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APPLICATION OF GEOMATICS FOR MAPPING LAND AND NATURAL RESOURCE USE AND RIGHTS: A CASE STUDY OF IFAD PROGRAMMES IN EAST AND SOUTHERN AFRICA

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Abstract

Spatial information technologies such as geographic information systems (GIS), global positioning systems (GPS), and soft-copy photogrammetry, known collectively as geomatics, can be combined with methods of sociological inquiry such as participatory enumerations to provide new techniques for gathering, organizing, analyzing, and conveying information about the land and resource tenure of indigenous people and communities. The application of these methods provides a means to solicit detailed information about complex and dynamic tenure status and resource conditions not ordinarily captured in automated land records or cadastral systems. Recordation of rights and interests in land or resources in automated systems recognized by groups outside a community may bolster tenure security for the community or individuals if appropriate access and system security mechanisms are part of the system. Mapping tenure relations not only provides spatial information about the land and landscape of natural resources, their use, tenure and ownership; it also maps the socio-political relationships underlying this environment, in particular the institutional structures that govern land and natural resource.

This paper provides guidelines and examples of how some countries and programs in Eastern and Southern African countries are increasingly incorporating geomatics and related ICT technology as part of their respective participatory enumeration processes.

Key Words:

Geographic information system, global positioning system, remote sensing, participatory enumeration, tenure security

1. INTRODUCTION

Mapping tenure relations not only provides spatial information about the land and landscape of natural resources, their use, tenure and ownership; it also maps the socio-political relationships underlying this environment, in particular the institutional structures that govern land and natural resource. Mapping is an exercise through which tacit knowledge, as embedded in people's spatial memory, is converted into explicit and externally usable knowledge. Herein lies the usefulness of mapping as a tool for empowerment, but also some of the risks that it entails (ILC, 2008).

The past 25 years have witnessed an explosion of participatory mapping initiatives throughout the world, in both developing and developed countries. Participatory mapping is, in its broadest sense, the creation of maps by local communities – often with the involvement of supporting organizations including governments (at various levels), non-governmental organizations (NGOs), universities and other actors engaged in development. The process of map making is undertaken by a group of non-experts who are associated with one another through a shared interest. Participatory mapping attempts to make visible the association between land and a community by using a commonly understood and recognized language of cartography. Participatory maps are not confined to presenting geographic feature information, they can also illustrate important social, cultural and historical knowledge (IFAD, 2009).

Participatory mapping uses a range of tools, including data collection tools that are commonly associated with participatory learning and action (PLA) initiatives. These tools include mental mapping, ground mapping, participatory sketch mapping, transect mapping and participatory three-dimensional modelling. Recently, participatory mapping initiatives have begun to use more technically advanced geographic information technologies, including Geographic Information System (GIS), satellite imagery, Global Navigation Satellite Systems (GNSS) like the commonly used Global Positioning Systems (GPS), and other digital-based technologies (IFAD 2009).

This is an unprecedented moment for information and communication technology (ICT) in the support of land governance, administration and management as well as natural resource management as geospatial information improves in terms of scope, availability and affordability. The three major core ICT technologies -the Internet, GNSS and GIS—are converging and creating huge opportunities to manage land and natural resources using ICT in much more thorough, inexpensive, efficient and effective ways. While it is still early, most countries are now slowly using and maximizing the advantages of ICT. This paper provides some guidance and examples of how some countries and projects are increasingly taking advantage of the emerging technologies (World Bank, 2012).

2. POTENTIAL USES OF MODERN GEOGRAPHIC INFORMATION TECHNOLOGIES

2.1. LAND ADMINISTRATION

The FAO (2007) has emphasized that the introduction of ICT has the potential to contribute to good land administration by improving efficiency, consistency, accountability, transparency and accessibility. Various literature claims that the benefits of land administration systems are enormous and they contribute to poverty alleviation, security of tenure, management of land disputes, improvement of land planning, management of natural resources and protection of the environment, amongst others (Antonio, 2011). In this context, there is a growing demand for professionals and non-professionals to further investigate, research, adopt, test and implement modern technologies in land administration applications and related activities.

As early as the 1990s in Côte d'Ivoire, Guinea, Benin and Burkina Faso, 'rural land tenure map' approaches were implemented with different scopes and in diverse institutional contexts (Gastaldi, 1998). These field operations were supposed to lead to a reform in the law in order to integrate the approach, define the types of rights acknowledged by the state and give legal acknowledgement to the rights identified in the field.

This 'instrumental' process (based on instruments identifying the appropriate rights and not on law as the starting point) relies on a determination to identify and map the existing rights at parcel level, whatever their origins may be. A participatory survey process and a flexible and effective mapping system is set up and leads to a simplified 'cadastre'. The objective is to map existing rights, which are accepted at local level on a consensual basis. The methodology is based on parcel-level field surveys done in the presence of rights holders and neighbors. The socio-land survey identifies rights holders and the land survey draws parcel limits onto an orthophoto. The survey record is signed by the rights holder and neighbors (procès-verbal). The process is presented as neutral since it is limited to the materialization of concrete existing rights (Lavigne Delville, 2006).

It is expected that by 2015, multi-constellation GNSS will have around 100 satellites for global positioning. These new GNSS signals and constellations will provide more accurate, reliable and affordable services. This development opens up the potential for GNSS technology to reach a wider range of users and stakeholders, including ordinary people (World Bank, 2012).

Although aerial photographs have been used to record boundaries since the 1950s (in Kenya, for example), digital cameras, high-resolution satellite imagery(less than a meter), digital terrain models and new software processing systems all increase the availability of reasonably priced orthophotos, which presents opportunities for more cost-effective, efficient and participatory ways to register the boundaries of land rights (World Bank, 2012).

In the past, the costs of land surveying (and the time it takes) have prevented many poor communities from being surveyed -sometimes the cost of the survey is more than the value of their land. Fortunately, this situation is changing as more development organizations and countries take advantage of emerging affordable ICT technologies. The sector has also realized that there is no rationale for having accurate, rigid and expensive land surveys for land where values are low. The

Global Land Tool Network and its over 68 international partners also advocate for the recognition of the continuum of land rights approach and the accompanying pro-poor land administration and records systems.

In Madagascar in the past, poor rural people were barred from owning the land they depended on for their survival. However, in 2005, the government introduced a land policy to improve land tenure security across the country. This enabled Malagasies to formalize ownership of the land they depended on, using a simple certification process. IFAD supports this extensive programme. As part of IFAD-funded projects (Project to Support Development in the Menabe and Melaky Regions AD2M, Rural Income Promotion Programme and Support Programme for Rural Microenterprise Poles and Regional Economies), local land administration offices have issued land certificates to local people to secure tenure of the land they are working. More specifically, existing titled ownership, and parks and reserves, have been mapped using existing records and have been validated by the community. At the same time, existing customary ownership rights have been identified and mapped in a participatory manner, using participatory rural appraisal (PRA) approaches, satellite imagery, orthophotos, GPS and GIS. This information has been used to develop local land occupation plans and to grant certificates of occupation.

Rwanda has strong pressures on land that affect tenure security and therefore food production. An ambitious, centrally driven land reform agenda seeks to address these issues. The IFAD-supported Kirehe Community-based Watershed Management Project has built on a successful land regularization trial. The government has developed a method whereby people can map their own boundaries using satellite images or aerial photography. Demarcation and adjudication is by an adjudication committee composed of members of the cell land committee and village leaders. The parcels have been digitized and information has been entered into the Land Tenure Regularization Support System, which is being used for the titling process.

2.2. LAND USE PLANNING AND NATURAL RESOURCE MANAGEMENT

Planning and managing land use is intimately linked to tenure security. Moreover, land-use planning goes beyond the determination of primary rights (ownership rights) to include secondary use rights (access to grazing land, water resources, fruit trees and forests). These are fundamental to defining the livelihood strategies of the communities' poorest members and partially defining the comparative advantage of a communal tenure system as an alternative or complementary to, an individual ownership/tenure system (ILC, 2008).

The application of remote sensing methods and GIS in landscape management allows for an analysis of the relationships between all environmental components and for monitoring the changes therein. The effective use of remote sensing images (e.g. aerial photos, satellite images) in solving landscape planning tasks requires accounting for the formation of specific images and the information they contain. Remote sensing images have the advantage of simultaneously visualizing all environmental components, which makes them a major information source for landscape planning. However, they have to be integrated in a geo-database with other ground-based data for further processing and analysis (Roumenina,et al., 2010).

The applications of remote sensing methods and GIS are diverse; they include watershed and irrigation management, land use planning, land management, rangeland management, coastal resource management and spatial planning. Using remote sensing methods and GIS for watershed and irrigation management has improved the efficiency of crop measurement and the associated administrative processes, e.g., customer inquiries, information searches, approval for growing crops, crop statistics and information presentation. Further, the integration of GIS databases with hydrologic models is helping to identify on-farm and regional impacts of irrigation management practices. GIS' visualization capabilities also help community interaction with the modelling scenario outcomes and are therefore a useful mechanism to help farmer groups to accept complex modelling results (Khan et al, 2001).

In Swaziland, remote sensing and GIS have been crucial in the planning and management of the IFAD-supported Lower Usuthu Smallholder Irrigation Project (LUSIP). The data gathered are used primarily to inform farmers on how to make the best use of the newly irrigated land. The GIS data, for example, are analyzed to identify areas that can be irrigated, to show soil types and to plot existing water sources. The project team then visits the farmers to advise on what crops to grow on the irrigated land, depending on the specific local conditions. The mapping information helps LUSIP staff to give advice to the traditional land authorities on planning future land use. The data can help them to designate grazing and rangeland areas, to resettle people onto irrigable land, and to develop guidelines for water supply, roads and electricity.

The IFAD-supported Kirehe Watershed Management Project (KWAMP) in Rwanda is assisting with the formulation of comprehensive watershed management plans and the establishment of permanent public/private institutions to manage the development of each watershed, including the implementation of soil and water conservation activities. The project has used participatory community mapping techniques, combined with basic survey approaches using GPS, to identify the extent and current land use in the various watersheds, including an inventory of physical, economic and social attributes. Maps based on satellite imagery have been extremely useful tools for the watershed communities, allowing them to identify features easily and to make plans for the management of resources. The KWAMP has also used maps to identify the 'winners and losers' in the implementation of a number of irrigation schemes. By overlaying parcel data on top of the plans for irrigation infrastructure, it has been possible for project managers to identify those landholders who have large holdings within the schemes, as well as those who might be negatively affected by infrastructure development. The project then uses these maps as a tool to discuss land allocation priorities and practicalities with the communities in question, including equitable access within the schemes.

In Malawi, the IFAD-supported Irrigation, Rural Livelihoods and Agricultural Development Project has assisted with the development of community-level PRA maps. These have been transferred onto 1:50,000 topographic base maps. Hand-held GPS units were used to indicate conservation hotspots, livestock facilities, infrastructure and stock routes. This information has been used to develop watershed conservation plans, to identify areas that may require further attention and to assess the impact of catchment conservation initiatives.

Arid rangelands account for almost 30 percent of world's land area. They are subjected to intensive use (overgrazing, human activity) and severe climatic conditions. Their sustainable management and use can be assured by employing remote sensing and geographic information systems that will enable countries to engage in extensive livestock production, while also curbing environmental degradation (FAO, 2003). The usefulness of remote sensing technologies for rangeland management is in their ability to plan stock routes, to define cattle resting and fattening areas, to determine cattle density, to understand where to establish water points, reserves and irrigation schemes, where to reforest and to plan the expansion of dairy farming.

To support sustainable rangeland development, the IFAD-supported Gash Barka Livestock and Agricultural Development Project in Eritrea facilitated the organization of communities and the formation of user-groups for the control and management of grazing areas within a community's rangeland. Satellite imagery, equipment and staff training were provided to identify possible locations for livestock watering points and drinking-water supplies. Where water is available for livestock, interested communities may select voluntary livestock exclusion areas of up to 1,000 ha to be managed by guards employed by grazing-management groups formed by the communities.

In Tanzania, the IFAD-supported Sustainable Rangeland Management Project aims to secure land and resource rights of pastoralists, agro-pastoralists and crop farmers, while improving land management by supporting village and district land use planning and rangeland management. Participatory range land mapping has proved to be a useful tool for documenting and gaining a better understanding of methods for facilitating livestock movements into the village land use planning mapping process. The project is now investigating possibilities for procuring affordable satellite imaging/aerial photos (±1:50,000) for land use and rangeland management planning.

Remote-sensing technologies are continually evolving and changing, and coastal managers are finding new ways to use this technology, including environmental monitoring, resource inventory and mapping, damage assessment, protected area management, and coastal hazards.

The IFAD-supported Securing Artisanal Fishers' Resource Rights Project in Mozambique envisages the mapping of existing and planned marine and land natural resource use, including fishing areas, protected areas, water access, forests and mangroves, as well as cultivation and grazing areas used by a range of different groups. There has been some mapping of different resource uses of artisanal fishing communities (not only fishing, but also water and infrastructure) and documentation of local natural resource use rules and practices; however, use of mapping and maps to provide a basis for planning and negotiating is not yet well developed in the country. Potential partners of the project have, however, been piloting the use of maps compiled within Google Earth as a means of capturing and sharing spatial data amongst a wide variety of users.

GIS and remote sensing technology is increasingly being harnessed and used to support critical decisions on crop marketing and export, crop inventory and commodity trading. Some of the key activities in the management of value chains that can be performed using remote sensing and GIS are: satellite-based crop mapping and acreage estimation at administrative levels crop health monitoring; satellite-derived indices and weather parameter based yield estimation; crop spatial distribution and satellite resolution based production estimation; comparative analysis of remote sensing-based production and its actual arrival in the market place; spatial database creation of agri-market location and proximity analysis; vehicle routing from farm to retail outlet using network analyses; decision support system for supply-chain design and management.

In Zambia, the IFAD-supported Smallholder Productivity Promotion Programme (S3P) uses geo-referenced satellite imagery for mapping: a) land use capabilities (soils, water); b) existing and proposed land use, including for cultivated and grazing lands, wetlands, forest reserves, national parks and game management areas, settlement areas, mines and commercial farm blocks; c) infrastructure and facilities such as roads and storage and agro-processing facilities; and d) zone, camp, ward, block and traditional authority boundaries / areas of operations. While hand-held GPS are used to survey the above features that are not identifiable on the satellite imagery, GIS is used to produce simple maps. The mapping and planning processes build on participatory planning and mapping processes done by camp extension officers. Freehand, not-to-scale maps produced by communities and special interest groups are transferred to the geo-referenced satellite images and from there are captured in GIS.

In Mozambique, the Pro-Poor Value Chain Development in the Maputo and Limpopo Corridors (PROSUL) supports community-based participatory mapping of existing and planned land use. This ensures that the land being used or proposed for use by the farmer group has the approval of the wider community and takes into consideration environmentally sensitive and conservation areas and broader water use. The mapping process also builds on and contributes to value chain development planning processes. These broader planning processes include mapping existing and planned infrastructure and facilities necessary for the development of the value chain. General information on existing and planned land use, infrastructure and facilities, relevant for the three value chains that PROSUL supports, is being captured in the project's M&E system. Satellite imagery, aerial photographs or maps compiled as part of the project's GIS are being used for community-based planning processes.

3. MONITORING AND EVALUATION

Monitoring and evaluation (M&E) is a management tool. At minimum, an effective M&E system should be capable of the following: supporting results assessment and its use for decision making; providing timely information to support operational as well as strategic management requirements; triggering learning and adaptation; and, eliciting participation and buy-in and responsiveness from key stakeholders (FAO, 2012).

Projects, no matter what their scale or complexity is, require a systematic and reliable flow of management information for their efficient functioning. Rapid developments in ICT have presented new opportunities to establish computerized management information systems and the integration of GIS and remote-sensing tools and applications; this permits more effective information management in support of project operations and monitoring, evaluation and learning (ME&L). The repetitive nature of satellite data capture creates an excellent opportunity for monitoring changes in land use and land cover and evaluating the impact on the environment. Different changes can be monitored: afforestation/deforestation, cropped areas, cropping intensity, landslides, floods, drought, forest fire, water spread, bio-diversity, mining, encroachments, etc. (World Bank, 2006). Furthermore, GIS and remote-sensing tools and applications can also be used to monitor (and properly report) the number of project beneficiaries and to avoid double counting (some people benefiting from more than one activity).

In Kenya, GIS, remote sensing and mapping have been widely used by the IFAD-supported Mount Kenya East Pilot Project as tools for natural resources management and for monitoring the project's progress. This includes interpretation and analysis of natural resource data for use in the development of the resource management plans (RMPs). Support has been provided by other institutions and projects, such as the Regional Centre for Mapping Resources for Development and the Centre for Training and Integrated Research in Arid and Semi-Arid Lands Development. The use of these tools has helped project implementers and beneficiaries to gain a better understanding of the complex interrelationship between physical, biological, cultural, economic and demographic considerations around a specific resource, and to make better-informed decisions on natural resource management.

The IFAD-supported Agriculture Services Support Project in Botswana aims to achieve a sustainable increase in smallholder agricultural productivity by bridging the gap between current and potential rain-fed crop yields. To closely monitor changes in land use, baseline maps have been produced in collaboration with the European Space Agency. Ortho-rectified satellite maps for each time period with information on topography were developed, together with land cover maps (including information on forests, clear cuts, natural re-growth areas, plantations, wetland, shrub land, agricultural areas, buildings, roads, water bodies, river and bare soil), demonstration land cover change maps and statistics on crop acreage and farmland use.

In Madagascar, the IFAD-supported Rural Income Promotion Programme (PPRR) uses aerial photography and GIS for M&E. Maps have been produced showing production in the market access centres and rice yields, comparisons between predicted and realized results against the project's objectives, information on the number and maturity of the groups involved in PPRR and areas of clove production and their yields.

4. CHALLENGES AND OPPORTUNITIES

There are a number of challenges related to the use of GIS and remote-sensing tools and applications. Overall the most important ones are: affordability, capacity issues, lack of modern telecommunication infrastructure (e.g. Internet) and limited access to competent technical advice and support services. Since GIS and remote-sensing tools and applications are generally expert-driven and centrally controlled by state agencies, scientific research institutions and private corporations, a number of risks have been associated with its deployment in the service of people-centred development (Quan et al, 2011). These include:

- Only expert knowledge or data that are readily available in digital form – as opposed to local knowledge – will be incorporated into GIS.

- Planning decisions will be made by experts and technocrats with access to GIS technology but without reference to those directly affected.

- Personal and community security may be violated if information supplied by local people is used by state authorities and developers without their knowledge, consent or understanding.

- GIS is relatively expensive and, unless safeguards are built in to ensure its effective use, the costs are unlikely to be matched by real social benefits.

Some of the key challenges in East and Southern Africa ae that fundamental data sets are not available, outdated map production technologies are used, institutional frameworks create difficulties, and funding and human resource capacities are lacking (GLTN, 2012).

However, in the light of advances in global positioning, mapping and imaging technology, improvements in rural communication infrastructure, and increasing number of private sector ICT service providers across the region, it is anticipated that such impediments would ease over time, making these technologies far more accessible and affordable. Geospatial information is becoming easier to access and use as mapping tools; for example, Microsoft Virtual Earth or Google Maps bring geographical data information to non-specialist users. Scientists and development organizations have created substantial sets of geo-referenced data on population, poverty, transport and any number of other public goods and variables through more affordable, usable geographic information systems available on standard personal computers and mobile devices using web-based tools. Satellite images and similar representations have improved exponentially in quality and detail, and these tools and remote sensors use less energy and require less human attention than in previous years. The capacity to overlay geospatial information with climate and socioeconomic data creates many options, as seen above (World Bank, 2012).

In East and Southern Africa, the Regional Centre for the Mapping of Resources for Development (RCMRD) provides the following services to its member states: advisory services, training, servicing and calibration of mapping equipment, data and information dissemination, and research and development. RCMRD can also assist with sourcing aerial photography, satellite imagery and orthophoto maps. Access to RCMRD’s services can be through the focal points (the ministries of land, environment etc.) or directly from the RCMRD. The Centre has to charge for services that fall outside the approved annual work programme that is supported by the member states (decided on through the Governing Council). However, the RCMRD has some leeway to provide services to others (training, support, etc.) and these are provided at cost; they include advice and technical assistance.

Furthermore, projects and programmes can benefit from IFAD’s in-house capacity in earth observation (EO) techniques and GIS tools. IFAD supports its projects and programmes with the following services: familiarization with information, resources and developments in Earth Observation techniques and GIS identification of how EO techniques and GIS tools can be incorporated; provision of tools and links to practical steps for using EO/GIS; help to better understand opportunities and constraints of these technologies; and facilitation of access to international centres of excellence and networks of experts.

The TSLI-ESA project also creates opportunities to benefit from the expertise of the GLTN Secretariat on pro-poor land information tools, and opportunities to link up with other GLTN partners and their corresponding network partners at regional and/or country level to access appropriate technical advice and support.

5. EMERGING TECHNOLOGIES: OPTIONS, APPLICATIONS AND LIMITATIONS

Geospatial information system as an inter-disciplinary science has many applications in many fields. Contextualization of any geospatial information not only adds value to any application area but also provides insights into other inquiries that further broaden the understanding. The technology is becoming open, less technocratic and more mobile, bringing new energies into the science of mapping. Emerging trends demonstrate that electronic maps and digital mapping coupled with mobile technology have edged out many sophisticated data collection, visualization and dissemination processes and have expanded the repository of data available today. The use of old and conventional technology that was relatively expensive and required experts to operate it is no longer the norm. The elementary method of mapping, i.e. sketching, is currently used by local people and is complemented with data from simple mobile mapping devices that use GPS.

The availability of free, very accurate electronic maps, good Internet connection and applications that support offline visualization has substantially influenced the thinking towards geo-enabled business opportunities and also accelerated the scope of their use. This technology has come in handy with the ease of portability and sharing of mapping data. There are various ways of capturing and acquiring geospatial information, including the following:

- From the field – the classic method: In this method, specialized survey and mapping instruments are used for data collection in the field. These instruments include optical instruments (e.g. theodolites, electronic distance meters, total stations), laser scanners (particularly used for three-dimensional modelling) and survey-grade (accurate) or map-grade GPS receivers. Except for the use of map-grade handheld GPS receivers, the classic method is usually costly and will require highly specialized professional expertise. It is also a comparatively lengthy process.

- From an existing map – transforming into digital information: In this method, new data or information is created from existing maps by converting the information from analogue maps to digital formats using manual or automatic.. The technique also allows updating of such maps using other data capture methodologies, for example, by using remote sensing technologies. By using aerial photos and satellite images, new data can be generated.

- Combined approach: This is the emerging methodology on data capture in which a combination of approaches is adopted. For example, while satellite imagery is used as the core approach in capturing geospatial information, there might be a need to further use the classic method as some parts of the target or project area might not be clear enough or might not have not been captured (due to cloud cover for example).

The use of GIS, geospatial data and other data/information, such as socio-economic data, household information, tenure, use and management data and other information can be integrated into a system that allows the users to make data analyses, manipulate data, generate maps/reports in an integrated manner, where the analyses and results provide useful information for design making processes, planning, advocacy, awareness building and programme management.

This section of the Learning Note highlights three emerging technologies that currently contribute enormously to mapping land and natural resources tenure, use and management. These include remote sensing technologies, global navigational satellite systems and GIS. These technologies are not only becoming accessible and affordable, they are also becoming easy to use. As Antonio (2011) says - the use of IT systems, satellite imagery, GNSS technology and GIS systems to create a land information system is no longer the exclusive privilege of the educated elites. Organized, poor communities and their networks are already learning to use these technologies and systems and finding them to be a vital tool.

5.1. REMOTE SENSING TECHNOLOGIES

Remote sensing is defined as the acquisition of information from a distance or without physical contact with the target object. Remote sensing data are captured using various instruments on board a platform that may be on the ground (i.e. towers, vehicles, etc.), in the air (i.e. plane, helicopter, balloons, etc.) or in space (i.e. satellites).

The data from remote sensing technologies may be available in many formats depending on the needs and the specified requirements. However, the data may be acquired 'raw' or 'processed' into a standard format. Processed data may be classified into two groups:

- Geo-rectified -introducing a coordinate system to imagery data by warping it to a known map projection to use it with other data in a similar projection.
- Ortho-rectified -introducing real world coordinates (ground true coordinates) to produce very accurately positioned data relative to the earth's surface.

The applications for remote sensing technologies are many and diverse. Remote sensing products or data can be used in different applications including, but not limited to, agriculture, land cover, resource management, water management, disaster and risk management, environment and climate change, coastal management, topography, geodesy, geology, mineral exploration and land management. Due to the availability of high resolution images, remote sensing technology can also be used for urban land management, land administration and cadastre. Increasingly, these products are becoming more affordable and accessible via the Internet. Today, in any projects that require geospatial information remote sensing is essential.

There are various and many advantages with remote sensing. One of these is the speed of acquiring large areas of the earth's surface and another is that inaccessible (e.g. highly dense forest) and dangerous areas (high risk areas) can be investigated without the associated risks that the classic method of data collection has. The other advantages are summarized below:

- Temporal information is very useful for detection of change analysis and monitoring and evaluation, particularly with satellites where data collection on the coverage of the earth's surface can be done repetitively.
- It can be time-efficient and cost effective because remote sensing techniques can cover huge areas and need little time for actual fieldwork.
- It enables continuous data acquisition, which means constantly available up-to-date data.
- It offers good visual interpretation and analyses, thus it encourages participation from different stakeholders and promotes transparency.
- Multiple users can use the same data when it is shared.
- Single data with multiple applications.

While there are promising developments, some of the key limitations of remote sensing technologies include:

- To be useful as maps, there is a need for correction and/or calibration against the reality on the ground. One must have a prior knowledge of the area being investigated to avoid misinterpretations and misunderstandings.
- Most remote sensors are not able to penetrate cloud cover and are affected by atmospheric obstacles.
- Resolution of satellite imagery is still comparatively 'coarse' for specific applications like detailed mapping and cadastre. However, there are now various satellite imagery products offering high-resolution images (i.e. Quick Bird, Ikonos, World View, Geoeye).
- Remote sensing creates large quantities of data that normally require storage and extensive processing and analyses. However, with advancements in computing and storage options (such as cloud computing), the issue is no longer as challenging.

- Remote sensing only captures surface or near surface data of the earth’s surface. This means that remote sensing data will not capture ‘depth’ information.

5.2. GLOBAL NAVIGATION SATELLITE SYSTEM

The Global Navigation Satellite System (GNSS) is a constellation of satellites providing signals from space that transmit position and time data; it is a GPS that provides an accurate location of moving and stationary objects anywhere on earth. There are various positioning systems operating, for example the American Global Positioning system, the European GALILEO, the Russian GLONASS, Japanese Satellite and China’s Compass system. GPS is the most common positioning system used today, however it is expected that in the few years’ there will be more satellites for civilian use for various applications.

GNSS technologies have many uses and applications, particularly as the need for location-based data and information increases in popularity. They can be used anywhere on land, sea or air. The basic function of GNSS is to respond to the question ‘where am I’. Indeed, GNSS’s first objective is to determine the location or position of any point on the earth’s surface; however, it has other uses and applications. For examples, all transport and navigational systems use GNSS technologies to find direction, for safety and for accuracy (e.g. planes, ships, etc.). GNSS technologies can be used for recreational and sporting events and help in agriculture, forestry, fishery, mining, research and scientific applications, and, of course, for surveying and mapping. Its uses are limitless.

5.3. GLOBAL POSITIONING SYSTEM

GPS as other GNSS systems is a satellite-based navigation system consisting of three elements: space, ground and user. The space and ground segments are managed by the United States Space Command, which is located in Colorado Springs, Colorado. The user element includes any organization, ship, person or plane that uses GPS. The space element consists of a constellation of at least 24 satellites in six different orbital planes at an altitude of 20,000 kilometres (12,400 miles) and powered by solar energy. On the ground are radar stations that monitor the satellites to determine the position and clock accuracy of each satellite. The locations of these ground stations are Hawaii; Ascension Island in the southern Atlantic; Diego Garcia, an island in the Indian Ocean; Kwajalein, part of the Marshall Islands of the western Pacific; and Schriever Air Force Base, Colorado. GPS was originally intended for military use but the United States Government made the system available for civilian use and application.

HOW GPS WORKS?

Although there is free access to GPS 24 hours a day, in any weather conditions and anywhere in the world, few people know how GPS actually works or how it determines location? All GPS satellites transmit signals containing information about its position and the current time at regular intervals. These signals are intercepted by GPS receiver, which then calculates how far away each satellite is based on how long it takes for the signals to reach the receiver. Once it has the information on the distances of at least three satellites, the GPS receiver can provide the location using a process called ‘trilateration’. The more satellites there are above the horizon the more accurately the GPS receiver can determine the location.

VARIOUS TYPES OF GPS RECEIVERS BASED ON ACCURACY

There is no single classification of GPS units based on accuracy, particularly on horizontal accuracy. Various literatures refer to this classification of GPS units using different terminologies. Most literature simply classifies them into two types: survey and mapping grade GPS units. Some references feature another classification called recreational, navigational or civilian grade GPS units. This section will try to explain these types of GPS receivers.

CONSUMER, CIVILIAN OR RECREATIONAL GRADE GPS

Most handheld GPS receivers available in the market have recreational grade accuracy, including those on modern mobile phones. Most GPS units in vehicles are also of this grade. These receivers can find a general location and are sometimes used in recreational and sporting events. Some models show only longitude, latitude and compass bearings, and a map is needed to identify the location. Some units have built-in maps and/or software, and others include specialized maps showing places of interest, such as museums or restaurants. Horizontal accuracy of recreational GPS receivers usually falls within 15 metres. The price for these units ranges from USD 200 to USD 1000.

MAPPING GRADE GPS

The next level of accuracy for GPS is mapping grade. According to United States Geological Survey, this grade has two sections: commercial grade and differential grade, with handheld models available for both. Commercial grade uses only the L1 frequency and has an accuracy of about three metres. Because their price does not greatly increase, people also use them for recreational purposes. Differential grade GPS devices use both the L1 and L2 frequencies for an accuracy of about one metre. Differential grade GPS allows for improved accuracy of the GPS unit by incorporating better quality antennae and by implementing differential corrections. A differential grade GPS device may cost more than 10 times the cost of a commercial grade unit and prices range from USD 1,000 to USD 10,000.

SURVEY GRADE GPS

This is the most accurate GPS device and is not available as a handheld unit. It consists of two units: a rover and a base station, and requires signals from a minimum of eight satellites. Normally, survey grade GPS has a one centimetre horizontal accuracy or even less. This is also the most expensive GPS receiver. The price ranges between USD 12,000 and USD 50,000.

SOME LIMITATIONS

Being knowledgeable about the use and application of GPS is essential these days due to its applications or even for personal use. However, GPS (and any other GNSS technology for that matter!) is not perfect. GPS receivers need a clear “view” of the sky to get signals from satellites. This means that GPS receivers will not work in basements, underwater, inside buildings, etc., and accuracy will be compromised if they are used under a tree canopy, near tall buildings, etc. So, when using GPS, it is important to ensure the device is used in an area with a wide and unobstructed view of the sky. There are, however, indications that in the near future GPS or GNSS receivers will be usable even inside or where there are obstructions.

APPROPRIATE PRODUCTS AND COST IMPLICATIONS

Several questions need to be considered before deciding what type of GPS should be procured and used. These include: What are the primary objectives in using GPS units? What type of information is being collected and for what purpose? What are the real needs of the project and what are the GPS features that are good to have but are not a priority? What type of GPS unit can be afforded, can it be used optimally and easily maintained? One important factor in choosing the right GPS unit is to do with ‘purpose’. It is tempting to buy the most accurate and most expensive unit without considering the cost, the scale of the work or task, portability, existing capacity, complexity of the equipment including its processing software, inter-operability and the specific purpose.

Probably, for mapping land and natural resources use and rights, mapping grade or civilian grade GPS units will be used. Both types of GPS are suitable for this purpose, unless there is a compelling reason to adopt a highly accurate GPS survey or mapping, i.e. specific legislation. Both products can also be used for GIS purposes. Both GPS units will only provide the position of the GPS units and will not do mapping. However, even mapping grade GPS units would need substantial investments if, for example, the area to be mapped is extensive. With this in mind, there are some key considerations in choosing between the two:

- Use mapping grade GPS if accuracy is extremely important for the project. For example, when a more accurate land area needs to be determined and a high level of accuracy is needed to resolve boundary disputes or conflicts.

- If you choose civilian grade GPS, be aware that position error could be up to 15 metres, even if the observation is correctly carried out and potential instrument and/or human errors were minimized. When using these types of GPS units, it is important to be aware of the location or situation being investigated or observed. It is also highly recommended that an existing map from a reliable source is used for orientation purposes, or GPS points should overlay an existing map (including Internet-sourced maps). In this way, obvious errors such as points on top of the roof of the house or points in the middle of the river or lake can be identified and eliminated.

- In some situations, combining the two types of GPS units will be useful. In this case, mapping grade GPS may be used to check or validate data sets or to locate accurate positions within the project area.

6. INTEGRATION OF MAPPING TECHNOLOGIES AND PARTICIPATORY APPROACHES

At first sight, rapid and participatory rural appraisal (PRA) and remote sensing appear to be poles apart. PRA stresses rural people's knowledge (sometimes known at indigenous technical knowledge. It entails investigations, analysis, planning and implementation by rural people themselves as well as by "outsiders" (non-rural dwelling professionals). It is based on learning, not only outsiders learning from rural people, but learning with and by rural people themselves. A basic tenet is that, as far as possible, knowledge should be owned and used by rural people, and that the process of PRA should be empowering, enhancing rural people's ability to command and manage their environments, and to make effective demands on services. In contrast, remote sensing is in at least two senses "high" technology, and it is also remote. In its more sophisticated forms, with false colour imagery, it may not be easily understood by laypeople. Its analytical categories are those of science, not those of farmers. The scale of images often covers large areas that do not correspond with the local micro-perceptions of rural inhabitants (Chambers, 1990).

Since the 1990s, the Participatory GIS15 (PGIS) movement has sought to integrate local knowledge and stakeholders' perspectives into the GIS. Stakeholders should also have access to GIS databases and products and be able to apply GIS and GIS products to development planning, resource management and advocacy. In considering participation, it is important to be aware of the distinctions and linkages between primary stakeholders (the ultimate beneficiaries, i.e. local communities and the poor) and secondary stakeholders (institutions involved in the delivery of assistance) in processes and projects which involve GIS. The direct users of GIS and its products – maps, forecasts, tables and conclusions about development options and scenarios – will generally be government institutions but also, increasingly, NGOs and community-based organizations. In the development of PGIS, it is primarily these intermediary 'bodies' that need to involve primary stakeholders in the development process, and to deploy GIS technology to help meet their needs (Quan, 2011).

Within applications of PGIS, participatory and perceptual mapping is a widely used tool as it is easily digitized and stored within the GIS. However, qualitative data collected through participatory and perceptual mapping tend to be spatially inaccurate. This can be corrected by proper sequencing of the mapping process, starting with free-drawn maps, which can then be reconciled with uniform base maps developed from aerial photographs and topographic maps (Matheret al., 1998).However, maps should not be used as a single tool to collect and explore local knowledge, because they do not allow for more complex concepts and interactions or triangulation (Chambers et al., 1989). An integrated approach using different tools for collection and analysis of both spatial and non-spatial data will enhance an in-depth understanding of locally produced perceptual maps. It will also reflect different stakeholders' perspectives and realities of the same land area, for example, those of farmers, gatherers of forest produce, private developers and local government planners. Uncritical, rapid questioning and recording of qualitative data and local knowledge may lead to misunderstanding, misconceptions and distorted results during the analysis within the GIS until more detailed work can be done. In addition, regular feedback with the local communities about the research process and preliminary results not only improves their understanding of local perceptions, but also gives communities a sense of ownership of the process. It allows them to have a level of control over the information entered and used within the GIS throughout the process, thereby limiting potential conflicts and securing future community involvement (Quan, 2001).

It is becoming clear that advanced technologies can be combined with community-driven development interventions and practices. The advanced technologies and related products, for example remote sensing data and handheld GPS units, can be used by communities to identify issues and corresponding solutions in a more systematic, location-based and visually-oriented manner. They will also be able to monitor the interventions. GIS technology, if driven by community members themselves, could be a powerful tool because it empowers people to better analyse the issues, identify options to resolve them, and to facilitate dialogues within the community and with the related government authorities and other stakeholders.

In this context, GLTN and partners, such as the International Federation of Surveyors, the University of Twente and others, are developing an information system called the Social Tenure Domain Model16 (STDM). This is a pro-poor land rights recording system that is based on a global standard (Land Administration Domain Model) and open source software packages (i.e. QGIS). STDM supports the concept of a continuum of land rights and builds on participatory approaches and methodologies (Antonio, 2011).Indeed, there are some potential applications of STDM in the context of the TSLI-ESA project.

7. CONCLUSION

IFAD-supported projects and programmes and other partners of the Global Land Tool Network (GLTN) are already using GIS, GNSS technologies and remote-sensing tools and application sto a greater or lesser extent. They include open-source GIS software and freely available satellite imagery. The TSLI-ESA could help to scale up the use of these tools simply by making projects more aware of where and how they can source them, and through sharing information between projects about their use, application and experiences. This could involve the compilation of a list of regional/international resources and contacts, the development of questionnaires for projects to feedback on their usefulness and the profiling of more detailed information on needs, potential uses and potential service providers or support. It would also help to inform the potential users of their options, sources of information and basic guidelines on how to assess needs and appropriateness of technologies. The TSLI-ESA can best support the development and adoption of tools and strategies that are important in the context of the mapping theme by:

- Building up a profile of, and developing strategic partnerships with, regional and/or national mapping/cartographic agencies and agencies that can provide training and capacity-building;
- Developing a regional and country-specific resource base of consultants and/or agencies that are able to provide training and capacity building on the use of GIS, GPS, map production, etc.
- Establishing and maintaining an archive of appropriate and relevant imagery that can be made available to IFAD projects, either within IFAD, or through partnership(s) with other agencies.
- Linking projects with other organizations and other GLTN partners and their country networks to inform, assist and support projects in their efforts to use the technologies.

- Providing simple guidance on the needs assessment, technology options and sources of information

- Facilitating the sharing of project experiences on the use and application of these technologies with other projects that have related projects and/or have the potential to use such technologies.

It is the intention of TSLI-ESA project to continue in this thematic area and to seek inputs from IFAD-supported projects and programmes and other GLTN partners to assess the needs, demands and appropriate interventions and potential activities.

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BIOGRAPHICAL NOTES

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