networks are vulnerable to catastrophic events. Hurricanes, earthquakes, floods and fires can damage ground infrastructures within minutes, where communications are needed most especially (*Zulu, 2008*).

Another example is given by the damage assessment using high resolution satellite data after the Bhuj, (India) Earthquake of January 26th, 2001. The study provided fast loss estimation, in terms of physical damage and human casualties. A Geographic Information System has been used in order to display the spatial distribution of damages. The results could be very useful for the rescue teams deployed immediately after the catastrophe (*Chiroiu, 2001*).

Another successful example of the use of GIS in disaster risk management is realted to a pilot initiative in Trijuga municipality in the Udayapur district of Nepal in 2008 where people's perception, traditional knowledge and geo-informatics were successfully combined by superimposing local knowledge on topographic maps by applying GIS technology. The result was splendid. Today, the local administration and citizens are well informed concerning potential risks and existing vulnerability to disasters of variuos magnitudes and at different levels. Local plans integrate risk reduction components. People are aware of safe exits, most vulnerable zones and likely impacts. Informed people are better prepared to deal with pressure and emergency. Geo-inforrmation technology provides information which empowers people and the pilot proved that the power of GIS and geo-information can be easily combined in a participatory setting with traditional knowledge sources to create a win-win situation (*Khrisnan, 2009*).

GIS use during flood emergency

Particularly, in case of floods, a GIS analysis of the region around the gauging site can provide relevant elements to estimate the impact of the flood. Population density, degree of slope, percentage of land used for agriculture and the density of infrastructure (roads and railways) can characterize the site as well as secondary risks such as landslides. A risk formula then must take into account the magnitude of the flood and the characteristics of the site to provide a risk score. The amount of agriculture land covered by the floods, combined with the time of year can indicate potential economic losses and possible need for food aid. Location of populated places and critical infrastructure, such as airports and main roads, can add value to the damage assessment flood report (*Zsófia Kugler, 2007*).

In case of floods, the support of a 'hydrological oriented' GIS structure is particularly required for:

- collecting rainfall data coming from the available remote sensors;
- identifying the area of potential occurrence of extreme meteorological events on the basis of the whole set of remotely sensed information;
- running the distributed rainfall-runoff procedures using, as an input, the rainfall scenarios predicted at the small scales by stochastic space-time rainfall models;
- providing predicted and/or simulated hydrographs at the sections of interest along the drainage network for different probability levels;
- providing the maps of eventually flooded areas and the vulnerability of the landscape with reference to the predicted events.

This implies, as a major task, that the real time acquisition of remotely sensed data should be done automatically and that procedures for the selection, georeferencing and interpretation of satellite and radar derived imagery should be included within the GIS facilities in order to be coupled with hydrological modeling (*Conti, 1994*).

3.2 GIS on line for DRR application: general information and useful web links

Many international agencies are dealing with satellite images and remote sensing tools in Disaster Risk Reduction programmes. Some of them are listed below:

UNOSAT is the operational satellite applications program of the United Nations Institute of Training and Research (UNITAR). It is supported by CERN (European Center for Nuclear Research) and is based in Geneva. (*Damme, 2007*)

GEOSS (Global Earth Observation system of systems**,** http://www.earthobservations.org/): GEO is a voluntary partnership of governments and international organizations. It provides a framework within which these partners can develop new projects and coordinate their strategies and investments. As of September 2009, GEO's Members include 80 Governments and the European Commission. In addition, 58 intergovernmental, international, and regional organizations with a mandate in Earth observation or related issues have been recognized as Participating Organizations.

GMES: stands for Global monitoring for environment and security. It is the main EU programme aiming to put space applications at the service of the protection of people and their environment.

UN-SPIDER: United Nations Platform for Space-based Information for Disaster Management and Emergency Response. It has been established in 2006 with the mission statement: "*Ensure that all countries and international and regional organizations have access to and develop the capacity to use all types of space-based information to support the full disaster management cycle*", The UN-SPIDER programme is an open network of providers of space-based solutions to support disaster management activities. It is a gateway to space information for disaster management support during the all stages of the Disaster Cycle Management. It serves as bridge to connect the disaster management and space communities and it is a facilitator of capacity-building and institutional strengthening, in particular for developing countries. UN SPIDER organizes events, seminars and also manages a knowledge portal where a space application matrix allows users to interactively explore the possibilities of integrating space technology with disaster management. Source of this information is the UN-SPIDER official web site: http://www.oosa.unvienna.org/oosa/unspider/index.html.

The ***International Charter, Space and Major Disasters*** provides a unified system of space data acquisition and delivery to those affected by disasters. This Charter is an agreement between several Space agencies aiming to provide satellite data free of charge and in real time when a disaster occurs, revealing its nature and impact. Each member agency devolves committed resources to support the provision of the Charter and to be used in case of emergency. A 24/7 service is available to respond to any requests from authorized users (more than 40 authorized users between civil protection, rescue, defense or security body from 36 countries). Non authorized users can make request to activate the Charter by other authorized users or by the UN. Data acquisition and delivery takes place on an emergency basis and a project manager, who is qualified in data ordering, handling and application, assists the user throughout the process. For further information on how to activate the Charter, please visit the web site:
http://www.disasterscharter.org/web

3.3 Future developments

Over the last decades, significant developments with monitoring, detecting, analyzing, forecasting and warning of weather-, water- and climate-related hazards have led to a significant reduction of their threat to life. For example, over the last 50 years, while the number of disasters and economic losses from weather-, climate- and water-related disasters have increased (respectively nearly 10-fold and 50-fold), the reported loss of life have decreased 10-fold. This is due to several factors, a critical one being the continuous development of natural hazard monitoring and detection and of development of specific end-to-end early warning systems, such as those for tropical cyclones (*Golnaraghi, 2007*).

Decision processes in DRR fall under three categories: (i) risk identification, which involves development of risk knowledge needed for development of strategies and measures for reducing the risks; (ii) risk reduction, involving: medium to long-term planning, emergency preparedness and early warning systems, disaster response, relief and recovery; (iii) risk transfer, involving catastrophe insurance and other financial risk transfer mechanisms that would enable the spreading of remaining risks to minimize impacts across sectors. These areas of decision making are served by different ministries and agencies at the national level, and by different UN and international agencies at the international level. In situ and satellite data as well as forecast products are critical for supporting various policies and operational processes in DRR. Specifically there is potential for widening the use of currently available satellite data for all stakeholders involved in different stages of DRR decision-making. In the future, requirements for satellite-based information for DRR decision-making could be identified for the most significant segments of these stakeholders.

A contemporary example of the use of technology in DRR is given by the Haiti earthquake in January 2010. In the heart of Washington, a room full of satellite imaging and aerial photography is where the rebuilding Haiti plan begins, containing materials assembled by thousands of volunteers from 103 organizations including universities, government and private aid agencies, and companies helping the earthquake-devastated nation. The software specialists, scientists and technicians from around the world have joined disaster experts and urban planners at the World Bank. "*For the first time the world is responding to a crisis in a 21st Century way*," said Joaquin Toro, a senior disaster risk management specialist at the World Bank. "*The technology allows us to have a big picture of what* *happened without having to spend a month or two months on the ground*", Toro said. Flying over Haiti several times a day, aircraft equipped with optical laser sensors and high-definition imagery have gathered aerial photographs of the devastation in which as many as 200,000 people have died. Downloaded to a server of the University of Puerto Rico, then transferred to the Rochester Institute of Technology, the images were processed and sent to the team at the World Bank (*Reuters, 2010*).

GIS is going to play a central role in the use of satellite images for climate change monitoring. This will particularly affect developing countries as location and land use make them vulnerable to natural disasters.

4. A case study of Disaster Prevention and Preparedness in Malawi Salima

4.1 General background about floods in Salima

Salima is a district in the Central Region of Malawi and its surface area is 2,196 square kilometers. It has a population of about 309,300 based on 2.5% annual growth projections from the 1998 Population and Housing Census. Chewas and Yaos and Tongas are the predominant tribes in the district. Main languages spoken are Chichewa and Chiyao. Christianity, Islam and traditional culture (Gule wa Mkulu) or the animism are the main religions. Main source of livelihood, for the majority population is subsistence agriculture and fishing; fisherman villages are distributed all along the lake coast.

Main landforms range from the rift valley floor to the scattered hilly upland areas lying between 200 and 1000 meters above sea level. Four main rivers: Lifidzi, Lingadzi, Linthipe and Chiluwa provide the drainage system into Lake Malawi. Being on a rift valley floor, the district is highly susceptible to severe floods primarily during the months of January up to March and due to Lingadzi and Lifidzi rivers especially. The impact of severe floods can be destructive to communities who have limited means to recover quickly from loss of property and livelihood. This factor also provides a great stimulus to floods preparedness and to a strategic approach to respond to recurrent floods. The impact of floods is usually causing: loss of human life, collapsed houses causing displacement of families, damage to bridges and roads, flooding of latrines, boreholes, shallow wells, loss of property/assets and livestock; heavy siltation of crop fields; excessive water logging, invasion of hippos and crocodiles into villages and loss/disturbance of biodiversity.

The actual intervention system in case of flooding is inefficient: people from affected areas leave their houses and villages during the floods and usually come back when the rainy season ends. There is not a strategic intervention plan in case of emergency, simply phone calls direct people to move on a temporary basis from flooding areas to safer places.

This is the reason why GIS can be a very useful tool; it can provide useful information in case of emergency as well as analyze land use and river course changes therefore contributing to an accurate and timely intervention strategy. However, constant monitoring is costly and requires continuous training.

4.2 Phase I: National Maps for Salima District

National maps for the Salima District have been created in collaboration with COOPI, the Ministry of Land Resources and Bunda College, Malawi.

GIS maps have been created by using data from the National Statistics Organization (NSO), that provided shape files for lakes, rivers, roads, protected areas, railways, elevation, villages, health centres and national and district boundaries. This same type of data has been shared from different governmental and private operators, facilitating the information transfer and exchange process between different actors and organizations. However, NSO data can also be old, therefore not always updated. Not up to date maps can reduce the effectiveness of the intervention: rivers courses, small roads and land use change during time especially in areas where flooding events are significant and during rainy season. Data at community level is missing in NSO maps, as well as other information related to risk reduction activities, such as elevation data, flood prone areas, evacuation points, resettlement areas and so on. Strengths and weaknesses of maps acquired from national geographical data are summarized in Table 7.

National data maps strengths	National data maps weaknesses
• various government ministries and private institutions have collected significant amounts of geographical data i.e. boreholes, schools, health centers, topography; • many georeferenced information layers (Shapefiles) are available; • data consistency with other national and private existing maps; • easy to update and elaborate.	• Limited information accuracy at community level. Maps are originally designed for national and district purposes: local knowledge not included; • geographical information not always updated; • lack of historical reference and trends; • lack of relevant information for DRR actions: flood prone areas, accurate elevation data, etc.; and, • challenges to combine official political and traditional boundaries.

Table 7: Maps from national available data: strengths vs. weaknesses

Some of the Salima district maps developed from national existing geographical data are shown in Figures 9 and 10. Developed maps have been given to District Committee (DC) and used by public officers during an emergency in order to coordinate intervention in affected areas.

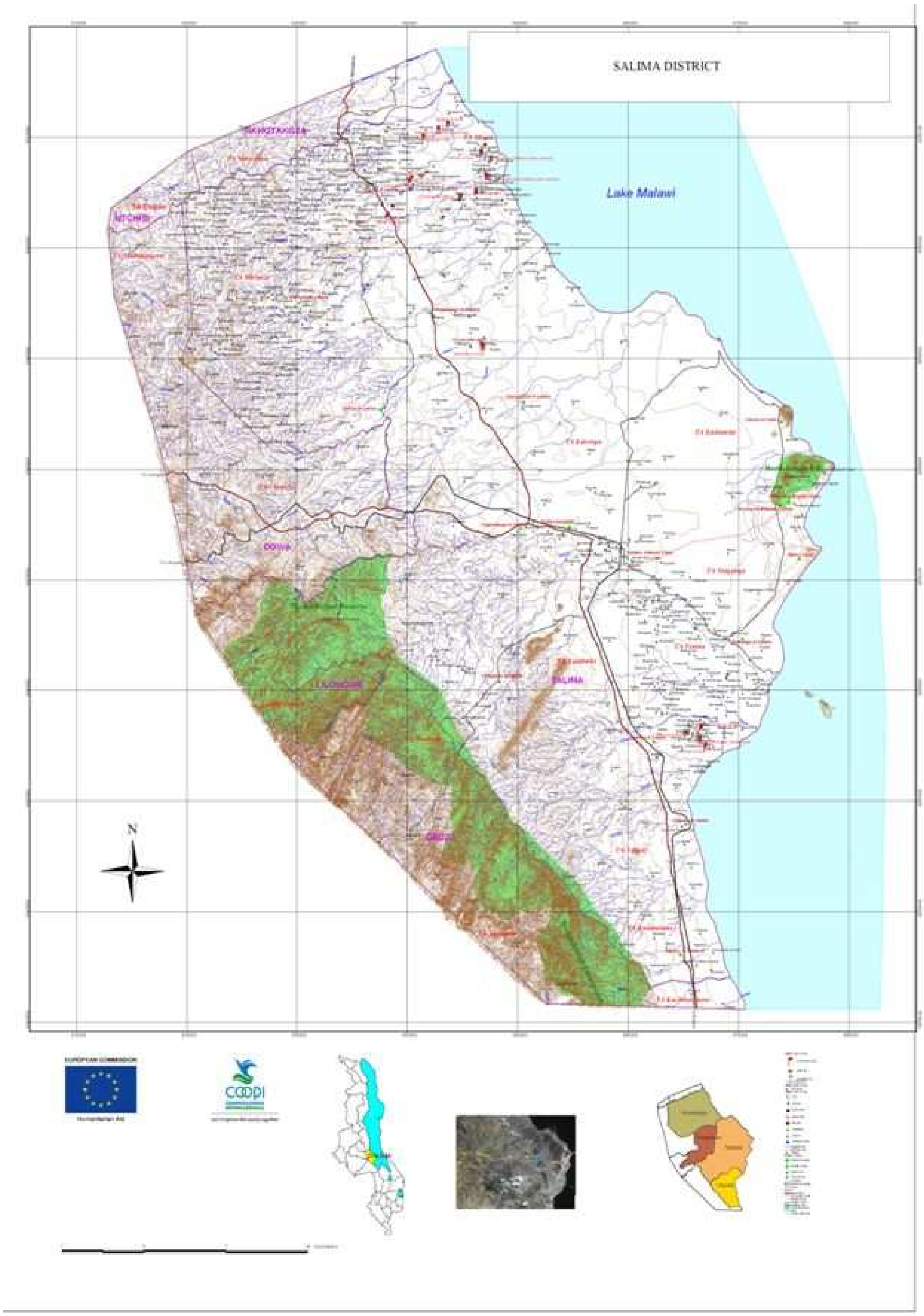


Figure 9: GIS Salima District maps from NSO data

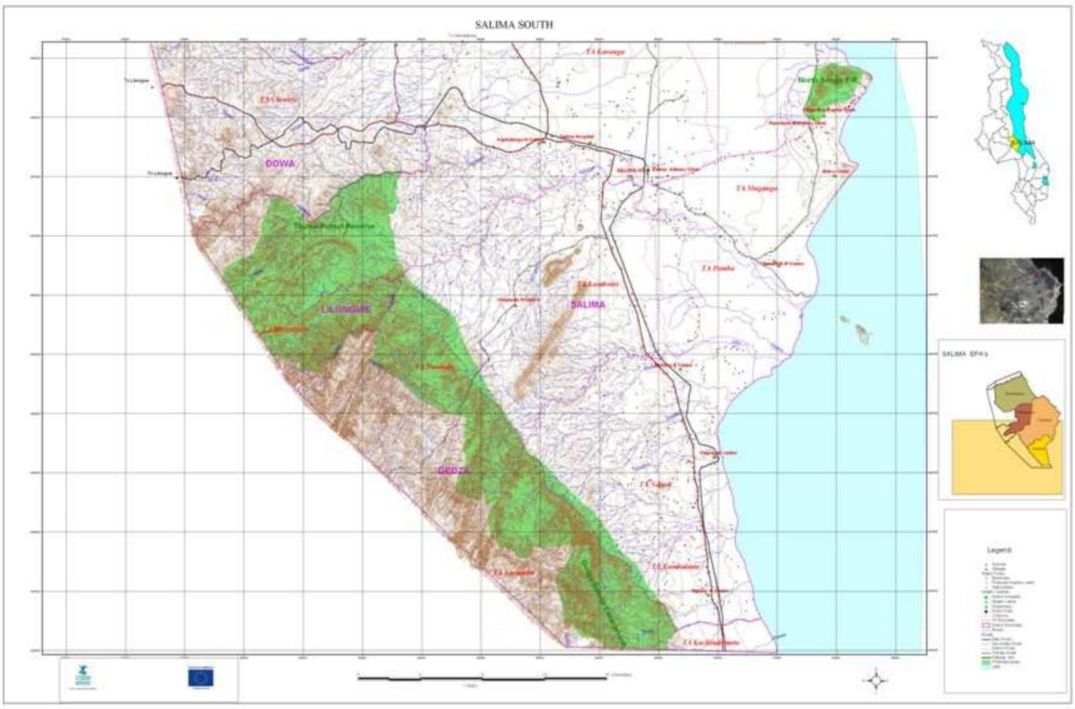


Figure 10: GIS North and South Salima District maps from national data

4.3 Phase II: Participatory Rural Appraisal (PRA) Maps in Salima District

Indigenous and cultural knowledge is extremely important in building and drawing maps. Although the ability of village people to develop maps has been underestimated up to the 1990s, their potential is very significant and Participatory Rural Appraisal is the result: local people can themselves produce maps of their own villages and surroundings areas as they know the area better than anybody else (*Chambers, 2006*).

Participatory mapping has been used for a whole range of purposes such as: social mapping, health mapping, mobility mapping, education, water and sanitation. Some studies have been developed about the use of PRA in Malawi to calibrate and correct census data, pointing to a rural population of 11.5 million compared with the official census figure of 8.5 million and implying plausibly an undercount of some 35 per cent (*Barahona, 2003*).

According to the PRA approach, people in the villages, assisted by NGO field staff, were asked to draw maps of their villages and related areas. For a proper and efficient use of maps, it is important to use data that can be understood also at community level. In the Salima case study, significant locations have been included in the drawn maps, such as: churches, schools, trade centers, village head houses, boreholes, grain silo, Community Based Organizations (CBO) etc. One of those maps is shown in Figure 11.

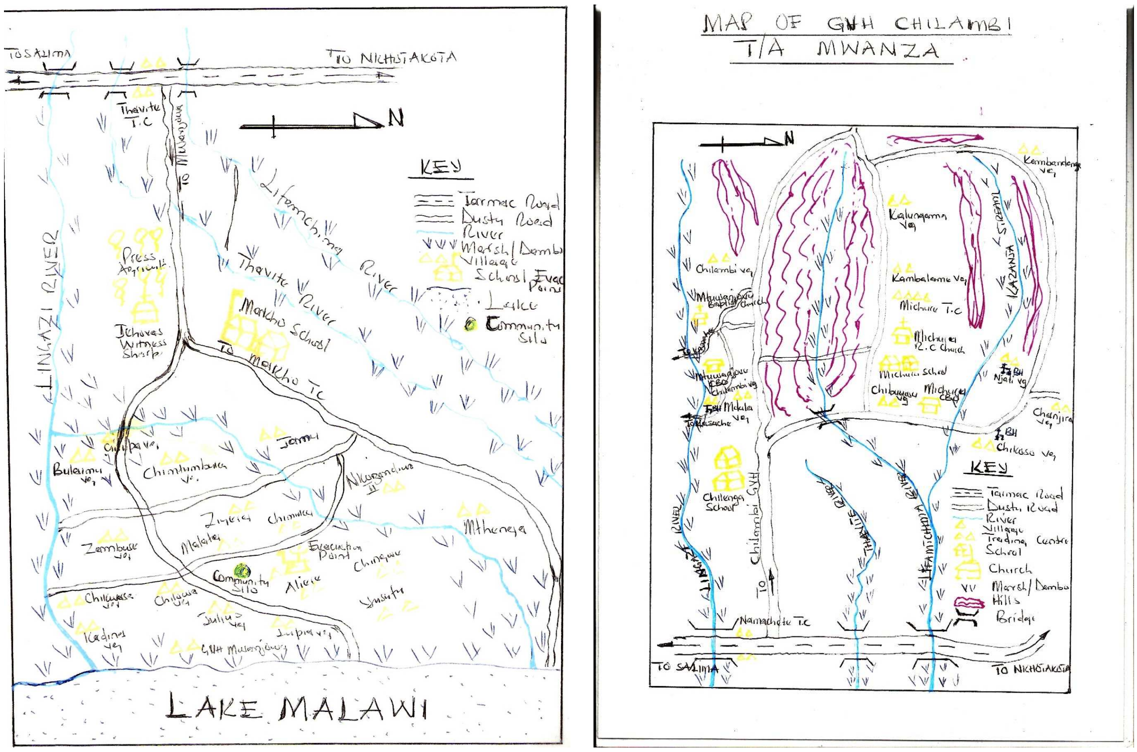


Figure 11: PRA maps in GVH Mwanjowa and Chilambi, Salima

Participatory appraisal exemplifies the problem of appropriate data types and sources for GIS. A substantial literature, both formal and informal, argues for people's participation in the construction of quantitative and qualitative data. This is relevant to understand their own situation, and to develop new techniques to elicit and present such information. Such knowledge would facilitate a micro-level planning which can be much more efficient than the classical but ineffective top-down approach. Therefore community participation has to be taken into consideration when answering to the question: "Can GIS, associated with top-down planning and control, be at the service of the people in most need"?

In many occasions, differences between people's perception and objective measures have been noticed while collecting roads or buildings data by GPS. This has been very interesting and it has provided some information about the way communities perceive and use their space.

However, there are several critics to the PRA approach. Some argue that the creation of PRA maps is also causing some problems such as: taking people's time from their field work, raising expectations, extracting information only for the outsiders' benefits while no real benefits are perceived by the local people rather than disillusion, exposing people to danger, causing violence in the community and finally repeating over and over the same activities. This last aspect has been particularly raised in some villages in Malawi that are said to have been 'carpet-bombed with PRA. Maps have been drawn and taken away by outsiders, over and over (*Chambers, 2006*).

Strenghts and weaknesses of PRA maps approach have been summarized in the Table 8.

PRA strengths	PRA weaknesses
• community participation and empowerment; • bottom-up approach to facilitate micro-level planning; • integration of geographic information and local knowledge; • identification of significant locations for DRR purposes such as flood prone areas; • often the only source of historical information related to disaster events; • information about community perception of geographical space and land use; • better definition of local boundaries perception.	• limited degree of accuracy and precision: space perception can vary from person to person; • time consuming both for communities and project team, involving associated costs; • require appropriate knowledge about methodology and qualitative approach; • subject to political biases: often community members provide information only related to their political boundaries; • difficult to digitalize: not easy to layer over other GIS maps and disseminate; and • often generated by various actors and not shared with communities and other partners.

Table 8: PRA strengths and weaknesses

4.4 Phase III: GIS maps: from GPS data collection to maps creation for a better orientation in case of floods

In order to create maps at group village level, data has been collected via GPS. Particularly, waypoints and routs were the type of data that was used in the Salima case study. UTM and Longitude coordinates as well as elevation information have been collected for each point and saved in a Garmin eTrex GPS. Also roads, particularly affected by heavy rains, have been tracked and data has been collected and transformed in shapefiles by the ExpertGPS software.

Figure 12: GPS, from field data to GIS

In particular and due to the Disaster Risk Reduction project purpose, data collection activities involved villages and specific locations used by communities during floods such as: evacuation points, grain silo and temporary resettlement areas. An excel file has been created to store detailed information about collected waypoints, including: location name, Traditional Authority (TA) name, village name and Group Village (GVH) name. A specific index has been also associated to locations used as evacuation point (index=1), Grain Silo (index=2) and Resettlement areas during rainy season (index=3). This allows distinguishing those important points from other locations. The excel file is shown in Table 9.

GISindex	TA	GVH	Village	Location	Categories	Elevation	UTM	Longitude	evac
1	Khombedza	Chimphanga	Mnungu 1	VH House	VH House	492	8505926	644798	0
2	Khombedza	Chimphanga	Mnungu 2	Borehole	Borehole	492	8509266	644798	0
2	Khombedza	Chimphanga	Mnungu 2	Chipangano Abraham Church	Church	489	8506600	644424	0
2	Khombedza	Chimphanga	Mnungu 2	VH House	VH House	493	8506450	644331	0
2	Khombedza	Chimphanga	Mnungu 2	Borehole	Borehole	497	8506476	644340	0
1	Khombedza	Chimphanga	Mnungu 1	Trading Centre	Trading Centre	499	8506484	644336	0
1	Khombedza	Chimphanga	Mnungu 1	Maize Mill	Maize Mill	499	8506514	644244	0
3	Khombedza	Chimphanga	Mgwayi	VH House	VH House	492	8506760	644549	0
4	Khombedza	Chimphanga	Chimphanga	VH House	VH House	492	8506256	645555	0
4	Khombedza	Chimphanga	Chimphanga	Chambawala School	School	492	8506658	644347	1
4	Khombedza	Chimphanga	Chimphanga	Agricultural Shed	Agricultural Shed	430	8503538	641542	0
5	Khombedza	Chimphanga	Chukuwa	VH House	VH House	487	8504998	645910	0
5	Khombedza	Chimphanga	Chukuwa	Borehole	Borehole	495	8504982	646130	0
6	Khombedza	Chimphanga	Chidzaye	VH House	VH House	507	8504536	643890	0
6	Khombedza	Chimphanga	Chidzaye	Borehole	Borehole	509	8504508	644203	0
7	Khombedza	Chimphanga	Kanama	VH House	VH House	526	8505444	642790	0
7	Khombedza	Chimphanga	Kanama	Chisamaliro CBO	CBO	518	8505538	643345	0
7	Khombedza	Chimphanga	Kanama	Trading Centre	Trading Centre	520	8504996	642930	0
7	Khombedza	Chimphanga	Kanama	Cashew Nut Plantation	Plantation	526	8504874	642810	0
8	Khombedza	Sosola	Siyasiya	VH House	VH House	540	8505942	638728	0
8	Khombedza	Sosola	Siyasiya	Borehole	Borehole	545	8505842	638761	0
9	Khombedza	Sosola	Sosola	Namachete Trading Centre	Trading Centre	558	8505080	638123	0
9	Khombedza	Sosola	Sosola	VH House	VH House	547	8505834	638701	0
9	Khombedza	Sosola	Sosola	Tawale School	School	552	8505070	638207	1
9	Khombedza	Sosola	Sosola	Borehole (village)	Borehole	545	8505842	638761	0
9	Khombedza	Sosola	Sosola	Tiyanjane Orphan Care	Orphanage	549	8505724	637731	0
9	Khombedza	Sosola	Sosola	Naphwatha J W Church	Church	540	8505922	637634	0

:

Table 9: Excel file about village demographic and GPS data

Therefore, indigenous knowledge, represented by PRA maps, and scientific data, represented by GPS waypoints and routs, are integrated in GIS maps. For this purpose, the collaboration with field staff and local communities has been fundamental to avoid the classical top-down approach and to make user-friendly maps available to the local population. People involved in the project had different expertise and knowledge. Cooperation between GIS technicians and local operators in DRR has been critical in correcting and adjusting data and creating maps that can be used by local Civil Protection Committee (CPC) at community level as well as by National Authorities.

Once data has been collected, verified and cleaned, it has been converted in shapefiles and imported in ArcView GIS 9.3. Maps of Salima District have been created by joining the created shapefiles with NSO data. The final map for a section of Salima district is shown in the Figure 13.

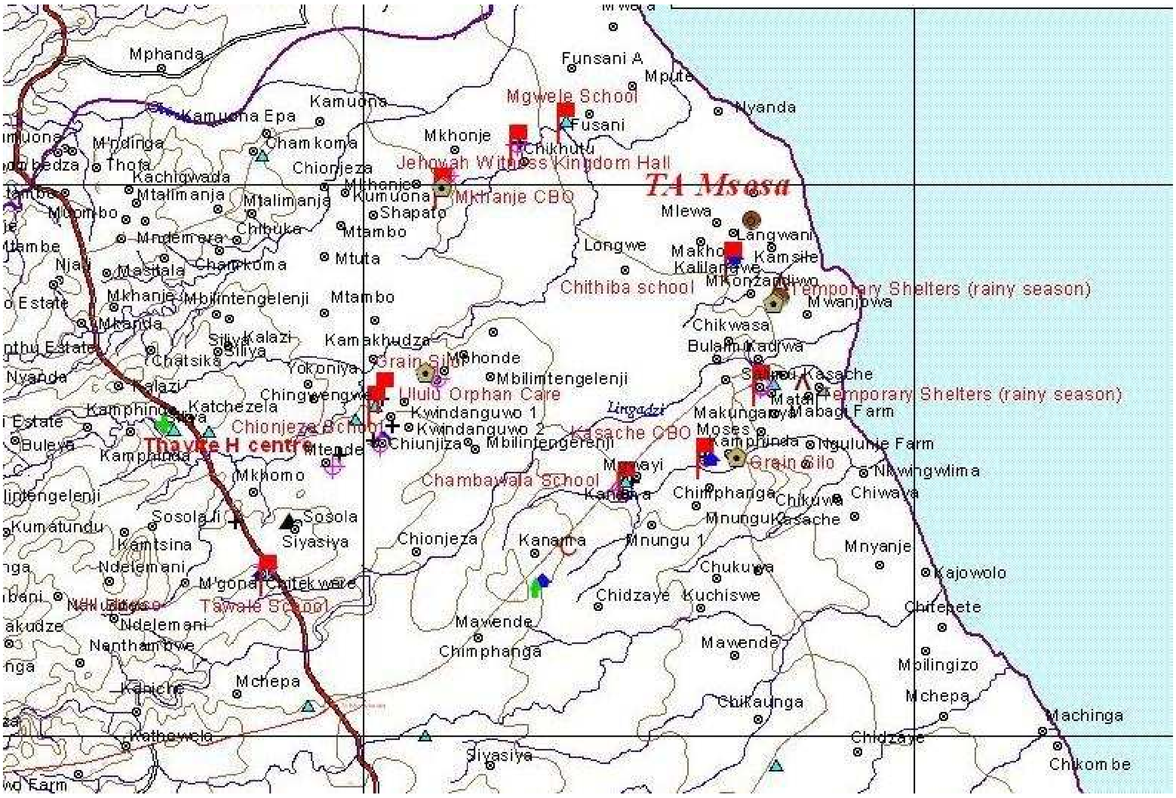


Figure 13: GIS map: Salima section

GIS maps can also show information at group village level by using a smaller scale of representation. Maps of several group villages in four Traditional Authorities (TA Mwanza, TA Msosa, TA Ndindi and TA Khombedza) have been developed, with particular attention to the following groupvillages: GVH Chimpanga, Kasache, Chionjeza, Mtende, Sanimaganga, Kandulu, Mphunga, Ruben, Makho, Mwanjowa, Mkhanje and Sosola. Results are shown in the next pages, Figure14 and 15.

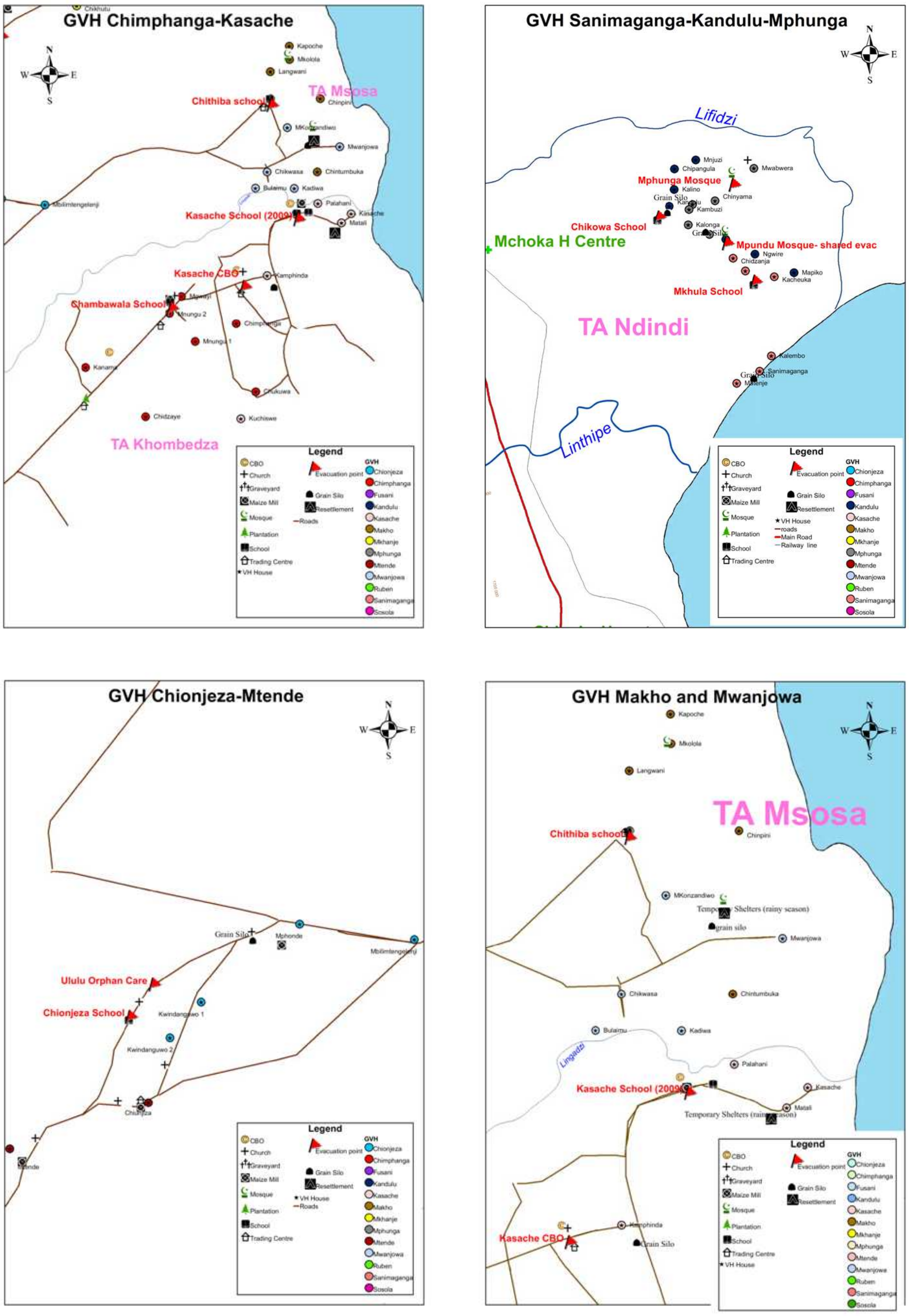


Figure 14: GIS maps of GroupVillages in Salima

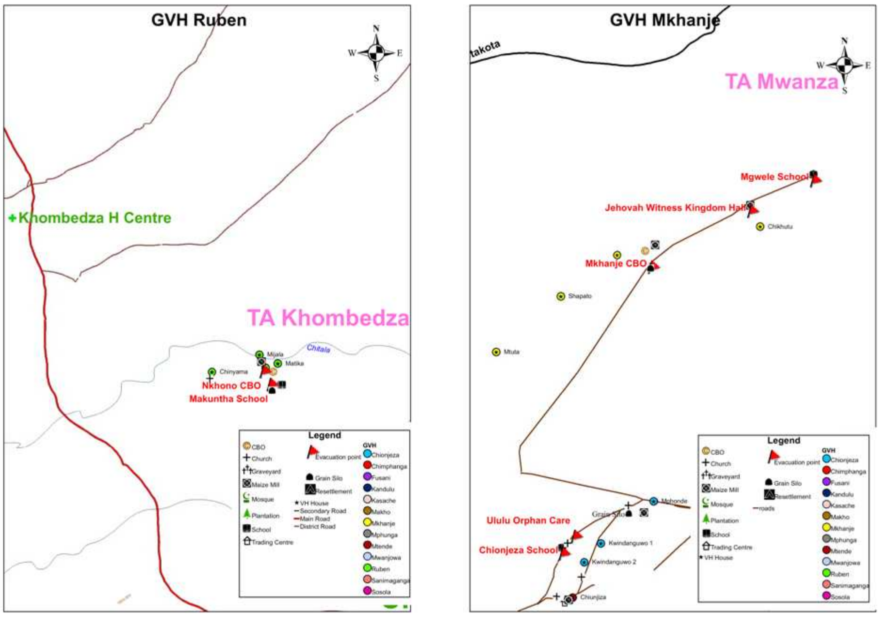


Figure 15: GIS maps of GVH village

It is very important for communities to have maps where focal points, such as evacuation points, grain silo or settlements areas are clearly shown in relation to other known locations such as village head houses, CBO, churches, schools and others. Important locations have been represented by different symbols and colors as shown in maps legend.

Strengths and weaknesses of GPS mapping have been summarized in Table 10.

GPS maps Strengths	GPS maps weaknesses
• relatively high accuracy and precision; • user-friendly device to manage; • golden standard to georeference any remote sensing images; • allow to quickly translate GPS coordinated into GIS projects; • easy to disseminate; • GPS information can be integrated with other georeferenced information; • allow to verify errors on maps from national data sources.	• time consuming to track all the roads and waypoints; • costs: purchasing GPS devices, salaries, fuel, vehicles maintenance; • require a certain amount of human resources involvement and need appropriate training; • require local knowledge about the areas (ex: PRA maps); • some geographical information cannot be easily collected (ex: river patterns due to crocodiles, flood areas, other).

Table 10: GPS maps strengths and weaknesses

4.5 Phase IV: Use of Satellite images in DRR projects

The potential and many applications of satellite images in DRR have been already discussed in Chapter 3. However, in this section, their specific use within Salima case study is described.

After GPS data collection and mapping, satellite images have been used to verify the accuracy of collected GPS data or to correct existing information (i.e.: obsolete rivers directions), as NSO data is often not updated. Data collection is a crucial activity and the probability of making mistakes is high as many operators are involved in it. Name of locations and appropriate coordinates can be easily misunderstood while interacting with different operators in the sector. This problem can be solved by overlapping satellite images to GIS maps and identifying incoherence as buildings, structures and small villages are clearly visible on satellite images with a 20 m resolution.

Satellite Images of TA Msosa have been purchased, approximately an area of 300Km^2. Figure 16 shows satellite images of the GVH Makho and Mwanjowa in TA Msosa. GPS data, such as roads, village headman house, grain silos, evacuation point, etc. has been overlaid on the satellite images, generating a more comprehensive data set and geographic information.

Figure 16: GPS maps over satellite images

By overlaying satellite images to GPS sourced maps and available GIS data, it has been possible to identify the differences in location of few rivers. As shown in Figure 17, the national available data about rivers and boundaries is represented by a full line while rivers and boundaries from satellite images are represented by a dashed line. Difference from the two data can be estimated and computed distortion has a range between 305 and 795 m.

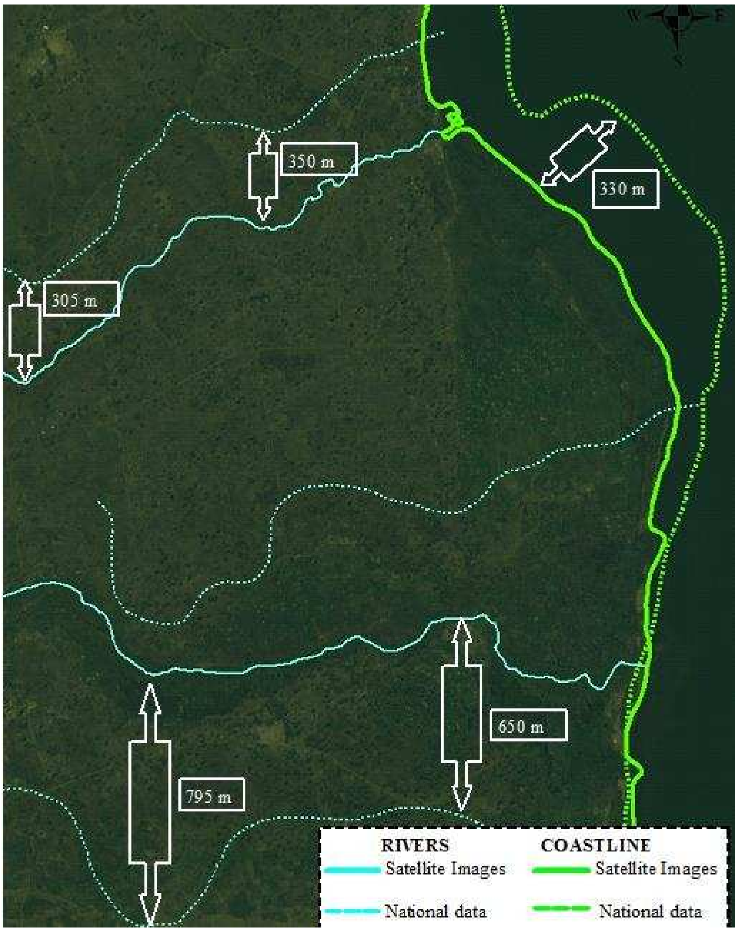


Figure 17: River distortion between National available data and SI

River courses may have changed over the years as indicated by few community members for the Lingadzi river case. However it cannot be excluded that those rivers were not originally exactly in the position indicated by the shapefiles made available at the time by several institutions. Although this data has indeed been very useful at nation level scale, it may cause inaccurate results during a detailed study analysis at local level. This example clearly shows how useful satellite images can be to correct and update the real position of rivers and coast line. Particularly, the use of satellite images spotting the same area over time may show changes of river patterns and facilitate projections of past and future flooding areas. The majority of shape files available does not report this change as updated satellite images do instead.

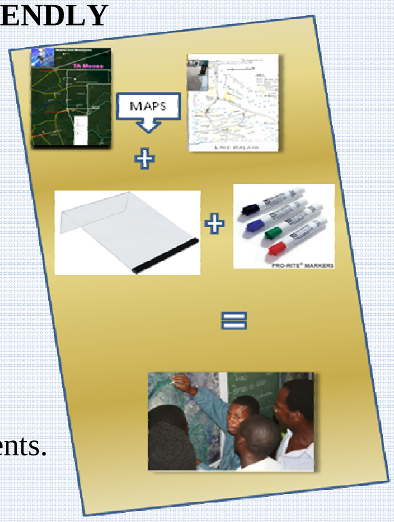
Advantages of the use of satellite images in DRR are many. Table 11 summarizes the strengths and weaknesses of this approach.

Satellite Images Strengths	Satellite Images Weaknesses
• relatively high accuracy and precision; • more and more available suppliers able to provide georeferenced and high resolution satellite images at affordable prices or at no cost (ex: Google Earth, NASA); • some remote sensing applications (ex: Google Earth) are user-friendly; • provide technical advantages: ✓ easy to layer over other GIS/GPS information / maps, ✓ allow variety of spectrum analysis and derived information, ✓ major information can be analyzed from remote locations without, ✓ physical presence on the ground, ✓ allows land use / land change analysis: trends over time of river, ✓ patterns, roads, deforestation, cultivated area, etc.	• technical knowledge required for further elaboration; • timing of spotting images depending on satellites company schedules; • quality and availability of images depending on weather conditions; and, • require local knowledge to adequately interpret some specific features at ground level (ex: school vs warehouse)

Table 11: Satellite Images Strengths and Weaknesses

KEEP IT SIMPLE AND USER FRIENDLY

The produced map can be used in DRR activities without necessarily using the computer. In fact, COOPI found it particularly useful to print maps in A0 format, laminate or frame them with Perspex 3mm. Any users, even IT illiterate, can work on the printed maps and underline different locations and information by using washable markers. Therefore that information can be also easily erased and corrected for future developments.



PRA Maps over Satellite Images: case study in Mozambique

An interesting case study about the utilization of satellite images is given by Stefan Kienberger during his work in Mozambique (*Kienberger 2008*). He utilized satellite images to design PRA maps at community level.

Quickbird satellite imagery with 0.6 m resolution has been used. Then important features have been identified and marked over the satellite images by the communities, such as: risk zones (as perceived by communities), populated areas (settlements), agricultural zones, critical infrastructure and boundaries. Finally, additional information has been collected by GPS device. A copy of the created maps has been left with the communities.

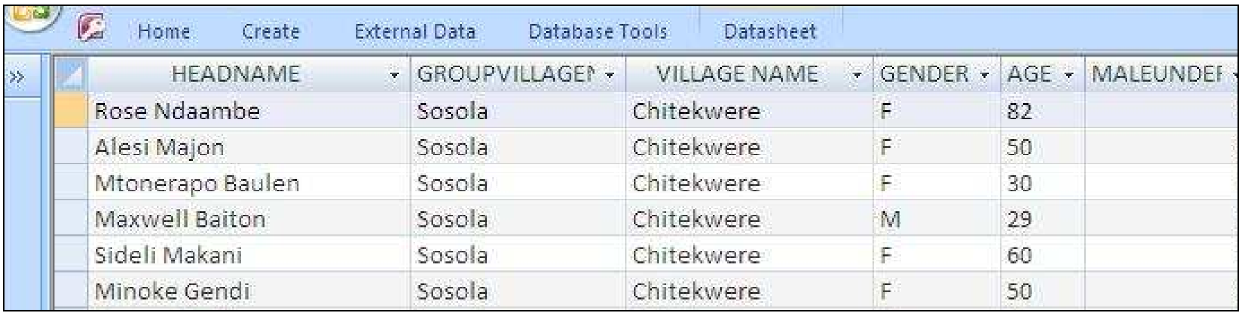
Figure 18: Building PRA maps from SI, case study in Mozambique (Kienberger, Mapping the vulnerability of Communities. Example from Buzi, Mozambique 2008)

This innovative approach has the great advantage to combine both the strengths of satellite images and PRA maps, particularly: local knowledge from PRA and accuracy and precision from SI.

4.6 Phase V: Population database and GIS representation: GIS-database link

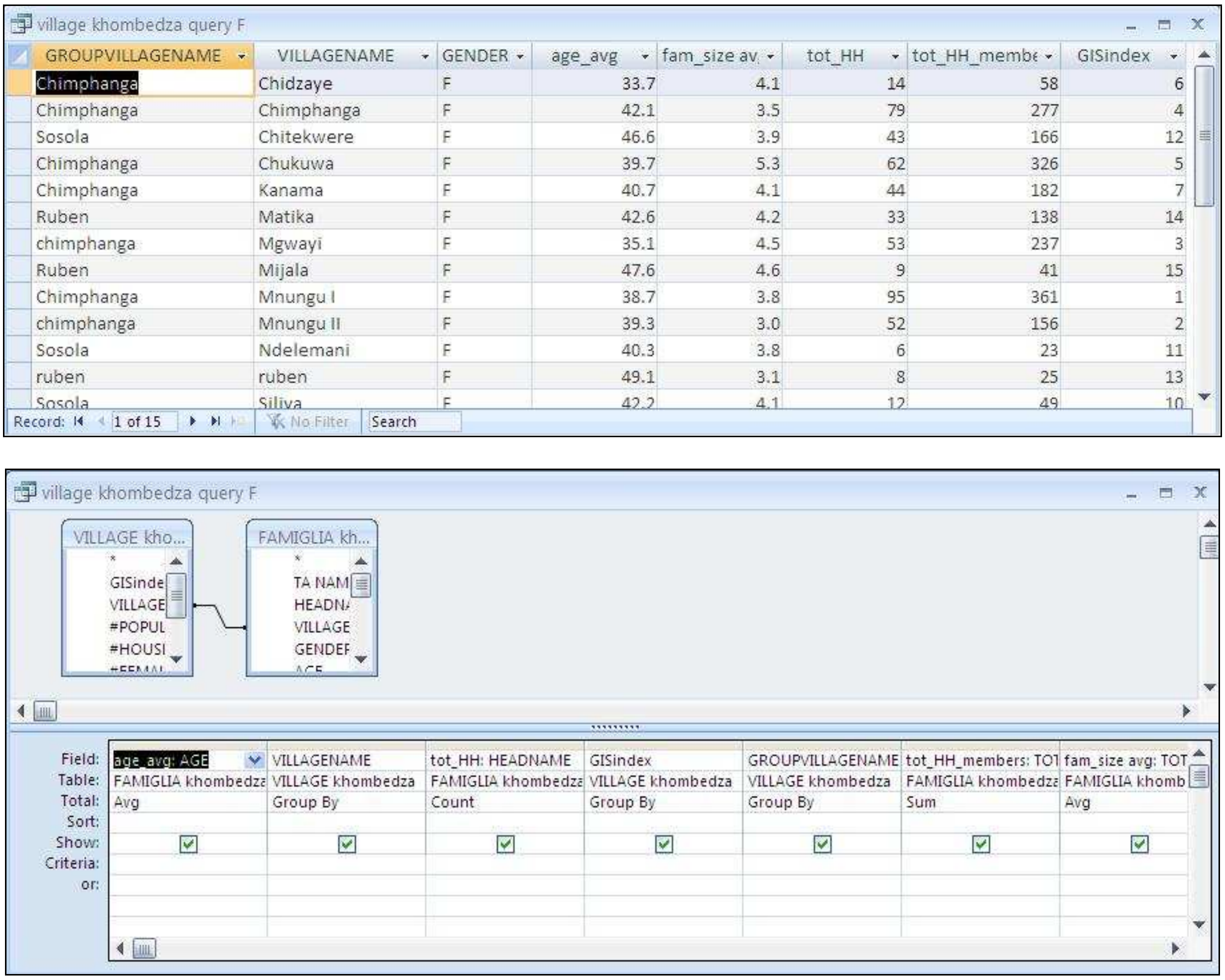
As part of the DRR project, a population survey has been conducted in villages affected by floods in order to monitor population census and elaborate statistical data. Literate Civil Protection Committees (CPC) have been selected for the specific purpose.

Once data about gender and age within households had been collected by local CPC, an Access database had been created. An example of database tables has been shown in Figures 19 and database queries in Figure 20.



HEADNAME	GROUPVILLAGEN	VILLAGE NAME	GENDER	AGE	MALEUNDEF
Rose Ndaambe	Sosola	Chitekwere	F	82	
Alesi Majon	Sosola	Chitekwere	F	50	
Mtonerapo Baulen	Sosola	Chitekwere	F	30	
Maxwell Baiton	Sosola	Chitekwere	M	29	
Sideli Makani	Sosola	Chitekwere	F	60	
Minoke Gendi	Sosola	Chitekwere	F	50	

Figure 19: Example of demographic database table



GROUPVILLAGENAME	VILLAGENAME	GENDER	age_avg	fam_size av	tot_HH	tot_HH_membe	GISindex
Chimphanga	Chidzaye	F	33.7	4.1	14	58	6
Chimphanga	Chimphanga	F	42.1	3.5	79	277	4
Sosola	Chitekwere	F	46.6	3.9	43	166	12
Chimphanga	Chukuwa	F	39.7	5.3	62	326	5
Chimphanga	Kanama	F	40.7	4.1	44	182	7
Ruben	Matika	F	42.6	4.2	33	138	14
chimphanga	Mgwayi	F	35.1	4.5	53	237	3
Ruben	Mijala	F	47.6	4.6	9	41	15
Chimphanga	Mnungu I	F	38.7	3.8	95	361	1
chimphanga	Mnungu II	F	39.3	3.0	52	156	2
Sosola	Ndelemani	F	40.3	3.8	6	23	11
ruben	ruben	F	49.1	3.1	8	25	13
Sosola	Siliva	F	42.2	4.1	12	49	10

Field:	age_avg: AGE	VILLAGENAME	tot_HH: HEADNAME	GISindex	GROUPVILLAGENAME	tot_HH_members: TOT	fam_size avg: TOT
Table:	FAMIGLIA khombedza	VILLAGE khombedza	FAMIGLIA khombedza	VILLAGE khombedza	VILLAGE khombedza	FAMIGLIA khombedza	FAMIGLIA khomb
Total:	Avg	Group By	Count	Group By	Group By	Sum	Avg
Sort:							
Show:	☑	☑	☑	☑	☑	☑	☑
Criteria:							
or:							

Figure 20: Example of DB queries

Entered data has been elaborated and additional information has been extracted such as: number of households in a specific village or group village, average family size per household and average age of heads of households, etc. Data has been also classified by gender and age.

The database user interface is shown in Figure 21 in the next page.

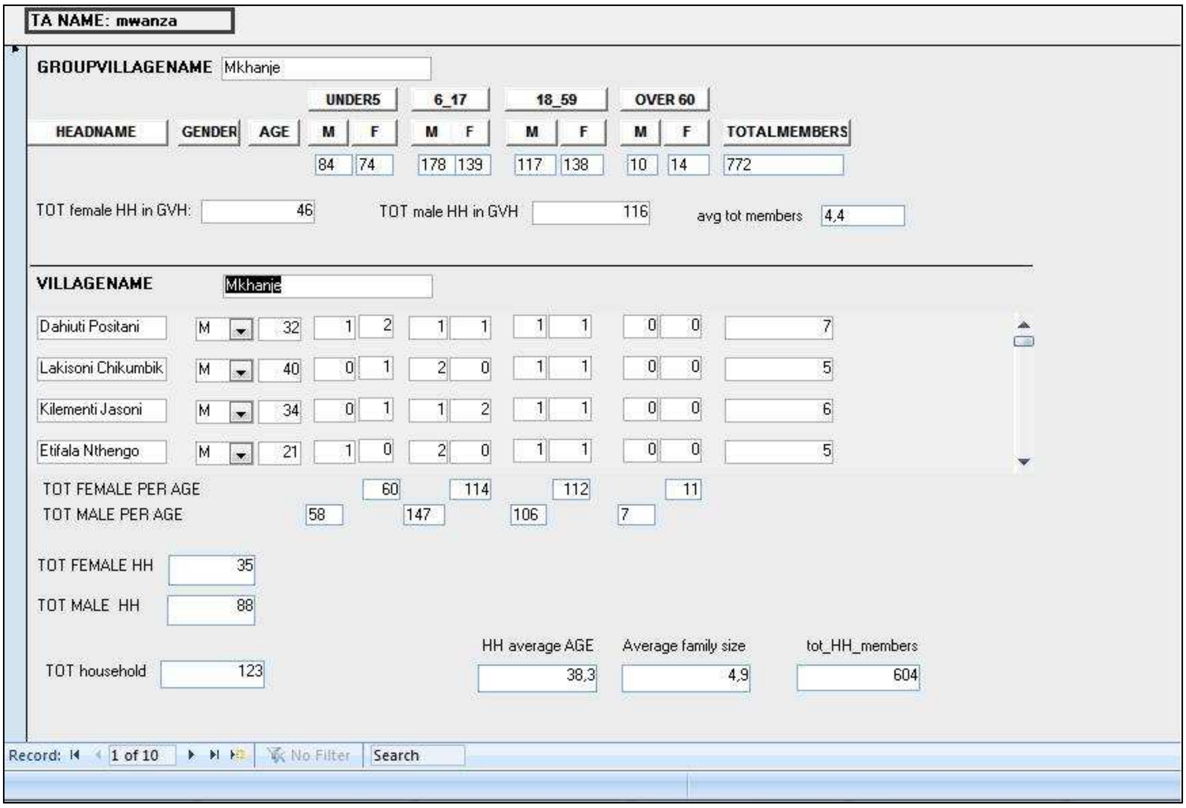


Figure 21: Demographic Database Interface

Reports have been created to summarize elaborated data, as shown in Figure 22:

Villages in TA khombedza

GVH NAME	*VILLAGE NAME*	*Average Head Household age*	*Number of Households*	*Family size average*	*male under 5 years old*	*Female under 5 years old*	*Male between 6 and 17 years old*	*Female between 6 and 17 years old*	*Male between 18 and 59 years old*	*Female between 18 and 59 years old*	*Male over 60 years old*	*Female over 60 years old*	*total population*
chimphanga	Mnungu II	39.9	117	3.4	14	50	70	63	80	89	12	16	394
Chimphanga	Mnungu I	39.8	197	4.0	52	111	130	130	148	171	20	28	791
chimphanga	Mgwayi	37.1	132	4.8	46	65	120	107	138	130	14	14	633
Chimphanga	Kanama	39.2	98	4.7	67	63	78	51	84	93	10	15	460
Chimphanga	Chukuwa	39.4	125	5.2	58	60	121	124	133	118	19	20	652
Chimphanga	Chimphanga	41.2	170	3.8	50	77	100	116	129	137	14	30	654
Chimphanga	Chidzaye	38.5	40	4.2	29	29	10	11	37	34	6	6	162
ruben	ruben	42.9	31	4.5	18	13	32	20	22	30	2	2	139
Ruben	Mijala	43.2	27	5.0	12	19	24	17	28	25	4	5	134
Ruben	Matika	40.6	92	4.7	62	65	60	73	76	78	12	10	435
Sosola	Sosola	39.4	213	4.5	125	127	141	151	166	197	27	28	961
sosola	siyasiya	45.3	78	4.6	28	41	57	72	68	62	17	14	358
Sosola	Siliya	39.7	39	4.8	22	37	23	24	38	35	3	6	188
Sosola	Ndelemani	39.9	29	4.1	14	16	19	9	32	21	3	5	119
Sosola	Chitekwere	43.7	175	5.1	121	120	135	133	153	162	24	38	885

Figure 22: Demographic database report for TA Khombedza

Data from database reports has been linked to GIS maps through specific tables and columns. Thanks to the Access-GIS link, it has been possible to visualize data related to a particular village by clicking on a specific village head house and querying about related information, as shown in Figure 23.

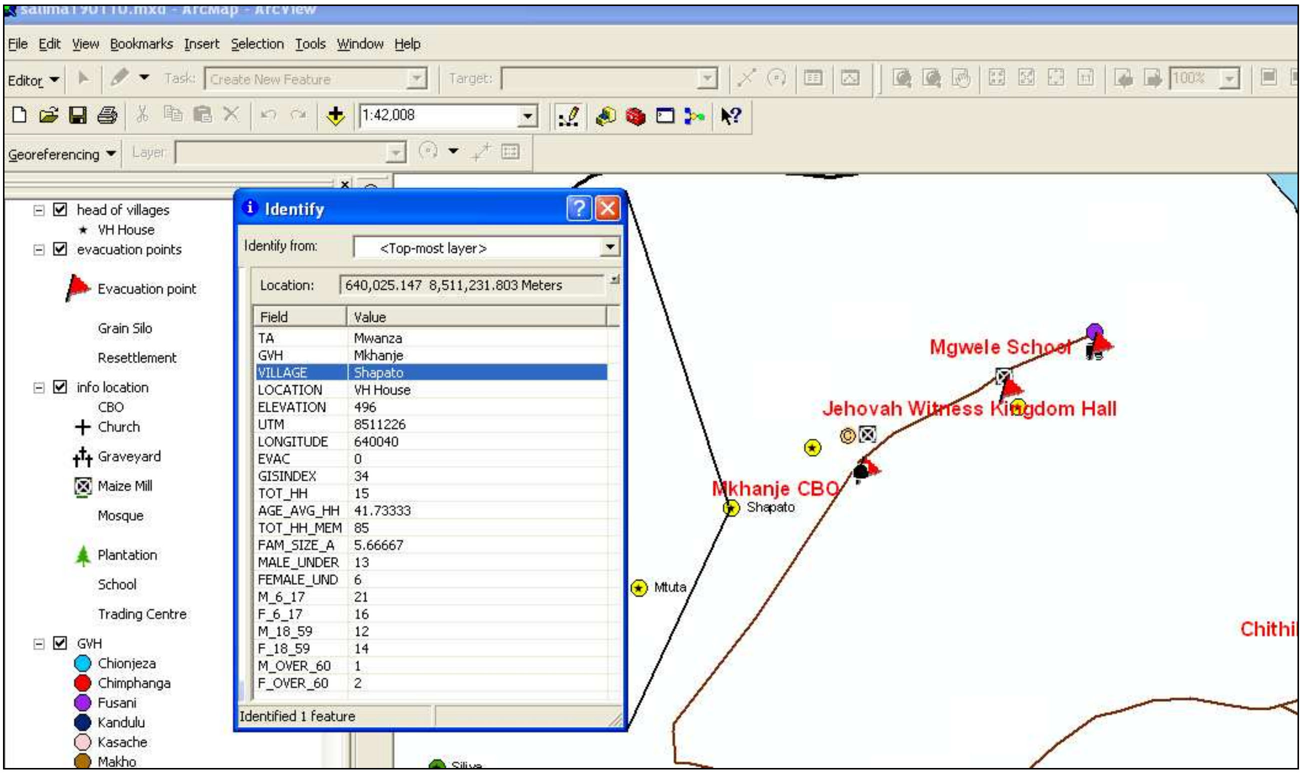


Figure 23: GIS and Demographic database link

This application shows the potential of GIS systems, where data from different sources can be shown at the same time through a geographic representation.

4.7 Salima Case Study Cost Analysis

As discussed in Chapter 4, it is difficult to have a GIS project general cost analysis, but it is possible to describe approximately the costs related to the Salima case study for the implementation of the overall GIS system. This is shown in Table 12.

PURCHASE DESCRIPTION	PRICE
Hardware **(1 laptop)**	**400 EUR**
Software **(2 ArcView 9.2 licences)**	**2500 EUR**
Maintenance	- No maintenance services has been provided
Services **(printing material and map accessories)**	**2500 EUR**
Training **(2 sessions of 2 days for 6 participants, allowances and room rent)**	**160 EUR**
GIS officers and consultants	**5000 EUR***
Total Data Acquisition:	**6515 EUR**
• **satellite images, approx area=250 km^2**	2630 EUR
• **8 GPS**	3185 EUR
• **GPS data collection, field staff, fuel**	500 EUR
• **PRA mapping**	200 EUR
TOTAL	**17075 EUR*, *costs related to the production and elaboration of GIS products**

Table 12: Salima GIS Costs

The overall cost for the Salima GIS project is approximately 17075 EURO. However this is just a description of the most relevant expenditures and other additional costs may have to be considered in the overall budget. The main cost components are human resources (GIS Officers and Consultants) and data acquisition/collection, followed by software, services and hardware costs. At this stage of the project no maintenance costs have been sustained.

4.8 The five phases in Salima case study

In this last section, the authors want to summarize the approach used for the Salima case study, by summarizing the five mapping phases: creation of maps from National Data, PRA maps, maps from GPS, maps from satellite images and finally database processing.

PHASE I: Maps derived from existing national level geographic information data:

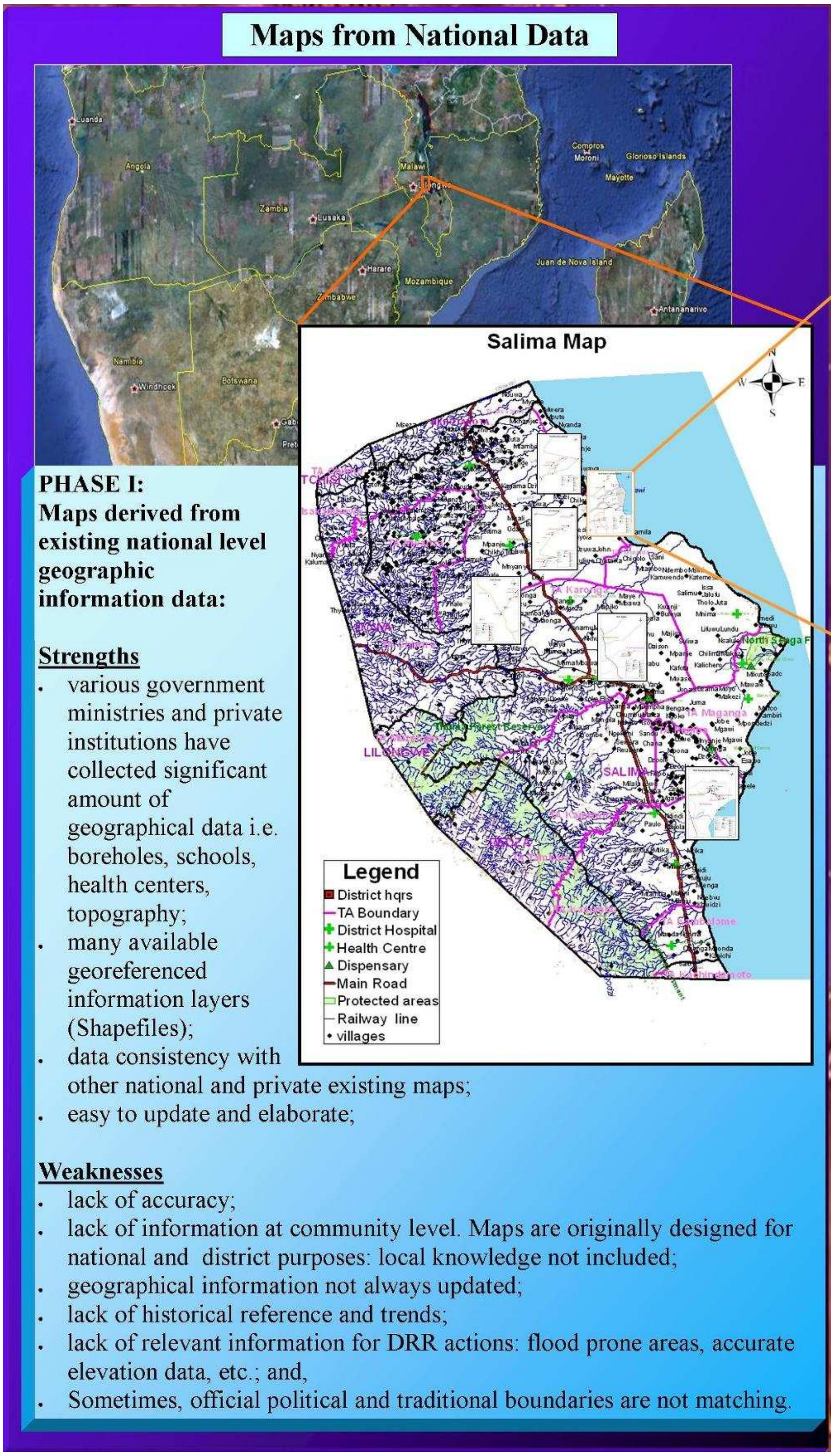
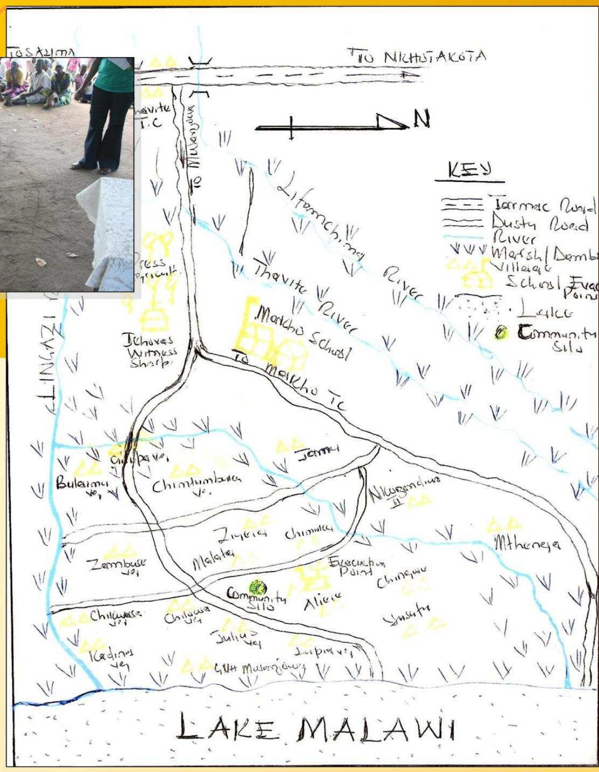


Figure 24: Phase I: NSO maps

PHASE II: Participatory Rural Appraisal Maps

Participatory Rural Appraisal (PRA) Maps



PHASE II: Participatory Rural Appraisal Maps:

Strengths

- community participation and empowerment;
- bottom-up approach to facilitate micro-level planning;
- integration of geographic information and local knowledge;
- identification of significant locations for DRR purpose such as flood prone areas;
- often the only source of historical information related to disaster events;
- Information about community perception of geographical space and land use;
- better definition of local boundaries perception;

Weaknesses

- limited degree of accuracy and precision: spacial perception can vary from person to person;
- time consuming both for communities and project team, involving associated costs;
- require appropriate knowledge about methodology and qualitative approach;
- subject to political biases: often community members provide information only related to their political boundaries;
- difficult to digitalise: not easy to layer over other GIS maps and disseminate; and,
- often generated by various actors and not shared with communities and other partners.

Figure 25: Phase II: PRA maps

PHASE III: GPS Maps

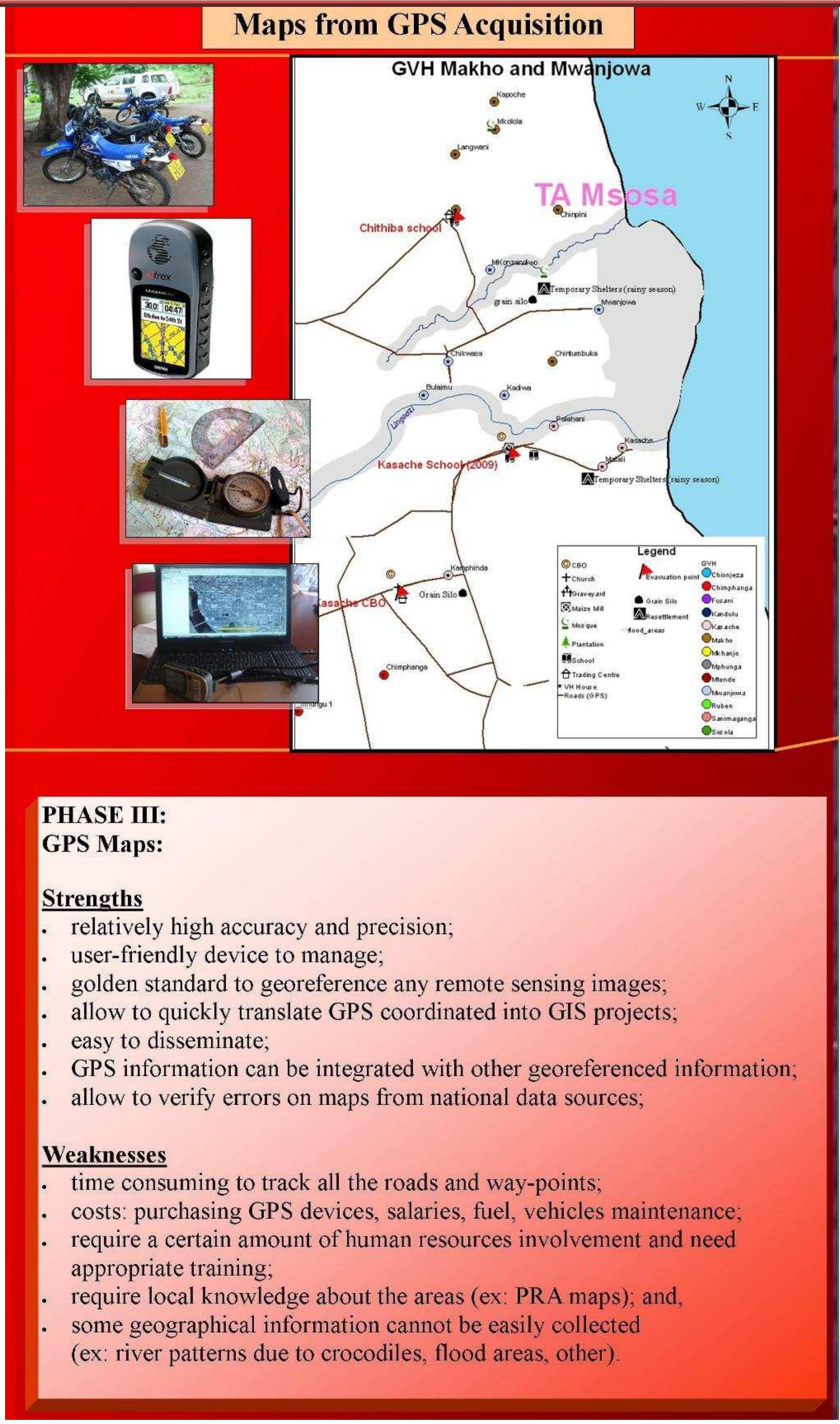


Figure 26: Phase III: GPS maps

PHASE IV: Satellite Images

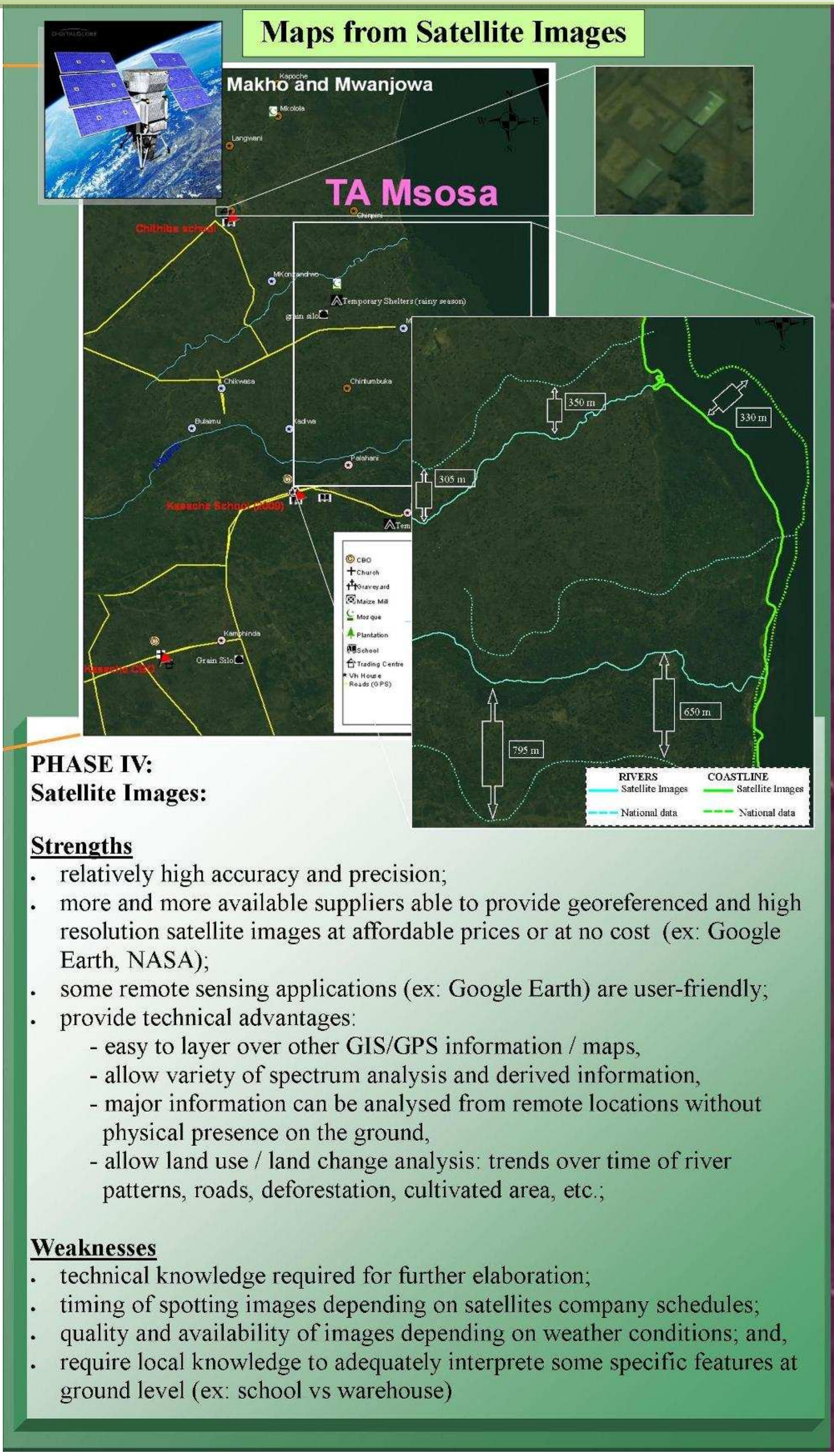


Figure 27: Phase IV: SI maps

PHASE V: Integrated Database processing

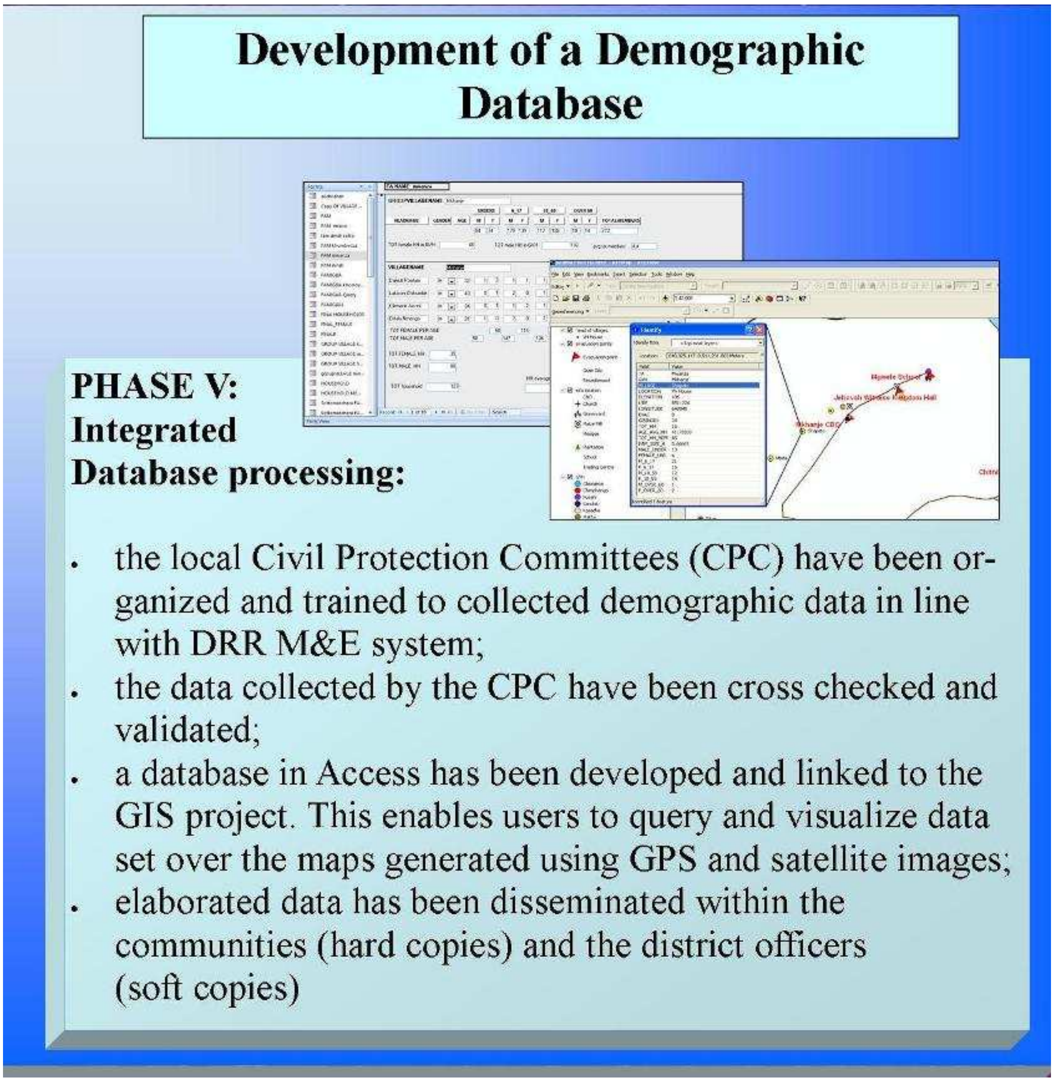


Figure 28: Phase V: Database processing

BIBLIOGRAPHY

Millennium Ecosystem Assessment. *Ecosystems and Human Well-being: Current State and Trends.* 2005.

Aliou Dia, Jacob Loulou Kouame, Jean-Paul Rudant and Soulèye Wade. «Use of Satellite Images to map Flood Extension.»

Barahona, Carlos and Sarah Levy 2003. «How to generate statistics and influence policy using participatory methods in research: reflections on work in Malawi 1999-2002.» *IDS Working Paper, IDS SUssex.* 2003.

Burrough, P.A. *Possibilities and constraints of GIS applications in developing countries.* Teefelen,v.P; Gustavson,V.L.; Verkoren, O (ed), Utrecht, 1992.

Butler, Rhett. *Satellites and Google earth Prove potent conservation tool.* Yale Enviromental 360, 2009.

Chambers, Robert. «Partecipatory mapping and geographic information systems: whose map? Who is empowered and who is disempowered? Who gains and who loses?» *The electronic Journal on Information Systems in Developing Countries*, 2006: 25,2,1-11.

Chiroiu, André. «Damage assssment using high resolution satellite imagery: application to 2001 Bhuj, India earthquake.» *Risk World*, November 2001: 13.

Chricton. *The Risk Triangle. In Natural Disaster Management.* London: Jon Ingleton, 1999.

Conti, L. Lanza and M. «Remote Sensing and GIS: potentiontal application for flood hazard forecasting.» *EGIS* (University of Genova), 1994.

Damme, O.van. «Earth Observation for Disaster Risk Management.» UNTAR-UNOSAT, 2007.

Dunn, Atkins,Townsend. «GIS for development: a contradiction in terms?» *Area* (University of Durham), 1997: Vol. 29, No. 2, 151-159.

Ehrlich, Stafan Schneiderbauber& Daniel. «Risk, hazards and people's vulnerability to natural hazards.» A review of definitions, concepts and data, Eurpean Commission, 2004.

ESPRIT/ESSI project no. 21580. *Cost-Benefit Analysis of GIS Projects.* Vol. chapter 9, in *Guidelines for Best Practicein User Interface for GIS*, di ESPRIT/ESSI project no. 21580. European Commission.

Freemantle, J. *Incorporation Google Maps and Google Earth into your remote sensing application.* 11 December 2006.

G. Di Martino, A. Iodice, M. Pasera, D. Riccio, G. Ruello. *Sensing for Developing countries: Landsat data and GIS.* Naples: Ingegneria senza frontiere Napoli, 2005.

GIS Development Pvt Ltd. «GIS Development Tutorials.» *GIS Development.* http://www.gisdevelopment.net/tutorials/tunam008.htm.

Golnaraghi, Maryam. *Response to new requirements beyond WWW updates from DRR.* Geneve: World Metheorological Organization, 2007.

Holloway, Ailsa. «Disaster risk reduction in Southern Africa: hot rhetoric, cold reality.» AFRICAN SECURITY REVIEW, Cape Town, 2003.

Huxhold, Bill. «Building Decision-Making Capacity by using GIS and Urban Indicator Analysis, Dakar, Senegal.» Dakar, Senegal, 2002.

ISDR and WB. «Global Facility for Disaster Reduction and Recovery (GFDRR), Parternship Charter.» 2007.

Jhonson, Russ. «GIS Technology for Disaster and Emergency Management.» *An ESRI white Paper.* ESRI 380 New York St., Redlands, CA 92373-8100: ESRI, May 2000.

Jonathan Deckmyn, Kristof Scheldeman, Gwendolyn Verstraete & Yves Van Gijsel. *GIS Education in Developing Countries: Ecuador.* CUENCA, 1998.

Khrisnan. «Partecipatory Vulnerability Analysis.» *Gim-international*, 2009.

Kienberger, Stefan. *Community based vulnerability assessment. The case of flood risk reduction in Mozambique.* Salzburg, Department of GeoInformatics, Salzburg University, 13-15 October 2008.

—. «Mapping the vulnerability of Communities. Example from Buzi, Mozambique.» *Toolbox&Manual.* September 2008.

Longley, P. A., M. F. Goodchild, D. J. Maguire, and D. W. Rhind. *Geographic Information.* New York: John Wiley and Sons, 2001.

Milla, Lorenzo, Brown. «GIS, GPS, and Remote Sensing Technologies in Extension Services: Where to Start, What to Know.» 2005.

Muhammad, Hamisu. «Nigeria to use space tech to fight flood disaster.» *Daily Trust*, 11 08 2008.

Ochieng, W. Y., & Sauer, K. «Urban road transport navigation: Performance of the Global Positioning System after selective availability.» *Transportation Research*, 2002: Part C 10, 171-187.

Payne, Marshall. «geo community.» http://geobids.geocomm.com/features/geonorth1/.

Pickles, John. *Ground Truth, the social implications of Geographic Information Systems.* New York: Guilford Press, 1995.

Prof. Sahay, Sundeep. *Geographic Information System for public health: challlenges and approaches.* 2009.

Rambaldi, McCall, Kwaku Kyem, Weiner. «Participatory Spacial Information Management and Communication in Developing Countries.» *The electronic Journal on information Systems in developing countries*, 2006: 25,1,1-9.

Reuters. «development workshop France.» 6 february 2010.

staff, geocommunity. *http://careers.geocomm.com/resources/gisanlystskills.html.*

Teefelen, V.P, V.L. Gustavson, e O. Verkoren. *Epilogue. Dealing with the constraints of GIS.* Teefelen,v.P; Gustavson, V.L.; Verkoren, O, 1992.

United Nation Statistic Division. *Integration of GPS, Digital Imagery and GIS with Census Mapping.* New York: DESA, 2004.

Weibel, Stefan Steiniger and Robert. «GIS software- a description in 1000 words.» university of Calgary (CA) and university of Zurich (CH), 8 May 2009.

Wikipedia. *Wikipedia.* http://en.wikipedia.org/wiki/Google_Earth.

Yagoub, Dr. M. M. *GIS market, cost, and benefits.* http://faculty.uaeu.ac.ae/myagoub/Practicum1/GIS%20Market%20Cost%20and%20Benefits.htm.

Yodmani, Suvit. «Disaster Risk Management and Vulnerability Reduction: Protecting the Poor.» *The Asia and Pacific Forum on Poverty.*

Zeller, Johannes. «GIS in developing countries: possibilities and contraints.» 2002.

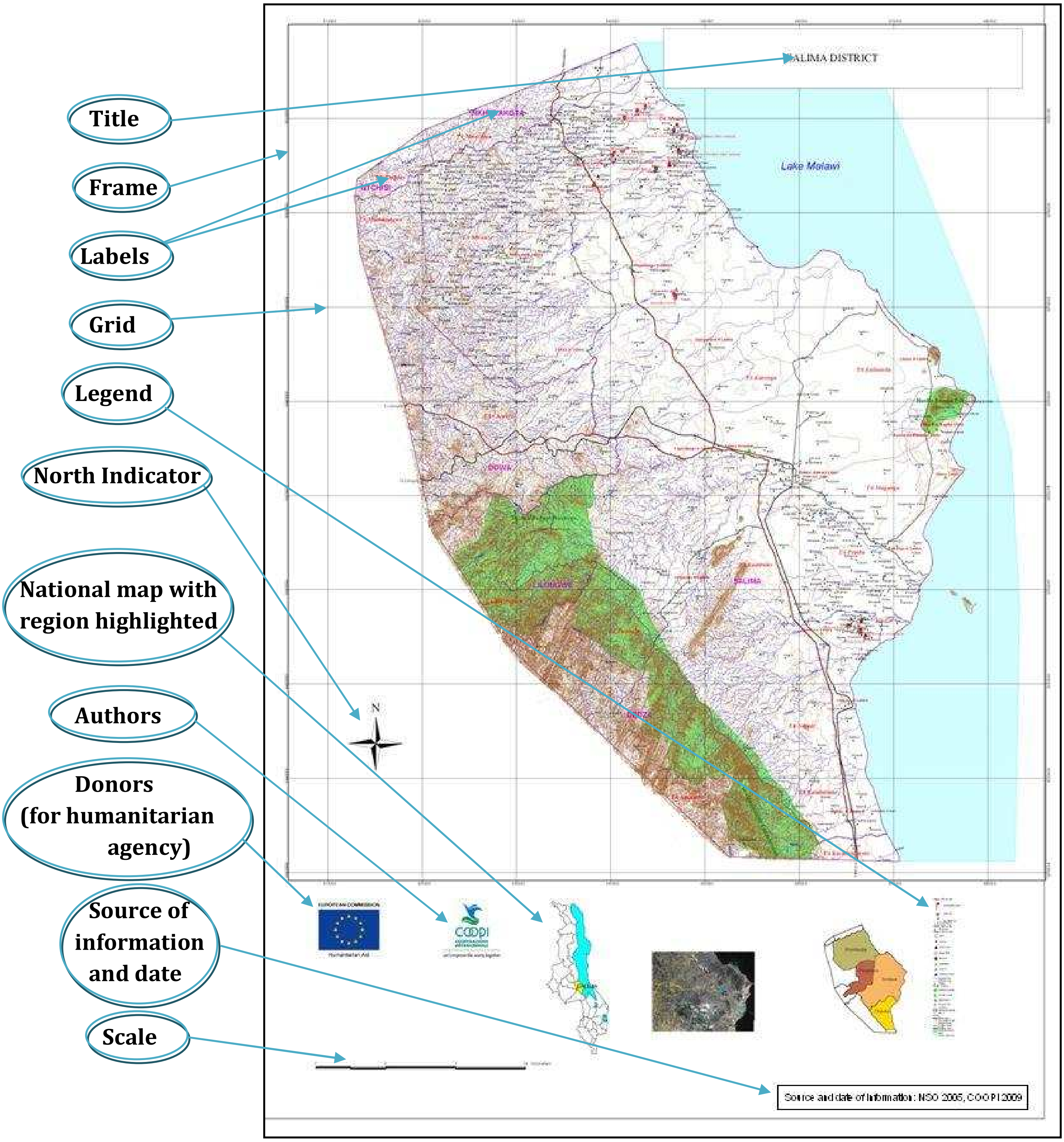
Zsófia Kugler, Tom de Groeve. *The global Flood detection system.* Ispra, Italy: European Commission, 2007.

Zulu, Brenda. «African officials urge use of IT for disaster management.» *Network World*, 21 July 2008.

Annex n.1: Poster presented by COOPI at the Knowledge Fair in South Africa, March 2010

Annex n.2: Elements necessary for a good map layout

In order to create a proper map layout, it is necessary to insert the following elements:



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