MONITORING AND EVALUATION (M&E)

Integrating Geographic Information Systems (GIS)

Contents

Document control

Organization	AIS
Title	Integrating GIS in M&E
Author(s)	Andrew Igbo (dataman@aidatasolutions.com) (igboamerican@gmail.com)
Date	January 03 2013
Description	A practical guide to integrating GIS in M&E
Approvals	
Distribution	Public domain through website
File name	Integrating GIS in M&E
Version	V2.2

Dissemination

Name or Class	Method	Date	Version
Public	Hardcopy, Electronic publication	03 June 2019	2.2

Publication of current version

	Location	Date of Publication
Intranet		
Website	www.aidatasolutions.com	03 June 2019

Level 1: Introduction - Spatial Dimension of public service delivery

1.1 Government ministries typically function as separate business units, resulting in complex and disjointed communications, which leads to inefficiencies and service ineffectiveness. For example, citizens and businesses alike expect convenient access to information on land and property ownership, yet in most cases, this can turn out to be a roundabout journey, often leaving many frustrated or feeling marginalized. This situation is further complicated when government employees find themselves negotiating their way through many processes in order to locate a cadastral map in one place, and land book in another, parcel map and ownership data in yet another.

1.2 Public service delivery is a fact of life for government, and meeting increasing service demands with fewer resources under constrained budgets is a major challenge for governments. What are some ways for government to "do more with less"?

1.3 Geographic information systems (GIS) are proving to be an indispensable component of good governance, especially at the local level. According to the Federal Geographic Data Committee, "[GIS] technology provides vital support for literally every function of a local government. Well-defined geospatial programs help jurisdictions provide quality service to citizens in a cost-effective manner." So what exactly is GIS and how does it support public administrators?

1.4 Globally, GIS is increasingly being used to support decision making processes in public administration, and contributes significantly to the design of administrative and management procedures that are more efficient, transparent and customer-friendly.

1.5 Adequately addressing the needs of citizens requires more than knowing where things are located. It demands a thorough understanding of the shared interests and the relationships across programs, related ministries, as well as a large community of public and private entities.

1.6 Integrating applications and data through a spatial framework provides the basis for collaborative planning, execution of work, and evaluation of outcomes towards the management of the entire government landscape. The adoption of GIS positions a government to take advantage of the future.

Monitoring and Evaluation (M&E) Overview

1.7 When we read that newborn mortality rate in a country has gone down by 20%, we may ponder how this data was obtained. Or when we hear that the percentage of children under age five who had diarrhea in the prior two weeks declined from 72% to 33%, we may ask, how was this calculation derived?

1.8 These types of statistics and other similar information result from "monitoring and evaluation" or "M&E" efforts. M&E is the process by which data are collected and analyzed in order to provide information to policy makers, program managers, and the public, for use in program planning and project management.

1.9 Monitoring of a program or intervention involves the collection of routine data that measure progress toward achieving program objectives. It is used to track changes in program performance over time. Its purpose is to enable stakeholders make informed decisions regarding the effectiveness of programs and the efficient use of resources.

1.10 Monitoring is occasionally referred to as process evaluation, due to it's focus on the implementation process and attempt to answer such key questions as:

- How well has the program been implemented?
- How much does implementation vary from site to site?
- Did the program reach it's intended beneficiaries? At what cost?

1.11 Evaluation measures how well the program activities have met expected objectives and / or the extent to which changes in outcomes can be attributed to the program or intervention. The difference in the outcome of interest between having or not having the program or intervention is known as its "impact," and measuring this difference is commonly referred to as "impact evaluation."

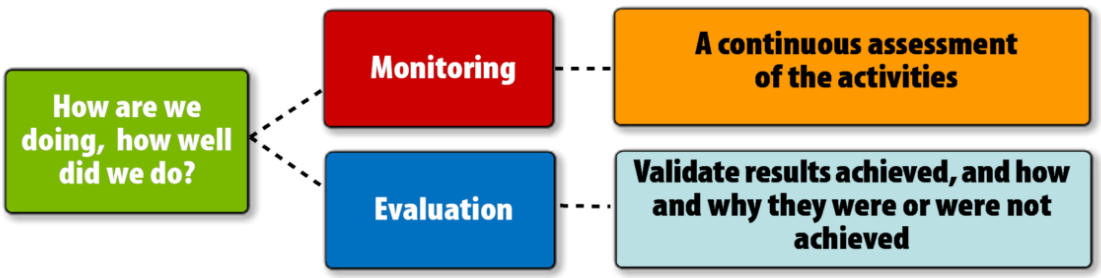
Evaluations require:

- data collection at the start of a program (to establish a baseline) and again at the end, rather than at specific intervals during program implementation;
- a control or comparison group in order to measure whether the changes in outcomes can be attributed to the program; and
- a well-planned study design.

Monitoring and evaluation helps program managers:

- make informed decisions regarding program operations and service delivery based on objective evidence;
- ensure the most effective and efficient use of resources;
- objectively assess the extent to which the program is having or has had the desired impact, in what areas it is effective, and where corrections need to be considered; and
- meet organizational reporting and other requirements, and convince donors that their investments have been worthwhile or that alternative approaches should be considered.

Figure 1 – M&E at a glance



1.12 Monitoring and evaluation are integral components of the program / project management cycle. Used at all stages of the cycle, monitoring and evaluation can help to strengthen project design, enrich quality of project interventions, improve decision-making, and enhance learning. Likewise, the strength of project design can improve the quality of monitoring and evaluation; poorly designed projects are hard to monitor or evaluate.

1.13 Performance indicators are at the heart of monitoring and evaluation, they provide a simple and reliable means to measure achievement, to reflect the changes related to an intervention, or to help assess the performance that is used to demonstrate change. Monitoring is generally carried out on a set of key performance indicators (KPIs) on a periodic basis (quarterly, semi-annual, annually) and the information is used to measure progress towards the achievement of targets, which will then be periodically compared against baseline.

1.14 On its own, Monitoring and Evaluation (M&E) can serve as an effective management tool that improves the prospects of achieving desired outcomes for any given project. Adding a GIS-based map output to M&E can dramatically improve the effectiveness and communications of results to management, stakeholders and end-users, and this guide shows you how. Geographic Information System (GIS)?

Figure 2 – Performance Indicators

What are Geographic Information Systems (GIS)?

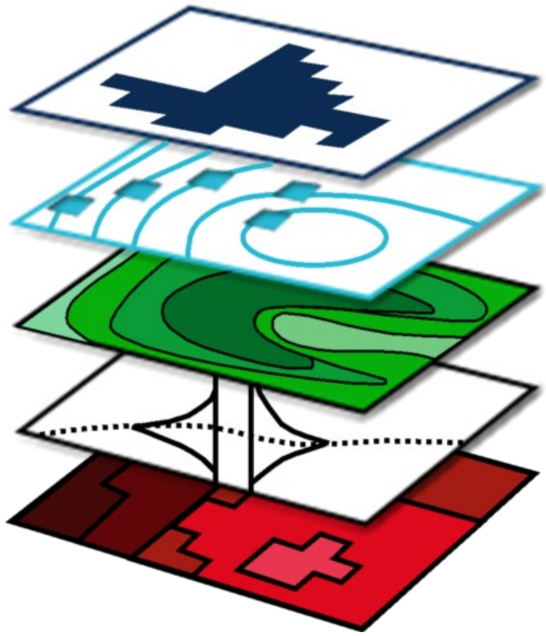
1.15 In the strictest sense, a GIS is a computer system capable of assembling, storing, manipulating and displaying geographically referenced information, i.e. data identified according to their locations. A GIS makes it possible to link, or integrate information that is difficult to associate through any other means. Thus, a GIS is able to use combinations of mapped variables to build and analyze new variables. Presenting data in the form of a map helps to understand the significance of where, when, and by whom.

1.16 GIS represents data on a map using points, lines, and polygons. Features that can be represented as points include schools, hospitals, and points of interest (POI). Streets and rivers are usually represented using lines; districts, towns and villages are depicted using polygons. GIS is designed to capture, store, manage, integrate, and manipulate various layers of data, allowing the user to visualize and analyze the data in a spatial environment (Figure 3).

GIS in public service delivery

1.17 Improve access to clean water and sanitation. Virtually all public health engineering services, such as sewer management, potable water, drainage, etc are linked to geographical locations. Maps and geospatial data form the basis for the design of systems that provide greater access to clean and adequate supplies of water to rural and urban households, as well as protect these supplies from contamination through improper handling of domestic water supplies and household waste

Figure 3 – GIS analyzes data in a spatial environment



1.18 GIS enables town planners integrate a wide variety of data into common formats, such as maps; in this way, a town planner is able to accurately generate a development plan for a new township based on transportation, landscape, and demographic information supported by spatial data.

1.19 Using geospatial data, planning zones can be mapped and accurately measured. These may be used in conjunction with tax information to provide a solution for precise budget planning. Land cover data can identify land use within the community. Environmental and development impact assessments can be visualized based on demographic projections.

1.20 Maps are at the heart of any land records administration system. GIS supports the land administration life cycle; data capture, data management and processing, and information dissemination. For Administrators responsible for land records, land use or land revenue, GIS provides geo-referenced maps with improved accuracy and quality, thereby minimizing waste, saving time and money.

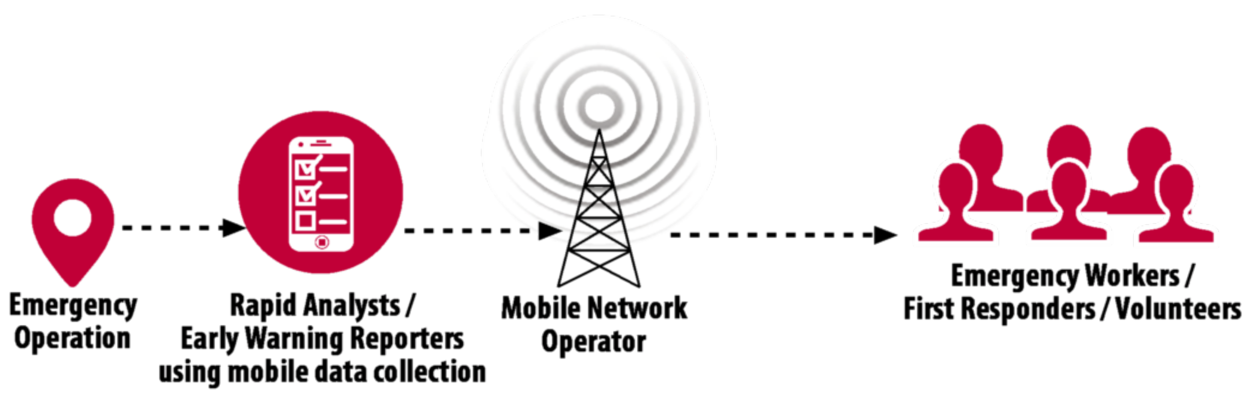
1.21 Provide a powerful means of analysis and decision making for forestry management. Satellite imagery and geospatial data form the basis for forecasting silvicultural stock, determining harvesting options, and to capture, analyze, and model ecosystem processes and functions. Geospatial data is invaluable in forest management, as it allows for planning and predicting by extrapolating trends and postulating changes.

1.22 Support reforestation efforts by providing a means of exchange of datasets among reforestation practitioners. Stakeholders and individuals engaged in reforestation projects are able to provide information about their projects as well as share related information such as carbon estimation and reporting protocols and specifications of information requirements

1.23 Increase agricultural sector productivity by supporting the development of a variety of hard copy maps for interpreting land use and vegetation classes from satellite and spatial data, making it possible to conduct change analysis in order to identify trends and the extent of vegetation and land use change.

1.24 Improved emergency preparedness and disaster mitigation. For emergency managers in both natural and man-made disasters, GIS can facilitate critical decision-making before a disaster impacts an area through the use of maps and satellite imagery. At all levels, GIS is able to support emergency response in the areas of detection, risk assessment, mitigation and prevention, preparedness, response, and recovery.

Figure 4 – GIS technology in emergency management



1.25 Improve sustainable management of natural resources and biodiversity conservation by providing accurate data for the development of integrated systems for the management and protection of groundwater using GIS and spatial hydrogeological databases. Groundwater is particularly vulnerable to pollution and overexploitation.

1.26 Equitable access to quality basic education by providing accurate data on school locations as well as community boundaries and other supporting datasets, which serve as the basis for planning and implementation of quality basic education and literacy programs based on spatial information, demographic patterns and economic conditions that help resolve issues of school clustering, access to education and improving education delivery.

1.27 Reducing, preventing and mitigating pollution by combining satellite imagery and spatial data in order to study the environment, report on environmental phenomena, and model how the environment is responding to natural and man-made factors.

1.28 GIS can serve as an indispensable tool that enables planners and others to visualize large quantities of transportation data, often rendering it more meaningful, and help highlight the transportation system's reach, coverage, modal relationships, key corridors, and relationship to economic activity and the environment.

1.29 Improved conservation efforts supported by spatial data and satellite imagery on soil degradation caused by erosion of the earth's surface, changes in flow regimes of rivers and other phenomena, which lead to better management of natural resources and the reduction of the impact of adverse environmental processes.

1.30 GIS enables telecommunication professionals integrate spatial data into analysis and management processes in network planning and operations. Marketing and sales, customer care, data management, and many other planning and problem-solving tasks that can be modelled.

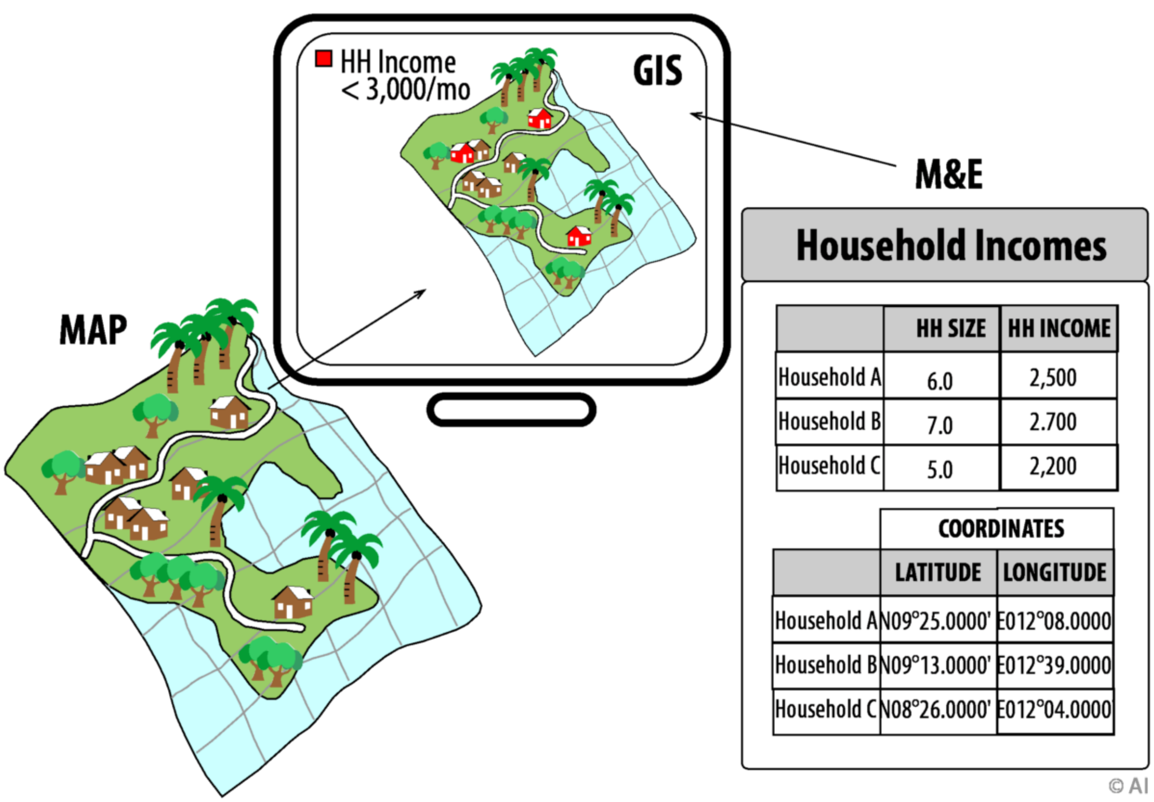
Level 2: Plan

Needs Assessment

2.1 Before embarking on an ambitious plan to integrate GIS in an existing M&E system, it is highly recommended that a proper needs assessment be conducted. It is important to be clear about expectations and whether presenting information using map-based outputs will necessarily add significant value to ongoing M&E efforts. Integrating GIS in M&E is not a fix for a poorly conceived and implemented M&E system.

2.2 M&E and GIS are fundamentally different; M&E is temporally focused on measuring changes and outcomes occurring over time, while GIS is spatially oriented – identifying where the outcomes are occurring. Therefore, the challenge is to merge these two different views into one tool that will display useful information in support of a successful outcome for a given activity. How this is accomplished greatly depends on how well data capture methods have been designed and carefully followed and whether the attribute data have been properly structured.

Figure 5 – GIS and M&E

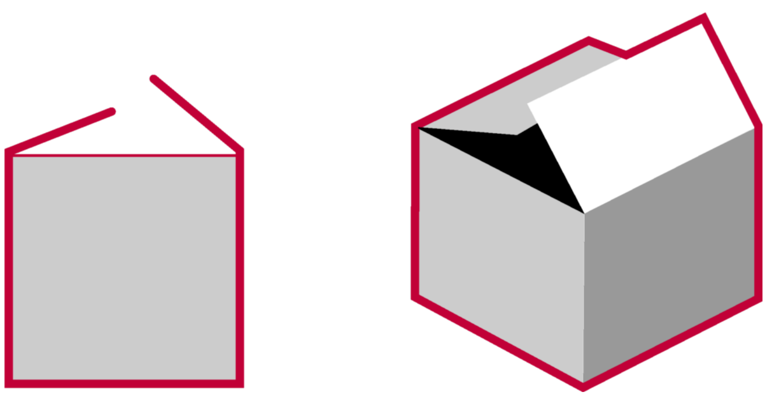


GIS; its more than just a map

Figure 6 – GIS is more than just a map

2.3 Surprisingly, a good number of M&E folks still think of GIS as simply a map; this couldn't be further from the truth! A GIS unlike a map, makes it possible to discern patterns from data that would be near impossible with say, only a spreadsheet or even a database. I often explain this by likening GIS to viewing data in 3D!

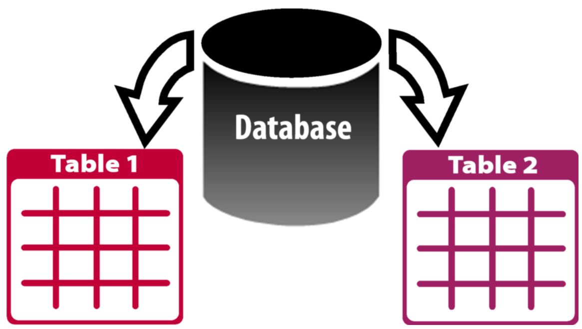
Figure 7 – Data also can be viewed flat or in 3D



2.4 Think of a spreadsheet; this is what is often referred to as a “flat file”. A flat file as the name implies, basically lacks “depth”, and much like a traditional paper map, presents data “one-dimensionally” On the other hand, you have a relational database, which provides a much more robust view of data by displaying information from “related” tables.

2.5 A relational database is what fundamentally makes a database different from a spreadsheet. A relational database is a collection of data items organized as a set of formally described tables from which data can be accessed or reassembled in many different ways without having to reorganize the database tables; GIS is very much like a “relational database” but spatially oriented, and with a map-based output.

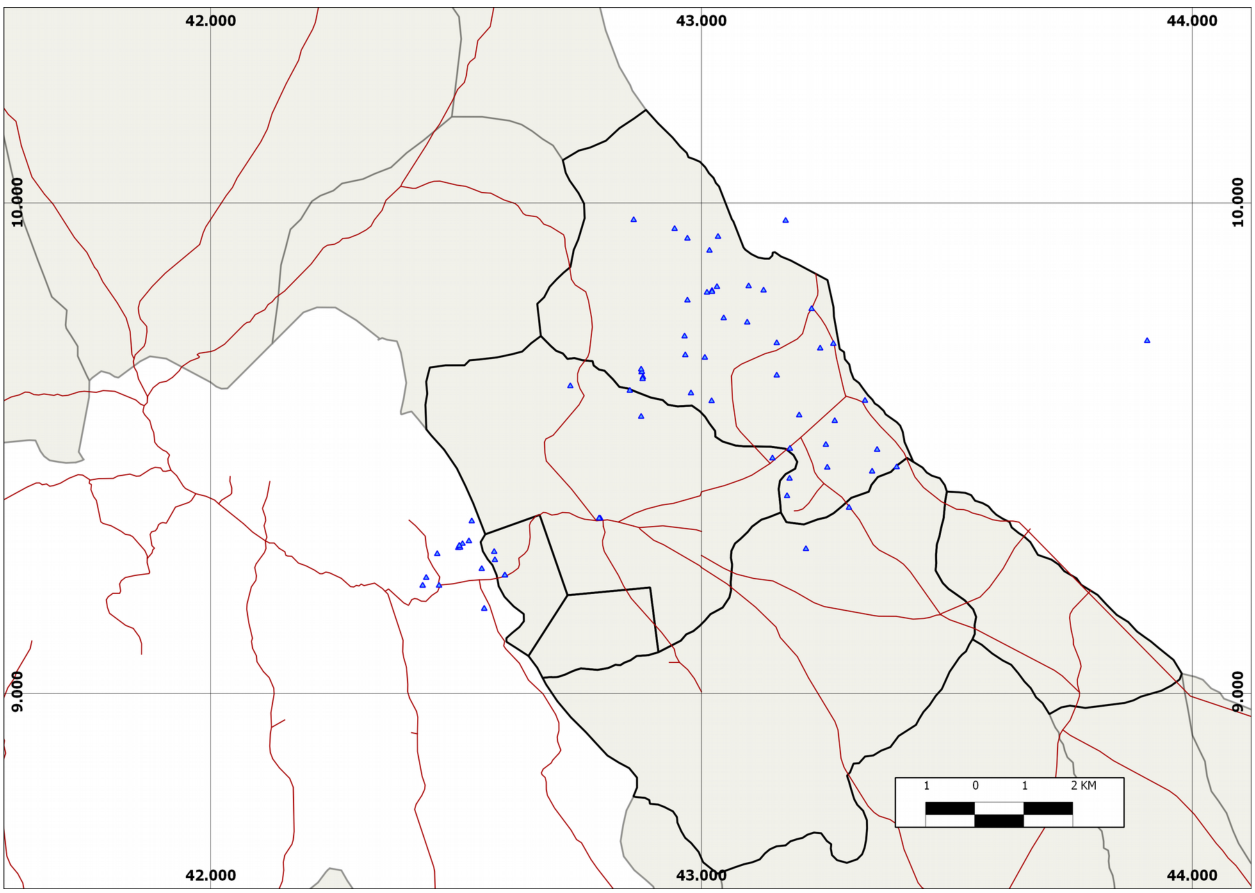
Figure 8 – Relational database is made up of ‘“related” tables



Training and preparation are key

2.6 An NGO working on a project to improve livelihoods for pastoralists in Ethiopia's Somali region, engaged me to support their M&E team with GIS mapping. The M&E team, like M&E folks at most NGOs, "knew" about GIS, and understood that it could be a useful tool in the monitoring of their project. Prior to my engagement, the M&E team had decided to undertake GIS mapping of their project, with minimal planning and rather disappointing results.

Figure 9 – Map showing animal health related activities in Jigjiga, Somali region of Ethiopia



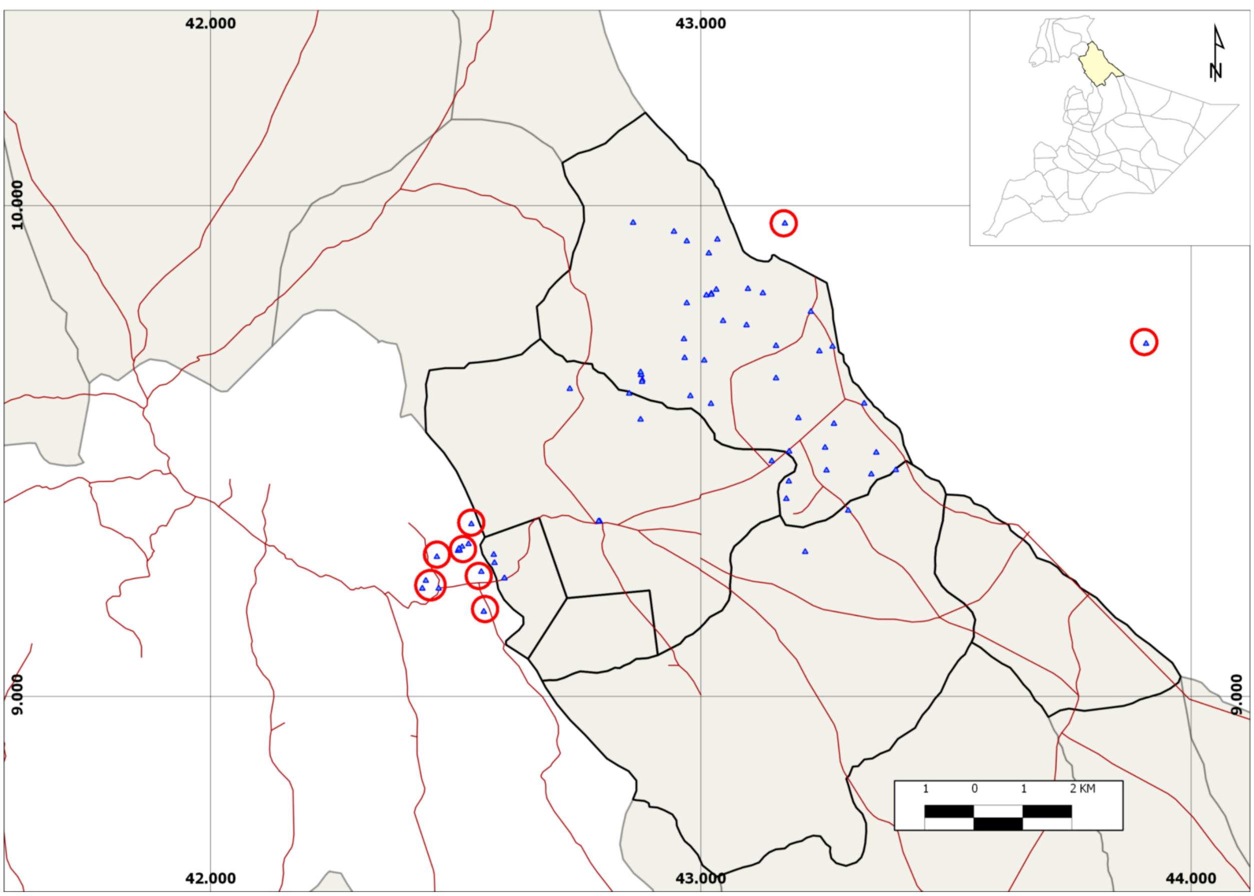
2.7 The map in figure 9 is the result of the NGO's initial foray into GIS. This map highlights some of the misconceptions around GIS; what it is, and what it isn't! For one, the map doesn't provide the user any information about the variables being mapped. But more importantly, the map is an example of inadequate planning and a fundamental misunderstanding of GIS and basic cartographic principles.

2.8 The map in figure 9 shows animal health related activities being carried on in Jigjiga, in Ethiopia's Somali region. The black line outlines the boundary of Jigjiga, and as is clearly visible, a number of the mapped coordinates are falling outside the boundary of Jigjiga; why is this happening?

2.9 In figure 10, I have circled the coordinates falling outside the boundary of Jigjiga; these are what I like to refer to as "rogue" coordinates, and they can be easily avoided by following the simple steps outlined in the pre-fieldwork section of this guide.

2.10 Efficient field data collection, processing, and mapping require that data capture methods be well designed and carefully followed and the attribute data properly structured. The importance of adequate training and pre-field work planning cannot be overstated.

Figure 10 - Map showing animal health related activities in Jijiga, in Ethiopia's Somali region with the "rogue" coordinates encircled in red



2.11 Some of the descriptions for the mapped variables in the map in figure 9 include such things as "community animal health worker (CAHW)"; now, while there may be some unknown logic to this, it would appear to be an attempt to map a "person" or grazing livestock, which would obviously yield unpredictable results! This is most likely the consequence of inadequate training and pre-field work planning.

Minimum requirements

2.12 While this may seem self evident, it is worth emphasizing. It is important to ensure that there is **at least one person who is sufficiently knowledgeable about GIS** to guide the GIS mapping exercise. A fundamental question to ask is; do we have the in-house capacity, or will we need to hire someone? Too often, disingenuous incumbent staff will claim knowledge of GIS and are thus appointed to lead the effort; this almost always produces unsatisfactory or sub-standard results;

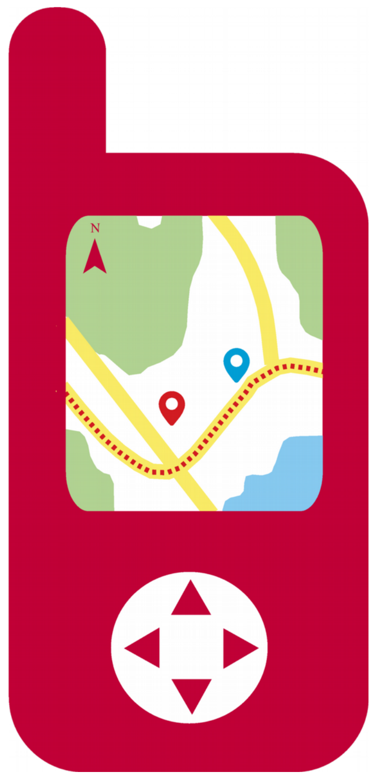
2.13 The indicators being monitored must possess **discrete geographic coordinates, locations or facilities where the activities and outcomes can be measured.** In other words, the indicators need to have a spatial orientation. As is clear from the descriptions for the mapped coordinates in the map in figure 9, a "community animal health worker (CAHW)" though central to animal health initiatives, does not represent a discrete geographic point or location that should be mapped!

2.14 A **functional M&E data management system** is already in place, if not, are there plans to develop one? If a functional M&E data management system exists, do the data already being collected have spatial parameters (coordinates) attached to each sampled data point? If not, would it be possible to determine the location of each data collection point?

2.15 A **toolkit of paper-based and electronic data capture forms** integrated with the M&E data management system. It is generally a good idea to generate blank data capture forms directly from the M&E data management system with some of the fields pre-filled with data, such as the name or description of the activity being measured, the names of districts, towns and villages so as to maintain consistency in spelling. (On many occasions I'm unable to decipher the writing on forms that have been returned to me from the field, and the person who completed the form is unable to recognize their own hand writing!)

2.16 At least one person with considerable **field work experience**, or experience in conducting surveys.

2.17 Basic model **Global Positioning System (GPS) handheld units**. Ideally, each person collecting data in the field should have their own handheld unit. (As of the time of writing this guide, there are 4 affordable, entry-level Garmin® GPS handheld receivers under 200 US dollars that I highly recommend; *Dakota® 10, eTrex® 30, eTrex® 20, and eTrex® 10*) If you work for a small NGO, and wish to integrate GIS in your M&E efforts, but cannot afford a GPS handheld unit, or the purchase of GPS units was not factored into the budget, fill out the request form found at; (www.aidatasolutions.com/gis/request.htm) and if you qualify, I will send one Garmin® handheld to you for free; however, you will have to cover the shipping costs!



Level 3: Implement

Pre-fieldwork

3.1 A major factor that will most likely affect the success or failure of GIS field activity is how well the activity has been planned. Deciding ahead of field activity, the data capture tools and procedures will determine the efficiency of the exercise and quality and reliability of the resulting data. Efficient field data collection, processing, and mapping require that data capture tools and templates be well designed and procedures carefully followed, and the attribute data properly structured.

3.2 In order to undertake field work, it is important to;

- Prepare data capture procedure with GPS handheld and paper. The form must be simple and not require lengthy completion time (If possible, generate blank data capture forms from existing database with some of the fields pre-filled with data, such as the name or description of the activity being measured, the names of districts, towns and villages. Whenever possible, use check boxes)
- Test GPS to PC connection to avoid any problems with data download, and import into GIS application
- Check GPS receiver settings. Lat/Long coordinates should be in decimal degrees and map datum in WGS84
- When collecting data, it is important to be as centered as possible and within relatively open space in order to pick up clear satellite signals
- Check that the GPS receiver has locked into at least three satellites before recording a position
- To mark a coordinate, wait at least one minute before recording the position. The mean position calculated after a one minute interval gives better results and allows for identifying possible irregularities

Table 1 Pre-fieldwork checklist

Item	Status
Do we have a clear description of the data to be collected?	Yes ❑ No ❑
Have data capture instruments to be used been clarified and agreed upon?	Yes ❑ No ❑
Have person/team responsible for data collection been identified and trained?	Yes ❑ No ❑
Have plans been made for short and long-term data storage: e.g., local storage and backup?	Yes ❑ No ❑
Extra batteries have been provided for GPS receivers	Yes ❑ No ❑

Data capture forms

3.3 Perhaps the most obvious yet overlooked aspect of GIS mapping and the one that will subsequently determine the ability (or inability) to integrate the GIS data is the design of the data capture form.

3.4 As part of an assignment to develop a strategic performance monitoring system (SPM) for the Somali Regional Bureau of Finance and Economic Development (BOFED), I worked with the BoFED GIS and M&E teams to integrate GIS in the Bureau's ongoing monitoring efforts.

3.5 The assignment involved developing a set of standardized paper-based data collection forms and templates to be used by BOFED staff for intensive, on-site monitoring and reporting, and to allow for data collected by BOFED as well as other regional bureaus at Zone, *Woreda* and *Kebele* levels to be captured on the paper forms and later keyed in to a database management system (DBMS).

3.6 Data capture forms were developed for 33 performance indicators, and on specific forms, two additional data capture fields; **Latitude** and **Longitude** were added in order to capture the geographic coordinates that refer to an activity's location (see Figure 12 - data capture form for performance indicator "Animal Vaccination Coverage" with GIS data capture fields added) There was no need to include the Latitude / Longitude data capture fields on data capture forms for those indicators that lacked discrete geographic coordinates, locations or facilities where the outcomes could be measured; in other words, the indicators did not have a spatial orientation!

3.7 For example, does an indicator such as "animal vaccination coverage" provide discrete geographic coordinates, locations or facilities where the outcomes can be measured? This is a fundamental question to ask about all indicators when considering GIS integration. An animal health facility clearly plays a central role in animal vaccination efforts in the Somali region. They are used to maintain the critical vaccine stocks used for vaccinations and ideally, also make available the services of a qualified veterinarian, or community animal health worker (CAHW) to the area farmers. As such, gathering location information on animal health facilities, and combining that with other performance data can provide some very useful insights. As such, adding the Latitude / Longitude fields to the data capture form is intended to capture information on the location of the animal health facility supporting vaccination activities in that area and NOT the species being vaccinated! (see Figure 11 - data capture form for performance indicator, "Animal Vaccination Coverage" simplified version).

Figure 11 – Data capture form for performance indicator, "Animal Vaccination Coverage" simplified version

Somali Regional State Bureau of Finance & Economic Development - BoFED
Animal Vaccination Coverage Data Capture Form

SERIAL NUMBER: 0501-000-211-01-01

IMPLEMENTING BUREAU: Agriculture

PERFORMANCE INDICATOR: Animal vaccination coverage

Number of animals vaccinated for each selected animal species against a disease in question during a specified period divided by that livestock population (expressed as a percentage.)

ZONE: Jigjiga

WOREDA:

ANIMAL SPECIES VACCINATED

- (●) Cattle
- ( ) Camel
- ( ) Sheep
- ( ) Donkey
- ( ) Goat

VACCINATED AGAINST

- [x] Anthrax
- [x] Blackleg
- [x] Pleuro-Pneumonia
- [x] Hemorrhagic-Septicemia
- [ ] Other

TOTAL ANIMALS VACCINATED: 27,000

TOTAL VACCINES USED (DOSES, ML, LITER): 135,000

EMPLOYEES INVOLVED IN THE PROCESS: 75

AVAILABLE VACCINES (DOSES, ML, LITER): 405,000

START DATE (MM/DD/YYYY): 01/01/2012

END DATE (MM/DD/YYYY): 03/31/2012

ANIMAL HEALTH FACILITY LOCATION (Take 2 readings at 1 minute interval)

LATITUDE (DECIMAL DEGREES)	LONGITUDE (DECIMAL DEGREES)

COMMENTS/OBSERVATIONS

No baseline data exists for animals vaccinated disaggregated by species. The baseline has been

3.8 As earlier mentioned, when embarking on field data collection, it is important to prepare data capture procedures with GPS handheld and paper, and to keep the form simple to ensure that it does not require lengthy completion time. To the extent possible, use check boxes and pre-filled data fields when designing the data capture forms!

Figure 12 - Data capture form for performance indicator "Animal Vaccination Coverage" highlighting GIS data capture fields

Somali Regional State Bureau of Finance & Economic Development - BoFED
Animal Vaccination Coverage Data Capture Form

SERIAL NUMBER
0501-000-211-01-01

IMPLEMENTING BUREAU
Agriculture

PERFORMANCE INDICATOR
Animal vaccination coverage
Number of animals vaccinated for each selected animal species against a disease in question during a specified period divided by that livestock population (expressed as a percentage.)

ZONE
Jigjiga

WOREDA

ANIMAL SPECIES VACCINATED
(●) Cattle ( ) Goat ( ) Donkey
( ) Sheep ( ) Camel

VACCINATED AGAINST
☒ Anthrax ☒ Pleuro-Pneumonia ☐ Other
☒ Blackleg ☒ Hemorrhagic-Septicemia

PERFORMANCE MEASURE

Animals Vaccinated (%)	6.15
Total Animals Vaccinated	27,000

TARGET

Quarterly Target (Count)	21,950
Species Population (Count)	439,000

PROGRAM UNIT COST

Total Expenditure (ETB)	337,500.00
Total Animals Vaccinated	27,000

SPECIFIED PERIOD

Start Date (MM/DD/YYYY)	01/01/2012
End Date (MM/DD/YYYY)	03/31/2012

VACCINE UTILIZATION INDEX

Available Vaccines (doses, ml, liter)	405,000
Total Vaccines Used (doses, ml, liter)	135,000

STAFF PRODUCTIVITY INDEX

Total Animals Vaccinated	27,000
Total Employees involved in the process	75

LOCATION (Take 2 readings at 1 minute interval)

Lat/Long (Decimal Degrees)		
1		
2		

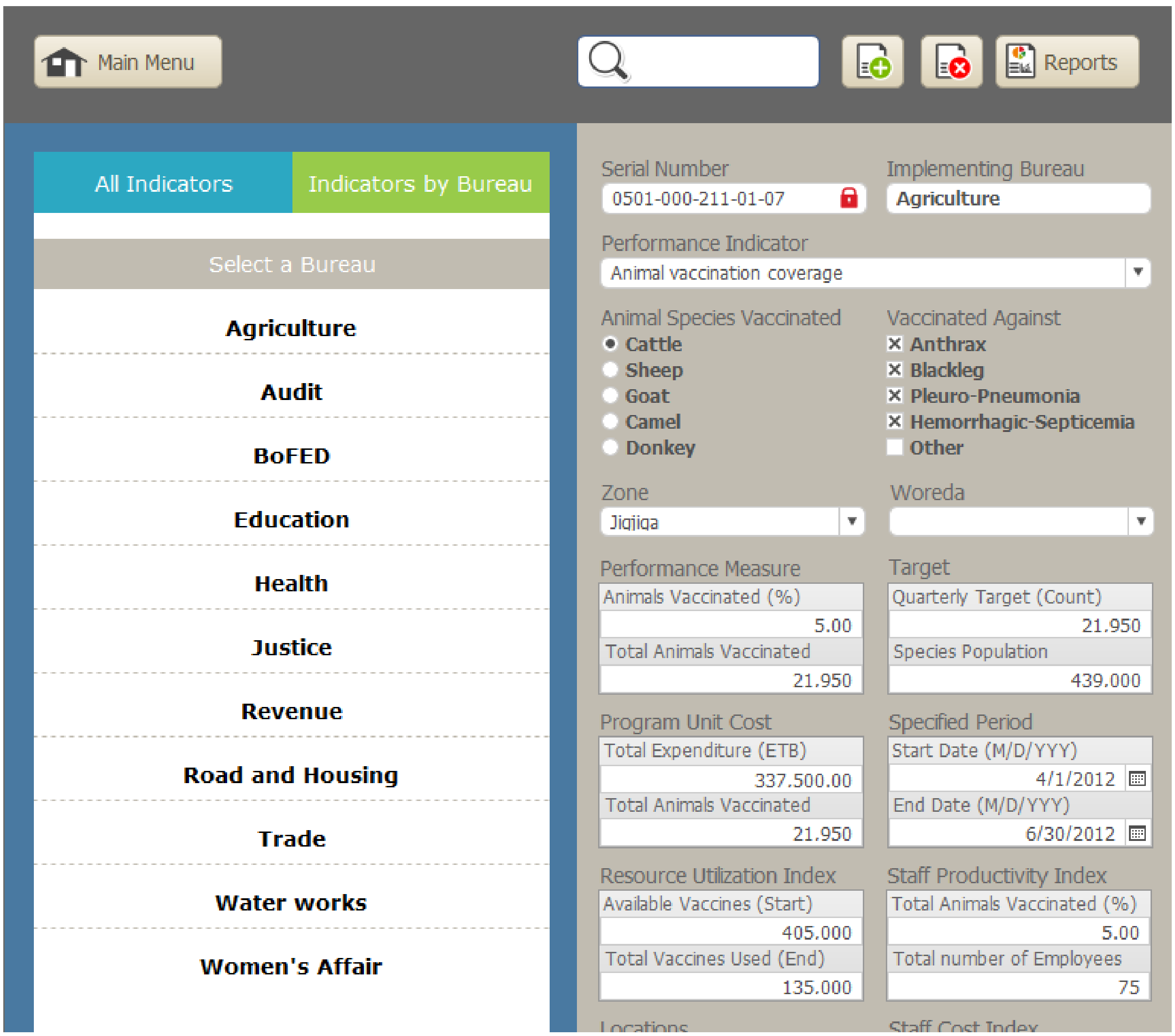
STAFF COST INDEX

Total Expenditure (ETB)	337,500.00
Total Employees involved in the process	75

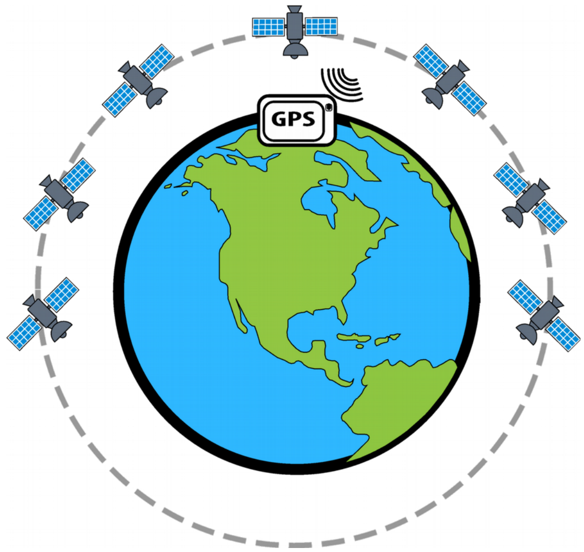
COMMENTS/OBSERVATIONS (also use this area to enter contact person information)
No baseline data exists for animals vaccinated disaggregated by species. The baseline has been "reconstructed" from secondary data

3.9 If you have an existing database or plan to store your collected data in a spreadsheet, I highly recommend that the field names in the database or column headings in the spreadsheet match exactly the items on the data capture form; this greatly minimizes confusion and data entry errors (See Figure 13 - The BoFED performance database data entry screen layout is similar to the paper form, figure 12)

Figure 13 - The BOFED performance management database data entry screen layout matches the paper form



Global Positioning System (GPS) handheld receiver



3.10 A GPS handheld receiver is central to GIS mapping, The GPS handheld receiver is what makes it possible to collect geographic coordinates. Just as with GIS software, GPS handheld receivers span the entire gamut from the basic inexpensive models to the highly sophisticated and expensive. For M&E purposes, a basic model costing no more than a couple hundred dollars will do just fine!

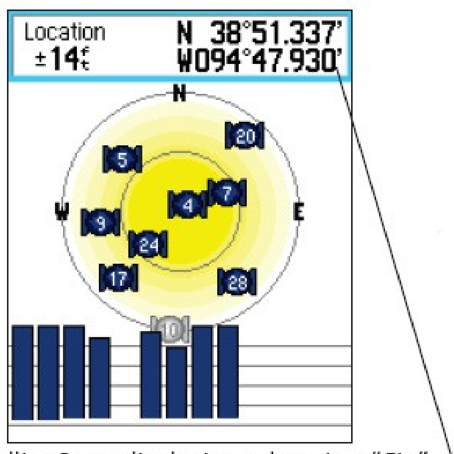
3.11 The key feature in selecting a handheld GPS receiver is the positional accuracy of the unit. Most receivers now come with built-in WAAS correction, which stands for Wide Area Augmentation System. Basically, it's a system of satellites and ground stations that provide GPS signal corrections, providing even better position accuracy, up to an average of five times better. A WAAS-capable receiver can give you a position accuracy of better than three meters 95 percent of the time. However, greater accuracy can also be achieved by observing simple rules such as keeping the unit stationary while collecting measurements. Other parameters can be set to enhance the measurement quality, refer to the unit's user guide to setup up the handheld as described below.

Table 2 GPS handheld unit basic configuration

Static Mode	A general guide to observe for static point position is to collect data at 1-second intervals. To collect a position measurement before recording the data, take at least 10 seconds to observe the

	quality of the signal
Coordinate format (Grids)	Lat/Long - degrees, decimal degrees (D.dddddd)
Map Datum	WGS84 (World Geodetic System) Positions are expressed in terms of a particular Map Datum. The standard datum for satellite derived positions is 'WGS84'
3D Mode	In this mode, the receiver must lock into signals from at least three satellites
Position Accuracy	Only record data when the unit's position accuracy is less than 15 meters

Figure 14 - Garmin eTrex Legend C GPS handheld receiver satellite page displaying a location "fix"



Satellite Page displaying a location "Fix"

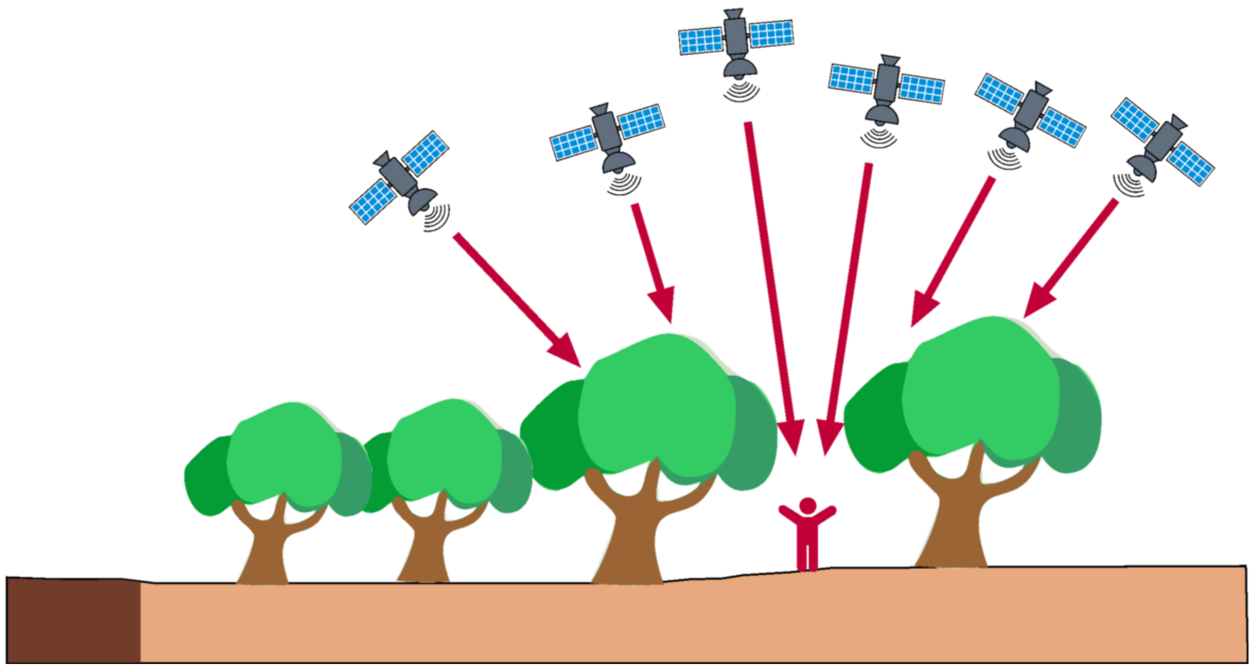
Capturing Coordinates

3.12 The following are general tips for capturing data and recording coordinates with a GPS handheld receiver

3.13 Ensure the GPS unit has been properly configured. The first time a GPS unit is used in a new location, it will need up to 5 minutes to orient itself.

3.14 Once you have located the target for data capture, make sure you have as clear a view of the sky as possible

Figure 15 - Ensure an unobstructed view of the sky as possible



3.15 Do not collect coordinates for stationary targets while travelling seated in a car or motorbike. Alight from car, or dismount from motorbike and move closer to the target.

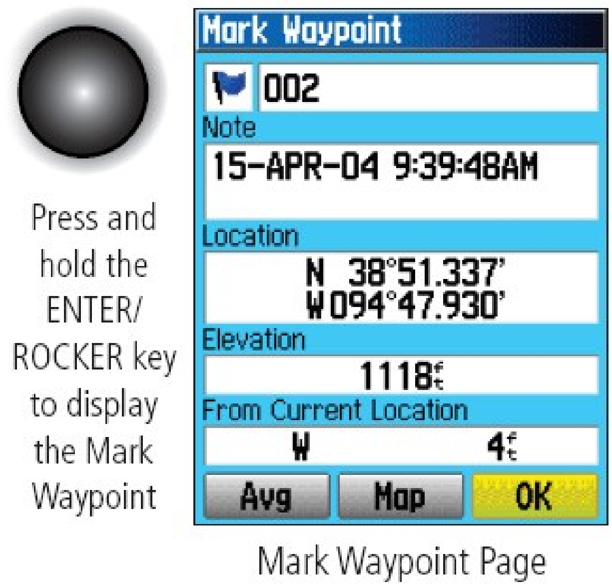
3.16 I use Garmin's *eTrex* line of products, which record a position as a waypoint so if you are using any of the *eTrex* GPS receiver models for data collection, record your position as a waypoint and record the corresponding waypoint number on your data capture form. I strongly recommend recording waypoint numbers as an added security measure in the event forms are improperly completed or the forms get mixed up

3.17 Fill out data capture form completely. If you use a Garmin *eTrex* model, be sure to include a field in your data capture form that allows for corresponding waypoint numbers to be recorded

3.18 Always check the accuracy level of GPS unit before taking a reading; less than 15 meters accuracy level is preferable

3.19 Depending on the memory capacity of your GPS receiver, you might want to periodically save TRACK LOGS[1] once the unit's memory is full, it will begin to overwrite the earliest tracks.

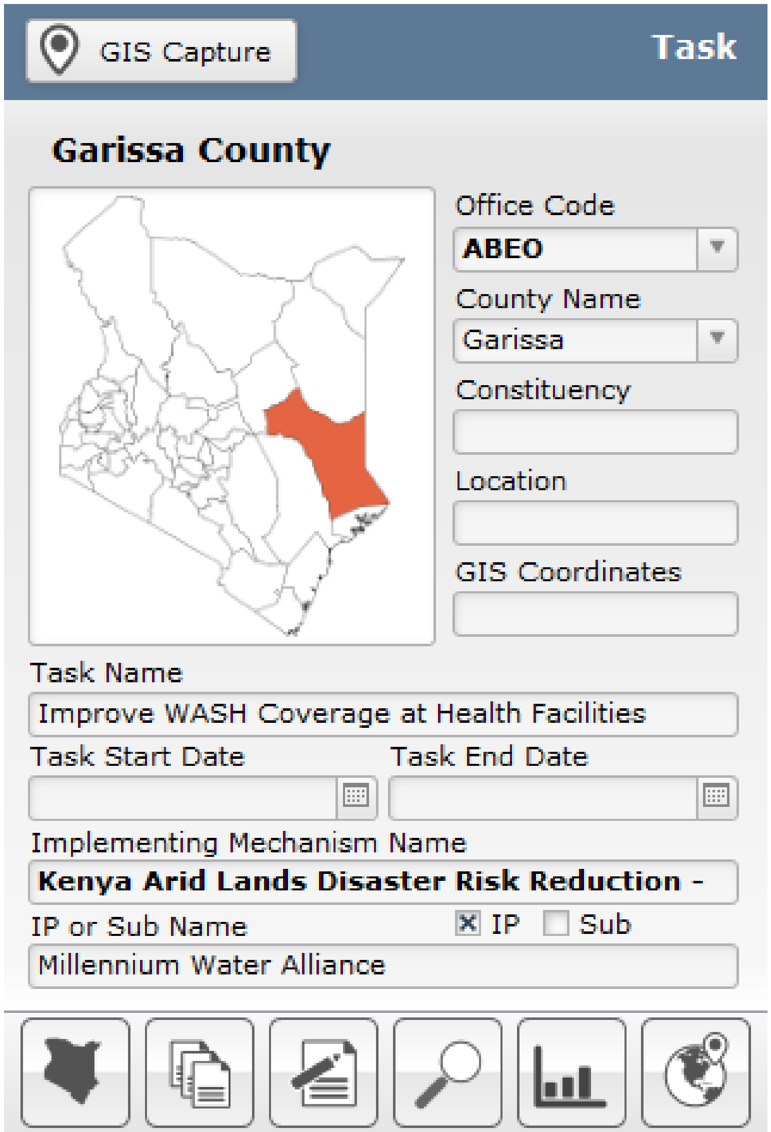
Figure 16 - Garmin eTrex Legend C GPS handheld receiver "mark waypoint page"



3.20 Most smart phones these days integrate functionality that facilitate the capturing of GIS coordinates. The mobile Activity Management Information System (AMIS) I developed for USAID Kenya offers this functionality. The mobile AMIS) provides USAID/Kenya senior staff with quick and convenient access to active awards data on the go—on their iPhones and iPads. Since the mobile AMIS runs on mobile devices, it allows for information to be collected from anywhere —whether it involves manually entering data using the mobile device's touch screen and virtual keyboard, capturing geographic coordinates at a facility, or taking photos in the field for a "Success story" using one of the mobile device's built in cameras.

[1] A track is a GPS feature that creates an electronic trail as you travel about and is referred to as a Track Log. A track log contains information about points along its path, including time, position and elevation (refer to your unit's user guide on how to save track logs)

Figure 17 – Mobile AMIS developed for USAID / Kenya. iPhone version allows for one-touch capture of coordinates; no additional equipment or software required!



3.21 In the upcoming edition of this guide, I shall be delving into the use of drones for mapping, which are quickly becoming a favourite tool of mapping!

Software

3.22 You have probably heard of all kinds of GIS software ranging from the simple and inexpensive to the highly sophisticated and very expensive. Most of the NGOs that I have worked with typically lack the resources to invest in high-end GIS software; and they don't have to! The good news is that there are a number of excellent open source and free alternatives that provide similar functionality as those found in the high-end expensive stuff (See Appendix 1) In any event, folks who work in development shouldn't really be shelling out thousands of dollars for high-end software!

3.23 Perhaps just as equally important as deciding which GIS software to use is deciding how to store and backup the GIS data. My recommendation is to save GIS coordinates as plain text or Comma delimited (CSV) file, and backup frequently to a removable drive. Your M&E data management system at the minimum should have the ability to export in either plain text or CSV format. It would be an added advantage if your data management system has the ability to export in .DBF format; the .DBF format is one of the three file formats that comprise the ESRI shapefile[2]

What are Geospatial datasets?

3.24 Geospatial datasets are collections of information that can be mapped, or located, so that the end-user is able to use a computer to research, analyze and plan. Geospatial datasets are much more than maps; they make it possible to mix and combine data by time as well as space, concept as well as location, relationships as well as values.

3.25 You will need the appropriate administrative level datasets that will serve as the base maps over which you will layer the coordinates you will be collecting.

3.26 Administrative level base maps available in **Map Maker DRA** format, **ESRI Shapefile** format and **MapInfo MIF** format may be downloaded from the .Map Library The Map Library is a good source of public domain basic map data concerning administrative boundaries in Africa. The data is broken down into manageable chunks to make it easier to download for those with slow internet connections

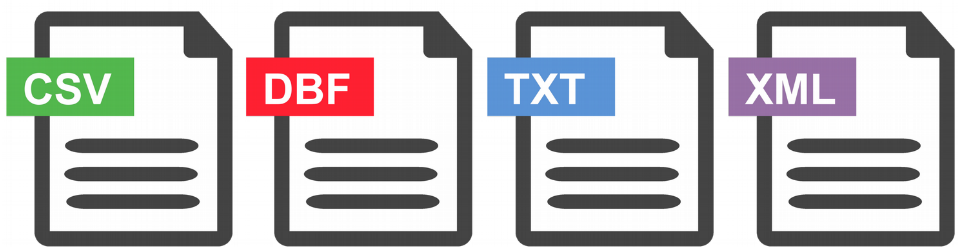
3.27 Another useful source of administrative base maps is the website for GADM Database of Global Administrative Areas GADM is a spatial database of the location of the world's administrative areas (or administrative levels) for use in most GIS software. The coordinate reference system is latitude/longitude and the datum is WGS84. The maps contain up to 5 administrative levels or subdivisions. Additional datasets such as roads, rivers, demographic data, etc are available from DIVA-GIS

[2] Although the term "shapefile" is commonly used to describe an "individual" file, a "shapefile" is actually a set of several files. Three separate files are needed to store the core data that comprises a shapefile: ".SHP", ".SHX", and ".DBF"

File Formats

3.28 As mentioned earlier, this guide is not intended to impart in-depth knowledge of GIS, and as such, does not go into much detail on the various file formats supported by GIS software. The main thing to keep in mind is that, whichever format you choose for your data, it should be universal, in other words, a format that renders your data accessible to a variety of software applications. To be on the safe side, it is best to store coordinates in TEXT (CSV or TXT) format, which any spreadsheet, or even text editor can read and write!

Figure 18 – Ensure data are in a compatible format



GIS in M&E

3.29 On the data capture forms (Figures 11 and 12) the inclusion of two data fields (Latitude / Longitude) to capture the geographic coordinates that refer to the location or locations of the activities being measured, the data collected can be mapped to reveal patterns that would be practically impossible to discern any other way. In addition to capturing the numbers of each animal species vaccinated, the diseases for which they have been vaccinated against, how many vaccines were used; we now also know the location of the animal health facility providing the services. This added piece of information when mapped, can provide invaluable insights. For example, location based information can tell us whether we have too many or too few animal health facilities, whether they are ideally located or too far and inaccessible to the farmers, why one animal health facility is meeting performance targets and the other is not. Perhaps vaccines supplies are low as a result of the remote and inaccessible location of an animal health facility. Undoubtedly, the inclusion of location based information adds a whole new dimension to M&E by making it possible to link, or associate information that would otherwise be difficult to associate through any other means.

Revealing hidden patterns

3.30 With location based information added to the performance indicator data, what does the output look like? What new knowledge can be derived from the data that was hitherto unknown?

3.31 The map in Figure 19a, which is the same as the one in Figure 9 shows animal health related activities including animal health facilities and animal health posts in Jigjiga. Take a closer look at the map in Figure 19b, which shows water sources in Jigjiga and compare the two maps. Notice the pattern? All the animal health related activities are clustered around water sources!

3.32 The animal health facility (highlighted in both maps) has not been meeting quarterly performance targets, why? The vaccine utilization index indicates sufficient vaccine stocks, and as is the standard, the facility is staffed by at least one community animal health worker (CAHW). However, upon comparing the maps in Figure 19a and 19b, we notice that there are no water sources within the vicinity of this animal health facility. As anyone familiar with the Somali region knows, water is a precious commodity! The average annual rainfall in the Somali region ranges from 300mm to 700mm moving from south to north with a climate classified as semi-arid. The low annual rainfall and its uneven distribution together with the frequent recurrence of drought have made water the single most important element that determines the living style of the population. People together with their herds of camels, goats, sheep and cattle move from place to place in continuous search of water and grazing.

3.33 Given this context, there is a compelling argument that the inability of the animal health facility to meet quarterly performance targets is not unrelated to proximity to a water source. This hypothesis begins to gain credence when we compare the performance to that of other animal health facilities, especially those close to a water source. Of course, we cannot conclude that proximity to a water source is the sole reason the animal health facility is unable to meet quarterly performance targets, but it certainly appears to play a prominent role.

Figure 19a - Map showing animal health related activities in Jijiga, with underperforming animal health facility highlighted

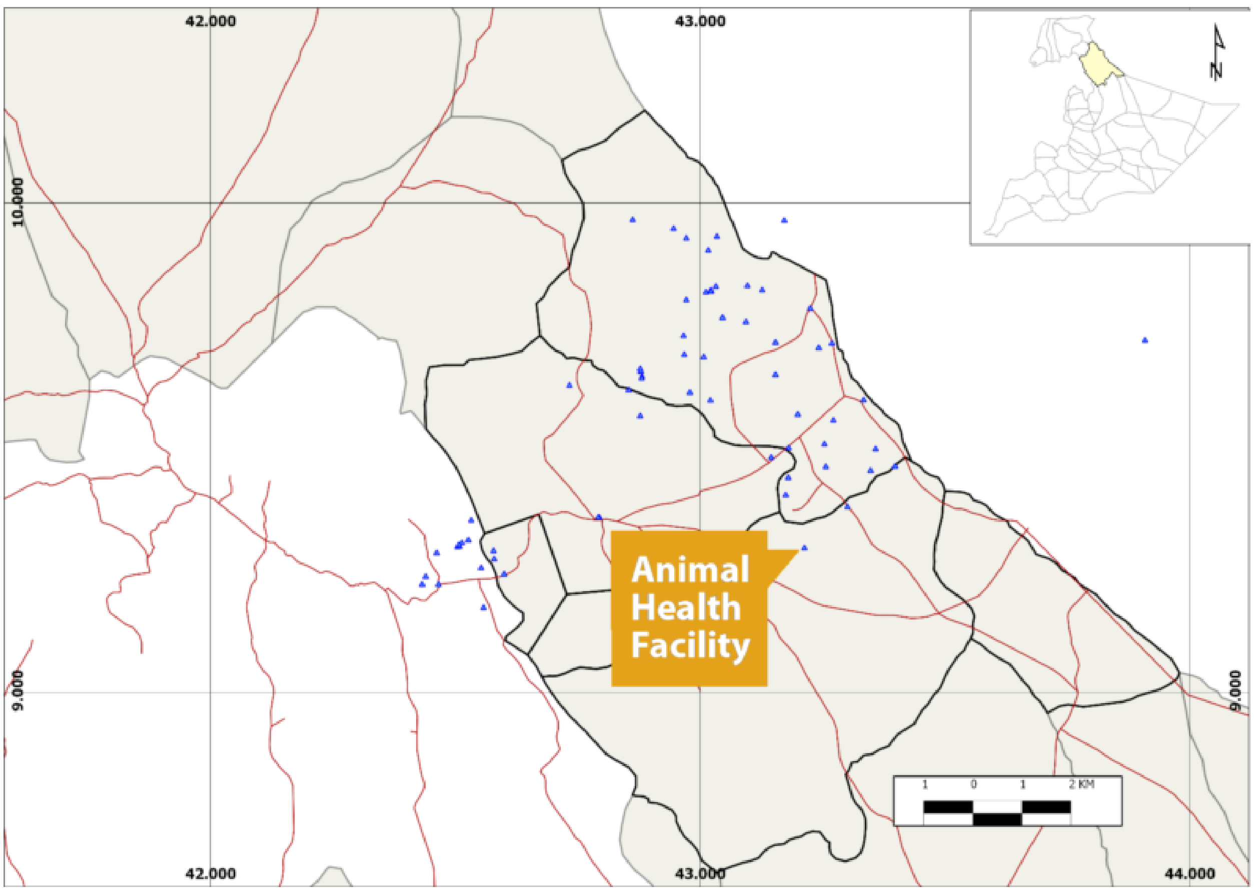
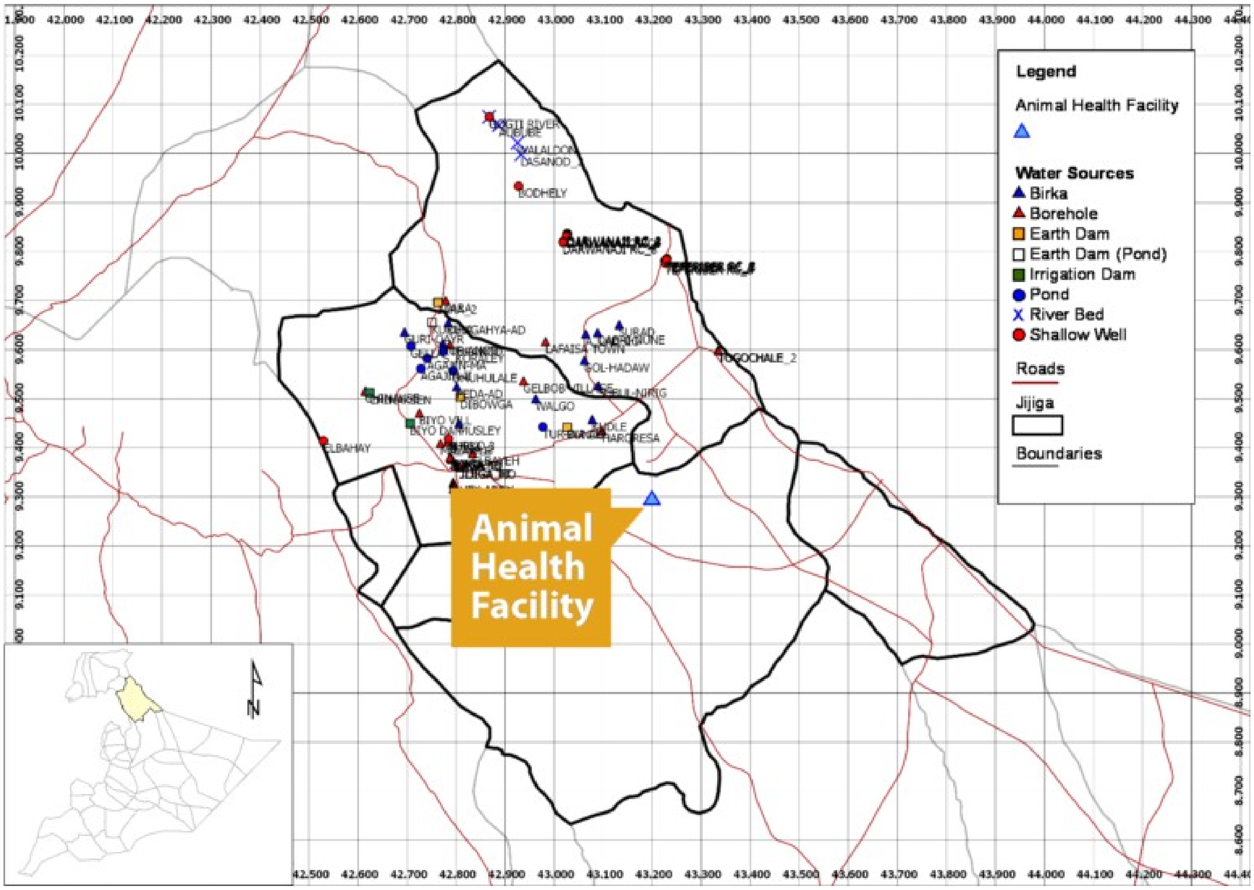


Figure 19b - Map showing water sources in Jigjiga, with underperforming animal health facility highlighted



3.34 Adding the location of the animal health facility to basic indicator data has added a whole new perspective to the ways in which we analyze and interpret information, and thereby raising important questions that we may not be asking, in the absence of location based information.?

Using GIS to identify spatial patterns of poverty in Nigeria

3.35 This was an assignment to use GIS to carry out a mapping of poverty in twelve select states within the six geo-political zones of Nigeria. The objectives of the mapping exercise were to;

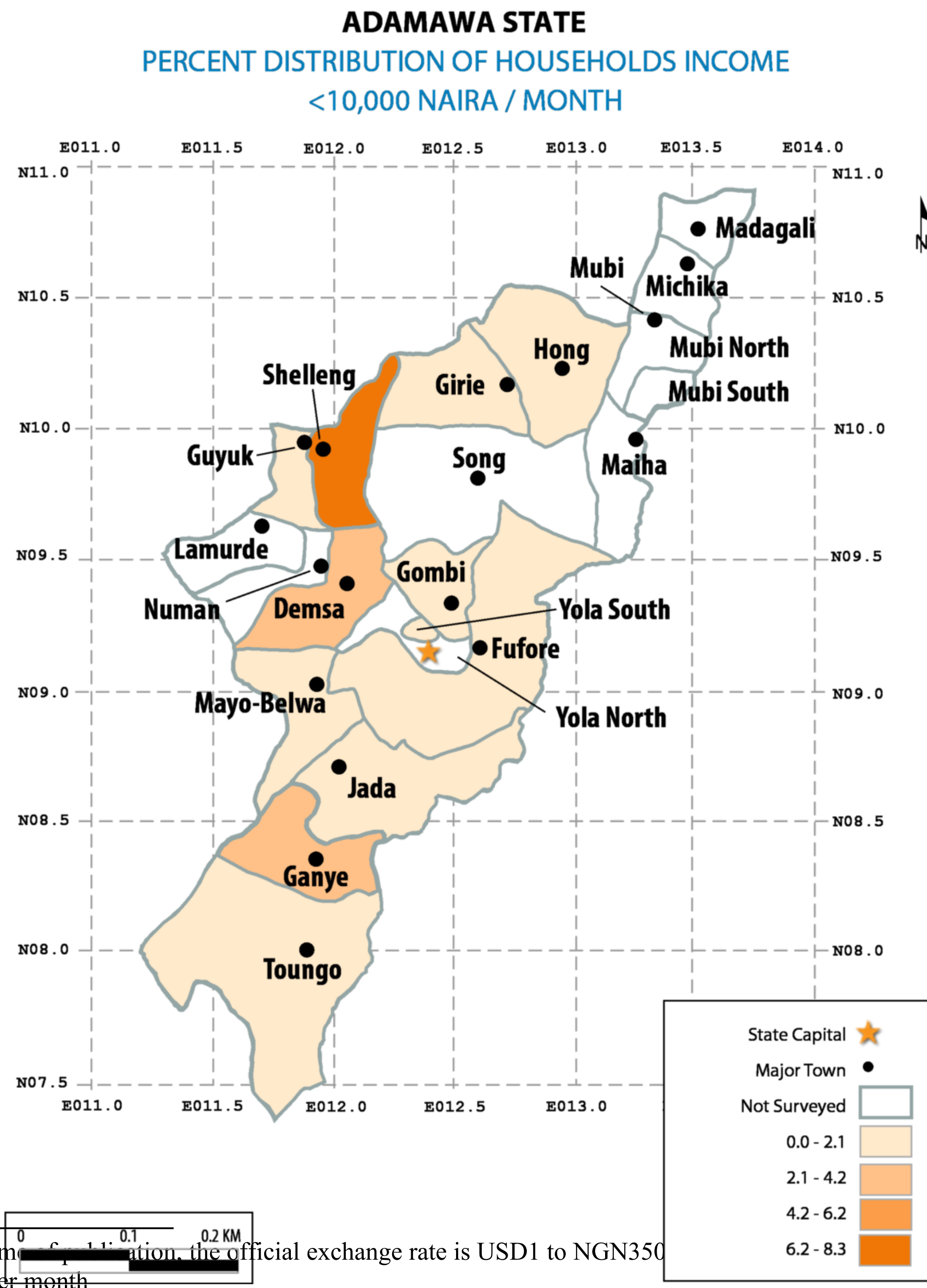
- Provide data on the spatial distribution of poverty at the state, local government and community level;
- Provide information on where poverty rates are highest and where the poorest are concentrated to facilitate design of policy interventions and enable planners identify areas for intervention;
- Produce risk and vulnerability profile to enable the design of appropriate mitigation strategies and improve the robustness of policies for poverty reduction;
- Highlight the role of other factors such as distance, topography, climate, environment and other geographical features in the location and extent of poverty;
- Provide data that will assist in better and more effective targeting of policy actions. Spatial maps of poverty, vulnerability or other synthetic indices of living standards can be used to identify and target geographic concentrations of the poor.
- Facilitate the creation of MDG[3] based national development strategies including costing and needs assessment of key interventions by sub-national government.
- Using the NBS[4] poverty line as the benchmark, construct the poverty gap index to capture the depth of poverty across each mapped state. This index measures the difference between the poverty line and the average household income expressed as a ratio of the poverty line.
- Construct poverty profiles with the objective of answering the question of who are the poor, where they are located, how many they are, and why they are poor, and whether they have access to economic infrastructure and support services such as social services and safety nets.
- Identify the spatial distribution of poverty and determine the most depressed areas in need of intervention in the socio-economic development strategies and policies of the state.

3.36 The data collected was used to generate a set of poverty maps. The maps represent the spatial distribution of poverty, and thereby serve as an effective means to quickly identify the most depressed areas that need intervention in the socio-economic development strategies and policies of each mapped state.

[3]Millennium Development Goals
[4]National Bureau of Statistics

3.37 The poverty maps aid in identifying spatial patterns of poverty, which can provide new insights into the causes of poverty, for example how much are physical isolation and poor agro-ecological endowments impediments to escape poverty. This in turn affects what type of interventions to consider.

Figure 20 – Adamawa State Poverty Map 11: Percent distribution of households with income of less that 10,000 Naira per month[5]



[5]As of the tim[…]tion, the official exchange rate is USD1 to NGN350 […]e equivalent to USD29 per month

Preparing data for distribution and dissemination

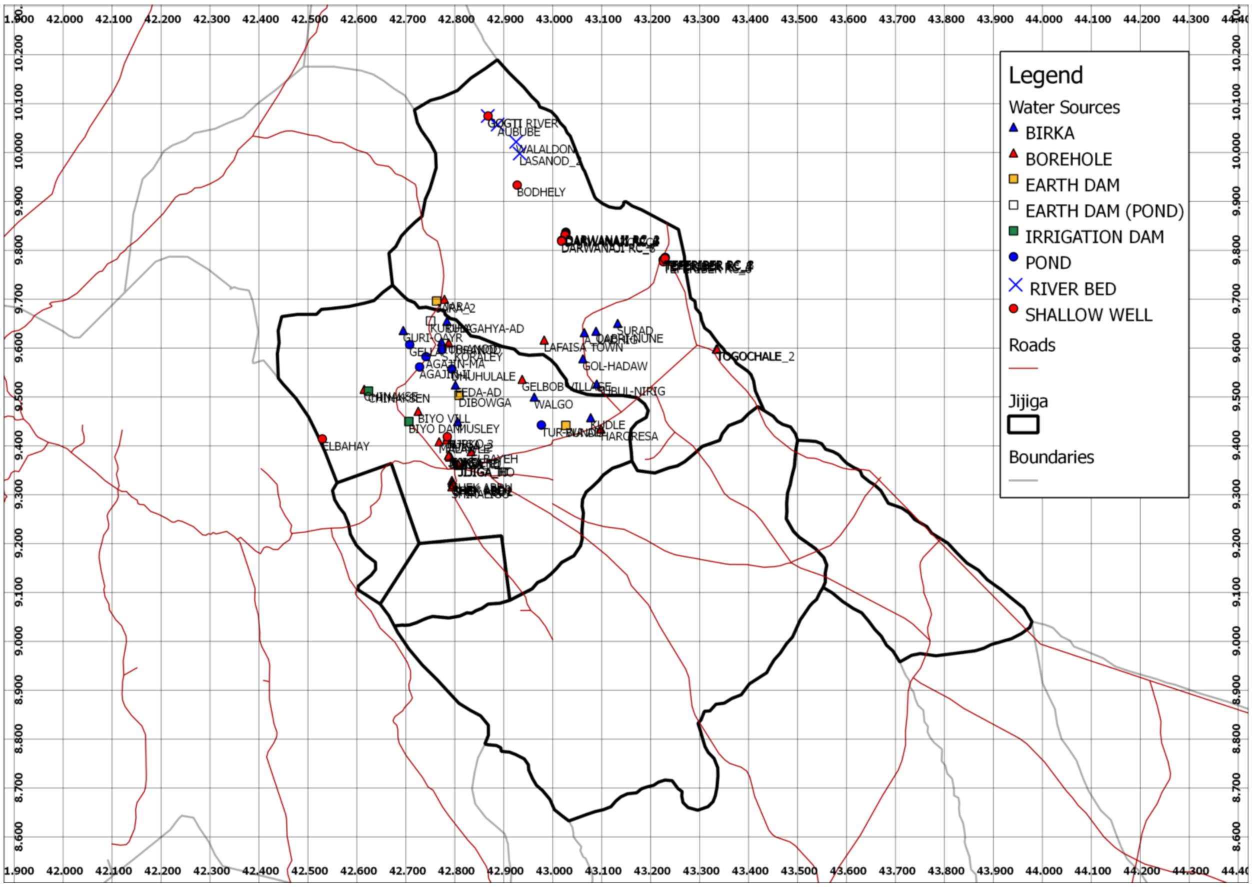
3.38 While on assignment in Jigjiga in Ethiopia's Somali region, I went online to search for geographic coordinates for resources in Jigjiga, and I came across a file documenting a water schemes mapping project in Jigjiga. The file was distributed by no lesser agency than the formidable United Nations. While the data contained in the file were poorly organized, the more egregious infraction was the absence of metadata! You would think that an agency such as the UN would know not to distribute GIS data without corresponding Metadata! An integral part of any geographic dataset is a well-organized description of its content. This explanatory information is called metadata; a written record of the most important facts about the dataset.

3.39 Metadata is critical to data creators who need to organize data and keep track of when it was created and what it contains. Metadata is equally important to those who share and use data and need clear and complete information about data they are considering using. Part of the appeal of GIS is the ability to share data with people around the world, and this is impossible when the metadata is missing

3.40 The water schemes mapping document was made available in Adobe PDF format, which means that the data cannot for example be imported into a GIS mapping software. I sent an email to the contact information provided on the document and never received a response (this is not entirely surprising when dealing with such heavily bureaucratic entities); again, this is a clear example of a fundamental misconception about the use of GIS. To simply generate a static list of coordinates, publish them in Adobe PDF format and then put it out there is a huge disservice to the GIS community of users!

3.41 Notwithstanding, I labored on. I felt the coordinates from the UN water mapping project could perhaps contain some useful data. Since the document was made available in PDF format only, it was necessary to key the coordinates into a spreadsheet and then import into GIS software. The resulting map was difficult to comprehend (Figure 21). Perhaps as a result of the scale properties, the mapped objects were too close together to discern what was being mapped. Still feeling hopeful, I created the map index in figure 22, which assigns numbers to each of the squares formed by the coordinate grid that encloses each area. Using a map index facilitates the creation of individual maps (using different scale properties) that show corresponding resources in greater detail, which also makes it easier to locate and download only maps that are of relevance. Since the water schemes mapping document evidently did not provide a map legend, I took the liberty to create a tentative one based on best guess.

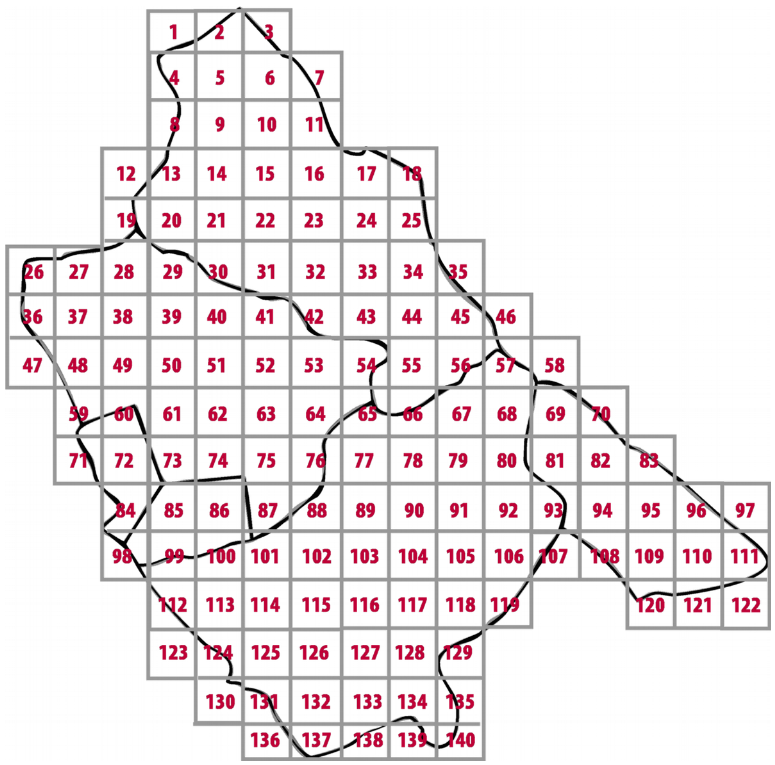
Figure 21 - Water schemes map generated from coordinates from a UN water schemes mapping project in Jigjiga



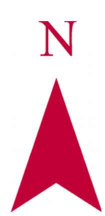
3.42 With the collaboration of colleagues at the Pastoral Community Development Program (PCDP) in the Somali region, we have been able to confirm 90 percent of the mapped water schemes. So in the end, the effort was worthwhile! However, what could have been done differently? What could have been done better?

3.43 The PDF document containing the coordinates could have included metadata, as well as a sample thematic map generated from the coordinates, with guidelines, and caveats on use of the data. Thematic maps are a standard output of GIS, that illustrate the geographic distribution of some phenomena, such as mortality rates or water sources. The agency should have considered the intended audience for the data, whether for development or GIS professionals, or for the public at large? What sorts of maps the end-users may generate with the data? Will it be on a printed page or online? Are the coordinates best presented in static form, or as a geospatial dataset?. Geospatial datasets represent collections of information that can be mapped, or located, so that the end-user is able to use a computer to research, analyze and plan. Geospatial datasets make it possible to mix and combine data by time as well as space, concept as well as location, relationships as well as values.

Figure 22 - Jigjiga Map index allows for the creation of individual maps (using different scale properties) that show relevant resources in greater detail



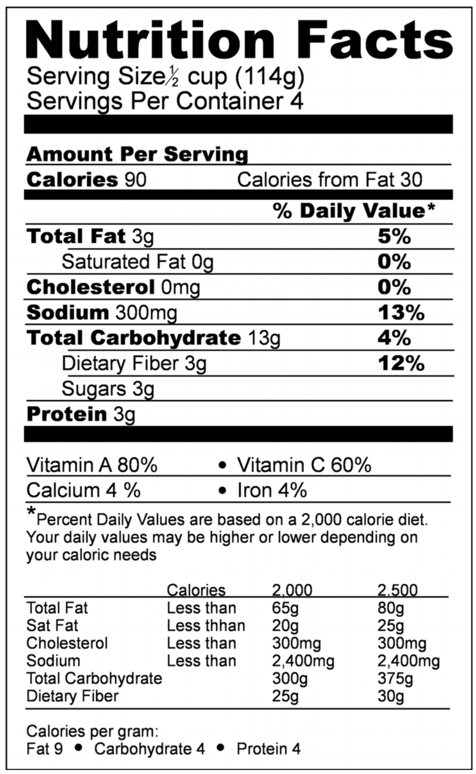
3.44 For many local governments, paper-based maps still form the basis for decisions concerning land use planning, provision of infrastructure, transportation, investment planning, natural resources management, health initiatives, facility management, major construction work, security measures, disaster preparedness, emergency relief, etc. Many of these paper-based maps are outdated and most often, were produced from incomplete data. Paper maps may not become completely obsolete anytime soon, so in the meantime, map communication can be enhanced by combining GIS with basic cartographic guidelines.



Would you eat that?

3.45 Figure 23 is a sample food label required by the United States Food and Drug Administration on all food packaged and transferred from one place to another. Some form of labelling has appeared on food in the United States since 1913. Today, this label with its mandatory and voluntary components, tells the consumer everything they need to know to make a decision about the packaged food's ingredients and nutritional content. Using this label the consumer can make an informed decision about the product's suitability for use or consumption.

Figure 23 - Sample food label



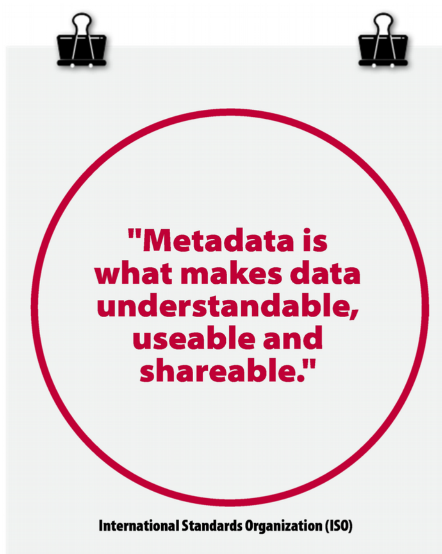
3.46 Sound familiar? Just as food is our body's fuel, spatial data is the fuel of GIS. How do you determine the "really good stuff" from the "junk food"? How do you know if the spatial data is "good" for your purpose? The Content Standards for Digital Geospatial Metadata were adopted by the Federal Geographic Data Committee (FGDC) to label geospatial datasets. Just like a company whose product is food, the metadata standard documents the characteristics of data so that consumers can determine the data's fitness for their purpose.

Why Metadata?

3.47 Well-designed metadata answers the following questions:

- What is this data about, where did it come from and when was it gathered?
- What is its quality?
- How is it organized?
- Where is the data set located on the earth's surface?
- What kind of features does this data set describe and in how much detail?
- How is this data set distributed?
- Who put this documentation together?

3.48 There are numerous free resources available that provide support for creating well formed Content Standard for Digital Geospatial Metadata (CSDGM) compliant XML Metadata that describe the content, condition, quality, spatial extents and other characteristics of geographic data. Most available resources integrate templates to help anyone working with Geographic Information Systems (GIS) to document their own data, as well as the streamlined version of ISO 19115 metadata standard, the Content Standard for Digital Geospatial Metadata, adopted by the Federal Geographic Data Committee (FGDC), as an official guideline.



Appendices

Appendix 1 – Goodies

Table 4

Software Title	License	Description
Geographic Resources Analysis Support System **(affectionately referred to as GRASS)**	Open source / Free	GRASS is a Geographic Information System (GIS) used for geospatial data management and analysis, image processing, graphics/map 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.
Quantum GIS	Open Source / Free	Quantum GIS (QGIS) is a user friendly Open Source Geographic Information System (GIS). QGIS is an official project of the Open Source Geospatial Foundation (OSGeo). It runs on Linux, Unix, Mac OSX, Windows and Android and supports numerous vector, raster, and database formats and functionalities. The latest release as of the time of writing this guide is QGIS 1.8.0
Map Maker	Proprietary /Free	Licenses for the professional mapping version, Map Maker Pro, is available for free to not-for-profit organizations, educational establishments, and students in Africa
MapWindow	Open Source / Free	The MapWindow GIS project includes a free and open source desktop geographic information system (GIS) with an extensible plugin architecture; a GIS ActiveX control; and C# GIS programmer library called DotSpatial.
GPS Utility	Proprietary	An indispensable utility that is inexpensive and definitely worth the investment
GOOGLE Earth	Proprietary /Free	Free for individual use and is a great program for visualizing imagery of the Earth. Personal geospatial data can be added and additional functionality is available through the Plus and Pro versions at a low-cost price.
ArcGIS Explorer Desktop	Proprietary /Free	A free GIS viewer that gives you an easy way to explore, visualize, and share GIS information. ArcGIS Explorer adds value to any GIS because it helps you deliver your authoritative data to a broad audience.
StatPlanet	Proprietary /Free	StatPlanet is a free, award-winning software for creating interactive maps which are fully customizable. In addition to maps, the software also provides the option to include interactive graphs and charts to create feature-rich infographics.
FGIS	Free	Forestry GIS (fGIS™) is a compact but robust *Shapefile* editing program, digitizer and GIS data query tool for Windows®. fGIS was designed for natural resource managers who are not GIS specialists. It's easy-to-use and simple to install. Many power users also like fGIS because they can run it on laptops or home computers without copyright issues, it produces data compatible with commercial GIS programs

Please note that this is by no stretch of the imagination an exhaustive list of GIS software, these are the ones that I'm personally familiar with and thus, feel sufficiently confident recommending.

Appendix 2 – The jargon

Absorption - the process by which radiant energy is absorbed and converted into other forms of energy

Aliasing - Unwanted visual effects caused by insufficient sampling resolution or inadequate filtering to completely define an object; most commonly seen as a jagged or stepped edge along object boundaries or along lines.

Base Station - carefully surveyed receiver that collects satellite data then calculates error vectors for correcting field data

Cartography - The organization and communication of geographically related information in either graphic or digital form. It can include all stages from data acquisition to presentation and use.

Coordinate System - A recognized reference system for the unique location of a point in space. The Cartesian coordinate system and the system of latitude and longitude of the earth are examples of coordinate systems based upon Euclidean geometry. A coordinate system is usually defined by a map projection, a spheroid of reference, a datum, one or more standard parallels, a central meridian, and possible shifts in the X and Y directions to locate X, Y positions of point, line, and area features.

Datum - Any point, line or surface used as a reference for a measurement of another quantity. A model of the earth used for Geodetic calculations.

Differential Correction - differential correction is the method used, via base station, to calculate error vectors that coincide with field data to correct the field data error

Digital Image Processing (DIP) – the use of the computer on raster image files, to carry out such operations as image enhancement, image compression, image analysis, mapping, georeferencing, etc.

Digitizing - A method of data capture that involves the conversion of data in hard copy or raster form, such as maps and aerial photographs, into a digital vector format. This is usually done by a human operator using on a digitizing tablet or sitting at a computer screen with a mouse, drawing over top of a raster image. Methods of automated digitizing and semi-automated digitizing also exist.

Electromagnetic Spectrum is the ordered array of known electromagnetic energies extending from the shortest cosmic ray, through gamma rays, x-rays, ultraviolet radiation, and including microwave and all other wavelengths of radio energy.

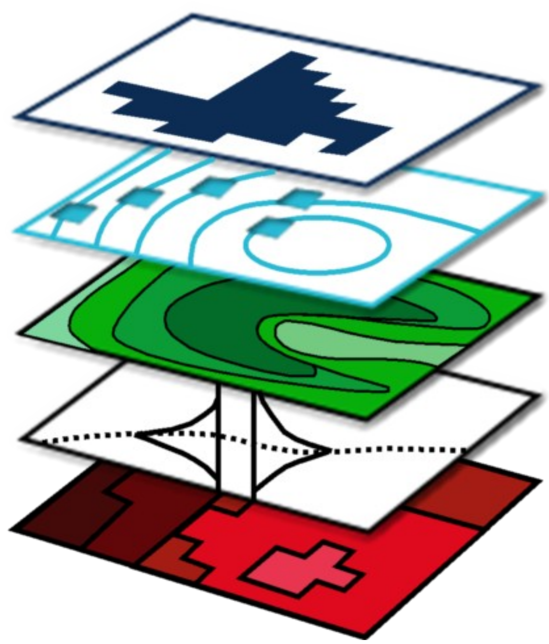
Ellipsoid – A three-dimensional ellipse which is used to represent the shape of the surface of the earth.

Enhanced Thematic Mapper Plus (ETM+) - the primary sensor system aboard Landsat 7

Features - A set of points, lines or polygons in a spatial database that represent a real-world entity. The terms feature and object are often used synonymously.

Geodesy - The science of measuring the shape and size of the earth, together with the determination of the exact position of particular points on its surface by taking the earth's curvature into account.

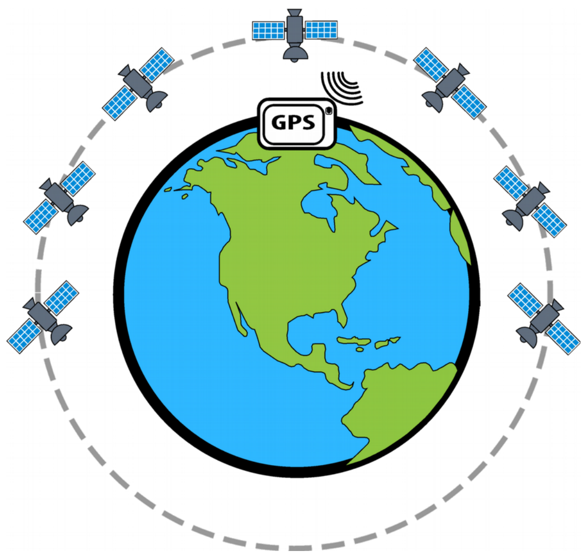
Geographic Information System (GIS) - A computer system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data related to positions on the earth's surface. Typically, a Geographical Information System (or Spatial Information System) is used for handling maps of one kind or another. These might be represented as several different layers where each layer holds data about a particular feature. Each feature is linked to a position on the graphical image of a map. Layers of data are organized to be studied and to perform statistical analysis.



Geoid - An imaginary shape for the earth defined by mean sea level and its imagined continuation under the continents at the same level of gravitational potential.

Georeferencing – the process of taking an image and assigning it geographic coordinates

Global Positioning System (GPS) - A satellite-based navigational system allowing the determination of any point on the earth's surface with a high degree of accuracy given a suitable GPS receiver. The network of satellites is owned by the US Department of Defence. Error in the accuracy of GPS derived positions can be introduced through the nature of local conditions. These errors can be greatly reduced using a technique known as differential GPS.



Metadata - Data about data and usage aspects of it. This information will often include some of the following: What it is about, Where it is to be found, Who needs to ask to get it, How much it costs, Who can access it, In what format is it available, What is the quality of the data for a specified purpose, What spatial location does it cover and over what time period, When and where the data were collected and by whom and for what purposes the data have been used, by whom and what related data sets are available, etc.

Network analysis - A data processing method using topologically linked data such as street maps or river networks with the purpose of determining routes between geographic locations, and other analyses requiring the consideration of path and direction. Such analyses might include finding the most efficient travel route, generating directions, or defining service coverage based on travel time.

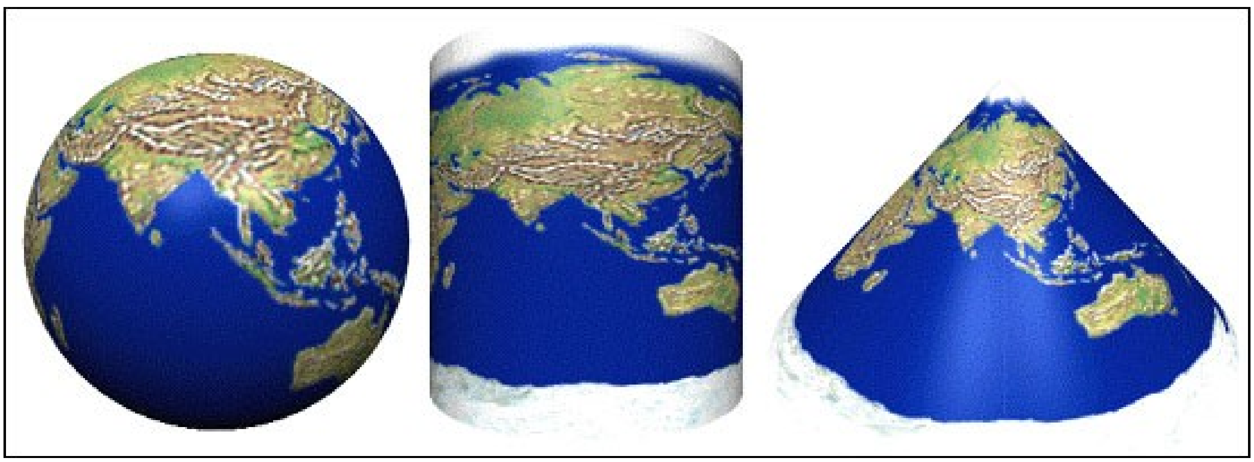
Orthophotography - A modified copy of a perspective photograph of the earth's surface with distortions due to tilt and relief removed.

Photogrammetry - the art or science of obtaining reliable measurements by means of photography.

Pixel - A contraction of the words picture element. Pixel refers to the smallest unit of information available in an image or raster map that can be independently assigned attributes such as colour and intensity.

Position Dilution of Precision (PDOP) - regulates amount of interference the rover unit accepts and still records data; the lower, the better.

Projection - A method of representing the earth's three-dimensional surface as a flat two-dimensional surface. This normally involves a mathematical model that transforms the locations of features on the earth's surface to locations on a two-dimensional surface. Because the earth is three-dimensional, some method must be used to depict the map in two dimensions. Therefore, such representations distort some parameter of the earth's surface, be it distance, area, shape, or direction. There are a variety of map projections, but all are generally of three basic types; these are the Azimuthal, conical and cylindrical projections. For example, the Transverse Mercator Projection is a variant of the cylindrical projection.



Pseudo Random Code - means by which time error is corrected between the receiver and the satellite via a code that the receiver matches with the satellite's

Radiometric Resolution - Radiometric resolution or radiometric sensitivity refers to the number of digital levels used to express the data collected by the sensor, in general, the greater the number of levels, the greater the detail of information. The number of levels is normally expressed as the number of binary digits needed to store the value of the maximum level, for example a radiometric resolution of 1 bit would be 2 levels, 2 bit would be 4 levels and 8 bit would be 256 levels. The number of levels is often referred to as the Digital Number, or DN value.

Raster Data - An abstraction of the real world where spatial data is expressed as a matrix of cells or pixels, with spatial position implicit in the ordering of the pixels. With the raster data model, spatial data is not continuous but divided into discrete units. This makes raster data particularly suitable for certain types of spatial operations, for example overlays or area calculations. Unlike vector data however, there are no implicit topological relationships.

Reference Ellipsoid - A geometric model of the earth, required for accurate range and bearing calculations over long distances. Ellipsoidal models define an ellipsoid with an equatorial radius and a polar radius. The best of these models can represent the shape of the earth over the smoothed, averaged sea-surface to within about one-hundred meters.

Reflection - Electromagnetic Radiation neither absorbed nor transmitted is reflected. Reflection may be diffuse, when the incident radiation is scattered upon being reflected from the surface, or specular when all or most angles of reflection equal the angle of incidence

Refraction - the bending of Electromagnetic radiation rays when they pass from one medium to another having a different index of refraction or dielectric coefficient.

Remote Sensing - the measurement or acquisition of information of some property of an object or phenomenon, by a recording device not in physical or intimate contact with the object or phenomenon under study

Resolution - A measure of the ability to detect quantities. High resolution implies a high degree of discrimination but has no implication as to accuracy. Resolution is a term that is used often within remote sensing.

Rover Unit - also termed: field unit or data logger - The mechanism used in the field that receives GPS satellite signals from outer space

Scale - The ratio of the distance measured on a map to that measured on the ground between the same two points. In Britain, most map scales are now metric and are shown, for example, as 1:50,000, which represents a scale of 1cm = 50,000 cm (or 500 metres). Often, the difference between large and small map scales are confused; the larger the ratio, the smaller the map scale. Therefore, a map of the world would have a very small scale, whereas a map of a town centre will have a large scale.

Scanning - A method of data capture whereby a hard copy image, map, or even text is converted into digital raster form by using a specialized high quality digital camera called a scanner.

Spatial Data - Any information about the location and shape of, and relationships among, geographic features. This includes remotely sensed data as well as map data.

Spatial Resolution - Spatial resolution refers to the area on the ground that an imaging system, such as a satellite sensor, can distinguish. There are many measures of spatial resolution, the most common include the Instantaneous Field of View (IFOV), and the Effective Instantaneous Field of View (EIFOV).

Spectral Resolution - The term spectral resolution refers to the width of spectral bands that a satellite imaging system can detect. Often satellite imaging systems are multi-spectral meaning that they can detect in several discrete bands, it is the width of these bands that spectral resolution refers to; the narrower the bands, the greater the spectral resolution.

Spheroid - A solid that resembles a sphere in geometry. One of the terms used to describe the shape of the earth.

Stereoscope - a binocular optical instrument for assisting the observer to view two properly oriented photographs or diagrams to obtain the mental impression of a three-dimensional model

Stereoscopic Vision - binocular vision which enables the observer to view an object simultaneously from two different to obtain the mental impression of a three-dimensional model

Tabular or Attribute Data - A trait, quality or property describing a geographical feature, a fact describing an entity in a relational data model, equivalent to the column in a relational table.

Temporal Resolution - The frequency of obtaining imagery of a particular area that a sensor/platform system maintains.

Thematic Map - A map depicting selected kinds of information relating to one or more specific themes. Examples are soil type, land classification, population density and rainfall maps.

Topographic Map - A map whose principal purpose is to portray the features of the earth's surface, these features might include the cultural landscape, but normally refer to the terrain and its relief.

Topology - The relative location of geographic phenomena independent of their exact position. In digital data, topological relationships such as connectivity, adjacency and relative position are usually expressed as relationships between nodes, links and polygons. For example, the topology of a line includes its from- and to-nodes, and its left and right polygons. Topology is useful in GIS because many spatial modelling operations don not require coordinates, only topological information. For example, to find an optimal path between two points requires a list of the lines or arcs that connect to each other and the cost to traverse each line in each direction. Coordinates are only needed for drawing the path after it is calculated.

Transmission - the passage of electromagnetic energy through a material such as air, glass, or water.

Triangulation - refers to the calculation of receiver position by way of at least four satellites

Vector Data - An abstraction of the real world where positional data is represented in the form of coordinates. In vector data, the basic units of spatial information are points, lines and polygons. Each of these units is composed simply as a series of one or more coordinate points, for example, a line is a collection of related points, and a polygon is a collection of related lines. Vector data may or may not possess topological relationships.