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Geospatial Science and Technology for Development

With a focus on urban development, land administration and disaster risk management

Unctad Current Studies on Science, Technology and Innovation N°6

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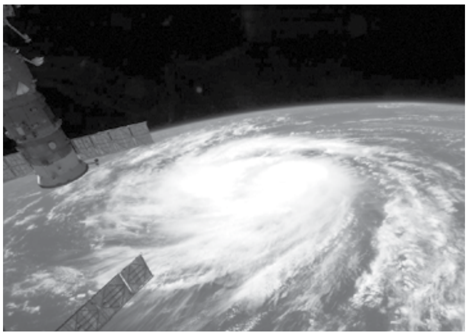

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ABBREVIATIONS

CBDRM	Community-based disaster risk management
CODATA	Committee on Data for Science and Technology
CORS	Continuously Operating Reference Stations
DEM	Digital Elevation Model
DRM	Disaster risk management
DRR	Disaster risk reduction
ECOSOC	United Nations Economic and Social Council
EO	Earth observation
ESA	European Space Agency
EU	European Union
FEMA	Federal Emergency Management Agency
GEO	Group on Earth Observations
GEOSS	Group on Earth Observations System of Systems
GGIM	United Nations Committee of Experts on Global Geospatial Information Management
GIS	Geographic information system
GMES	Global Monitoring for Environment and Security
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GS&T	Geospatial science & technology
GSDI	Global Spatial Data Infrastructure association
HAZUS	Hazards U.S.
HRSI	High-resolution satellite imagery
ICSU	International Council for Science
IDNDR	International Decade for Natural Disaster Reduction
IMD	Index of Multiple Deprivation
InSAR	Interferometric Synthetic Aperture Radar
IRDR	Integrated Research on Disaster Risk
ISDR	International Strategy for Disaster Reduction
ISSC	International Social Science Council
LASRI	Low-altitude remotely-sensed imagery
NGO	Non-governmental organization
PAGER	Prompt Assessment of Global Earthquakes for Response
PGIS	Participatory GIS
PRA	Participatory rural appraisal
RRA	Rapid rural appraisal
SADC	Southern African Development Community
SBA	Societal benefit area
SMS	Short message service
SNL	Supersites and natural laboratories
UNITAR	United Nations Institute for Training and Research
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
VHR images	Very high resolution images
WFP	World Food Programme
WHO	World Health Organization

CONTENTS

I. INTRODUCTION

1.1 Structure and scope of this study

This study explores the ways in which geospatial science and technology (GS&T) can support development.

Chapter 1 introduces the study and describes its structure and scope. It also gives a definition of GS&T and provides a brief overview of its applications.

Chapter 2 argues that a **multi-level approach** is required to examine GS&T, including the global, regional, national/subnational government, and community/citizen levels. It describes each of these levels and related recent developments in them. The following three chapters then consider three specific areas[1] where GS&T can be applied to support development, namely:

Chapter 3 deals with **sustainable urban–regional development**, a response to urbanization by local governance actors and one of the most significant global processes today. Sustainable urban–regional development impacts a range of development issues, including food and water security, economic development, accessibility to infrastructure, shelter and social services and natural risks. All of these issues have a strong geospatial dimension at different jurisdictional levels (national, provincial, local), which makes them appropriate to examine through the lens of GS&T.

Chapter 4 deals with **land administration**, a field where Government acts as the guarantor of fundamental property rights and land tenure security. Land administration systems in the developed world have evolved at a glacial rate over several decades to their current level of sophistication. Appropriate high-speed and low-cost geospatial technologies could help developing countries to leapfrog towards sustainable land administration systems.

Chapter 5 deals with **disaster risk management**. It examines the role of GS&T in disaster relief, reconstruction and rehabilitation, in hazard risk management and in disaster preparedness. It also shows how new technologies enable large numbers of volunteers to be mobilized in disaster risk management.

Chapter 6 then sets out a number of general **challenges** to successfully implementing GS&T to realize its potential benefits. These challenges are grouped under the following seven headings: global strategy and vision; national strategy and vision; infrastructure and data; participatory geographic information systems (GIS) and crowdsourcing; cost and cost-efficient access to geospatial data; human resource capacity-building; and research.

Chapter 7 then makes a number of **recommendations** for steps to overcome these challenges and **concludes** the study. These recommendations are grouped under the same seven headings used in Chapter 6.

1.2 What is geospatial science and technology

GS&T can be considered the tools and methodologies that are used to collect, manage and analyse geospatial data.[2] Geospatial data is data related to the Earth. Examples include topographic data, land property records, spatial plans, soil and forest survey inventories, and a variety of geographically referenced social and economic data such as population characteristics. Geospatial data are spatially referenced in a consistent manner, for example by means of latitude and longitude, a national coordinate grid or postal codes or some other reference system. Often geospatial data also have a temporal dimension, to signify that features change over time.

Governments at all levels—national, provincial and local—need data in order to govern. They use geospatial data in a wide variety of areas, including legislative and policy development, the allocation and management of natural resources, defence and public safety purposes, spatial planning and many others. Specialist government agencies[3] around the world have long traditions in the collection of geospatial data. Each agency employs specialists to organize the collection, updating and management of the type of geospatial data for which it is responsible.

The academic study of GS&T is a cross-disciplinary research domain that draws on concepts and methods from engineering, natural and social sciences. It encompasses the methods, techniques and theories required to (1) generate information about Earth processes from Earth observation (EO) and from data stored in geographic information systems (GIS); and (2) examine the impacts of geospatial technology on individuals, organizations and society, and vice versa.

GS&T as a field has undergone significant transformation in recent years. In the past, the process of collecting geospatial data was laborious and performed with ground-based methods. The updating cycles often spanned several years, and the outcomes (such as paper maps) could not be easily shared across government agencies. The potential for integration and multiple applications, a key characteristic of geospatial data, could not be exploited.

Recent technological advancements have changed this state of affairs. GIS uses modern software and hardware to store, access, visualize, map, analyse and disseminate geographic data. Geospatial data can now be referenced to a globally defined coordinate system. Global Navigation Satellite Systems (GNSSs) such as the Global Positioning System (GPS) use satellites to allow users to determine their exact location, velocity, and time in any conditions, making traditional positioning instruments such as tapes and theodolites obsolete. The products of these new digital geospatial technologies include digital maps, satellite image maps, topographic maps, and land use change statistics. With GIS, it is easy to combine and share these different geospatial data sets. An integrated analysis of these combined data can provide new insights into the interaction of geographic phenomena. These new geospatial technologies can support the realization of many diverse benefits which the intergovernmental Group on Earth Observations (GEO – see chapter 2) has categorized into nine distinct societal benefit areas (SBAs). These SBAs and the associated geospatial decision support systems which enable benefits to be realized are set out in table 1.1 below. The wide range of potential benefit areas in table 1.1 demonstrates the scope of GS&T.

This study examines a subset of these benefit areas, namely: sustainable urban–regional development, land administration, and disaster risk management.

To realize benefits in these areas, action will be needed across multiple levels, ranging from global coordination to the actions of communities and individual citizens. Chapter 2 explains these different levels and why each is important to understanding the use of GS&T in development.

Table 1.1: Societal benefit areas and related decision support systems

GEO societal benefit areas (SBAs)	Related GEO decision support systems
1. Disasters	Hazard and risk assessment/simulation models, forecasting/early warning, monitoring, damage assessment, prevention/planning
2. Health	Air quality forecast/early warning/monitoring, epidemics forecast, relation between diseases and environmental factors
3. Energy	Resource assessment for renewable energy, energy resources exploration support, pipeline monitoring and optimization of biofuel production (crosslink with Agriculture SBA)
4. Climate	Monitoring and modelling, carbon accounting schemes and prediction and mitigation of effects
5. Water	Ocean topography, temperature and currents, ocean water quality & chlorophyll (crosslink with Agriculture SBA (fisheries)), drought monitoring/early warning (crosslink with Disaster SBA), hydrologic information systems (including agro-meteorology) (crosslink with Agriculture and Disaster SBA), soil moisture modelling (crosslink with Agriculture SBA) and monsoon monitoring/forecast
6. Weather	Forecasting global/local; precipitation monitoring/forecast (crosslink with Agriculture SBA); and sand/dust storm forecast (crosslink with Health SBA)
7. Ecosystems	Marine and coastal ecosystems (global/regional), terrestrial and freshwater ecosystems (global/regional), biogeophysical variables (vegetation, soil, radiation, water cycle) (crosslink with Water and Agriculture SBAs) and local applications, for example protected areas
8. Agriculture	Satellite-based fishing (crosslink with Water SBA), precision agriculture, monitoring and modelling of crop conditions, including food security (crosslink with Climate and Water SBAs), insurance monitoring (EU: Common Agricultural Policy), forestry monitoring, including illegal logging (crosslink with Climate SBA)
9. Biodiversity	Biodiversity modelling & monitoring, invasive species monitoring and ecological forecasting (crosslink to the Ecosystems SBA)

NOTES

1. There are many other possible applications of GS&T in support of development (and other goals) in addition to the three areas explored in detail in this study. See table 1.1 for a comprehensive list of GS&T applications.
2. Geographic, spatially referenced, or georeferenced data are alternative terms for geospatial data.
3. Such as National Mapping Agencies, Cadastres, Statistics, Forest, Soil, Hydrographic, Geological Surveys and Land Affairs departments, among others.

2. A MULTI-LEVEL APPROACH TO GS&T

GS&T is a complex field in which activities take place and impacts are felt at multiple levels. Earth processes, such as disasters, epidemics, climate change, deforestation, soil degradation and loss of biodiversity do not stop at national boundaries. They have spillover effects that affect entire regions and require regional and global human action and institutions to mitigate or prevent. Equally, geospatial technologies such as satellite-based EO and GNSS can often also be global in nature. A global lens must therefore be used when examining some aspects of GS&T. However, the majority of GS&T implementation is led either by multiple countries working together at a regional level or by countries working at the national/subnational government level. As these are the two levels where most activity occurs, it is also essential to consider GS&T through regional and national/subnational government-level lenses as well. It is important to note that on these three levels, governments are not the only actors: initiatives may also include non-state actors such as supranational bodies, the private sector or NGOs. The fourth and final level at which GS&T must be considered is the level of communities and individual citizens. Technological advances have increased the ease with which communities and citizens can both consume and create geospatial data, making them important players in the field. The remainder of this chapter briefly discusses these four levels and recent developments within them. An understanding of the multiple levels at which GS&T operates provides the contextual background to the more practical examples and discussions covered by chapters 3 to 5.

2.1 The global level

As discussed above, by their very nature Earth processes often take place at the global level, which implies that many EO systems will also need to be global in scale. Accordingly, a global view of the potential challenges and solutions related to GS&T is essential.

To address this need for a global view on GS&T, the intergovernmental Group on Earth Observation (GEO) was launched by the 2002 World Summit on Sustainable Development and by the Group of Eight (G8) leading industrialized countries. GEO is a voluntary effort of (currently) 88 national governments plus the European Commission and 64 organizations around the world. GEO aims to build on and add value to existing GS&T systems by coordinating efforts across nations, addressing critical gaps, supporting their interoperability, sharing geospatial data, reaching common understandings on user requirements, and improving delivery of data to users (GEO, 2005). GEO promotes scientific connections and interoperability between observation systems, with a particular focus on nine societal benefit areas, as discussed in chapter 1.

In 2005, GEO issued a 10-year plan for implementing the Global Earth Observation System of System (GEOSS) initiative. GEOSS aims to be a global and flexible ‘system of systems’ allowing decision-makers to access an extraordinary range of information in a coordinated manner at their desk. This ‘system of systems’ “will proactively link together existing and planned observing systems around the world and support the development of new systems where gaps currently exist. It will promote common technical standards so that data from the thousands of different instruments can be combined into coherent data sets.”[4]

Another relevant global institution is the Global Spatial Data Infrastructure (GSDI) association. GSDI is a collection of organizations, agencies, firms, and individuals from around the world. Its purpose is to promote international cooperation and collaboration in support of local, national and international spatial data infrastructure developments.[5] Spatial data infrastructures or SDIs are essentially strategies for geospatial data management, often at a national level. The association supplies geospatial data providers and users around the world with the necessary background information to evaluate and implement geospatial strategies to ensure regional and global (technical and institutional) interoperability. The information GSDI provides includes existing and emerging standards, open source and commercial standards-based software solutions, supportive organizational strategies and policies and best practices.

A further recent global institutional development is the United Nations initiative on Global Geospatial Information Management (GGIM), established by the United Nations Economic and Social Council (ECOSOC) in July 2011. This initiative aims to, among other things, “provide a forum for coordination and dialogue among Member

States, and between Member States and relevant international organizations, including the United Nations … on enhanced cooperation in the field of global geospatial information."[6] It is expected to be comprised of experts from all Member States, as well as experts from international organizations, as observers, and should further promote a coordinated, global view of GS&T.

There are also a number of private sector actors operating globally in the GS&T field. Global sales of geospatial software, services and data were expected to exceed $5 billion in 2011.[7] A 2009 study by industry analysts identified Esri, Bentley, Intergraph, Autodesk and PB MapInfo as the key suppliers of GS&T to the public sector.[8] These businesses are important actors in the global GS&T field, and often interact with global GS&T institutions to discuss policies, trends, standards, products and initiatives.

The institutions and companies mentioned above all take a global view of GS&T. Given the global nature of GS&T, such a view is essential, and the further actors can coordinate at a global level, the more effective GS&T can become.

2.2 The regional level

The developments described in section 2.1 are global institutional innovations that can offer a common global vision. However, while global focus is vital, it is at the regional and national levels where most activity will occur in harnessing GS&T to support development. While the market for GS&T is global, it should be noted that sales are not evenly spread. North American accounts for almost half of the industry's annual sales, followed by Asia/Pacific and Europe. The geospatial market outside of these three key regions is growing fast but currently accounts for just eight per cent of total industry sales.[9] This illustrates the strong inequality in GS&T capacity between regions. For developing countries in regions with little established GS&T capacity, collaborating on a regional basis may in many cases be more achievable than working alone. Regional approaches allow countries to pool resources in order to address common, regional needs.

One form of regional collaboration is for governments to work together to establish and implement a regional geospatial strategy. Such a strategy could typically address at least three crucial elements: (1) the development of a regional capacity-building strategic plan; (2) identification of the appropriate decision support systems for the region; and (3) the installation of low-cost reception stations at strategic locations. Regional geospatial strategies can be the outcome of deliberation among geospatial scientists, government officials and private sector providers. The Southern African Development Community (SADC) region plans to implement a regional geospatial strategy containing these three elements which could serve as a template for other regions.

2.3 The national and subnational government level

A national government has the authority to legislate open data access, promote the sharing of geospatial data across networked government agencies,[10] and regulate aspects of dissemination, security, copyright and pricing, in contrast to global or regional (supranational) initiatives that are voluntary in nature. National geospatial strategies, or SDIs, are older than GEO/GEOSS. They date back to the early 1990s, when several national governments around the world embarked on ambitious schemes to join up stand-alone GIS systems across agencies and levels of government to Internet-based, networked environments (Nedovic-Budic et al., 2011).

A national SDI forms the geospatial base for wider government strategies and initiatives, such as electronic government (e-government). Ideally, an SDI encompasses the institutional, technical and economic arrangements that enhance the availability (access and use) for up-to-date, fit-for-purpose and integrated geospatial data and services. The aim is to create a "one stop shop" for geospatial data, where data are collected once then used many times for a variety of purposes. Government agencies collaborating in a national SDI can be spread widely over several locations. In an SDI, the functional components of a GIS are available as web-based applications. Much of the functionality is provided by geospatial web services, i.e. software programmes that act as an intermediate between geospatial databases and users on the World Wide Web. Geospatial web services can vary from a simple map display service to one that involves complex spatial calculations.

However, national governments only account for half of public sector spending on geospatial technology and services. The other half comes from subnational governments, and is driven by the need for cities and counties to manage property information and other municipal assets.[11] The government level must therefore consider subnational as well as national government agencies as key consumers and creators of geospatial data.

2.4 The community and citizen level

Specialist government agencies, who have traditionally been the authoritative providers of geospatial data, still have a major role to play in the provision of geospatial data, but a growing community of users with roots in civil society, some of whom might be described as geospatial activists, has been active in participatory geographic information service (PGIS)[12] for decades. PGIS is a community-based approach that seeks to involve local affected communities in the acquisition and analysis of geospatial data. This is with the aim of better meeting the needs of the affected community and achieving the right outcomes. PGIS consists of many tools for non-conventional data acquisition, ranging from semi-structured interviews and open-ended discussions to the whole range of participatory rural appraisal/rapid rural appraisal (PRA/RRA) methods, particularly sketch maps, diagrams, historical time lines, time-space diagrams, etc. Table 2.1 gives an overview of appropriate tools and methods for specific applications.

Table 2.1: Overview of Participatory GIS methods and tools according to their applications

TOOL OR METHOD / SUITABLE APPLICATIONS	Boundary mapping	Environmental issues	Land allocations	Land use planning	Location marking	Risks and hazards	Safety and security	Service and utility planning	Slum upgrading
RRA & PRA methods (for spatial info)		o		o		o	o		o
P-mapping with: sketch mapping				o		o	o	o	
P-mapping with: topo maps	o		o	o	o			o	o
P-mapping with: aerial photos	o	o	o	o	o	o	o	o	o
P-mapping with: satellite images	o	o		o		o	o	o	o
Participatory 3D modelling	o	o	o	o	o				
Mobile GIS, GPS, CyberTracker	o				o	o		o	o
GIS (mainstream)	o	o	o	o		o		o	o
Visualization, graphics software		o		o		o	o		o
Digital camera, video, multimedia		o				o	o		
Web-based GIS				o		o	o	o	
Virtual reality		o		o			o		o
Interactive planning tables	o	o	o	o	o	o			

Source: adapted from McCall and Verplanke, 2008

In recent years, commercial geobrowsers (e.g. Google Earth, ArcGIS explorer) and the new possibilities for data collection or "sensing" by citizens with Web 2.0 are transforming PGIS into a global crowdsourcing phenomenon. Crowdsourcing relies on mobile communication technology, GNSS receivers, SMS-based services and the representation on maps of the needs of citizens and grassroots organizations, especially regarding basic public services (Georgiadou et al., 2011). Citizens "sense" and report failures of governance (e.g. corruption) and the condition of public services via a standard mobile phone or computer, much like non-human sensors record temperature, river flow, or the speed of vehicles. Examples of the potential of crowdsourcing are discussed in more detail in subsequent chapters.

2.5 Summarizing the multi-level approach

The four levels discussed above are all necessary for understanding the use and application of GS&T, and they feature accordingly throughout the remainder of this study. The following three chapters discuss the ways in which GS&T can support development in three key areas, offering examples of initiatives at each of the four levels discussed. These four levels form the contextual background against which the more practical applications of GS&T take place. Without this background and the activities that happen at each level, many of the examples discussed in subsequent chapters could not be taken up in their current form. The challenges and recommendations discussed in chapters 6 and 7 also cover each of the four levels.

NOTES

4. See http://www.earthobservations.org/geoss.shtml
5. http://www.gsdi.org/
6. Terms of reference of the Committee of Experts on Global Geospatial Information Management available from http://ggim.un.org/docs/meetings/Forum2011/E-C20-2011-2-TOR.pdf
7. http://govpro.com/technology/gis_gps/gis-geospatial-market-20091201/
8. *Ibid.*
9. http://www.geospatialworld.net/uploads/magazine/f98ffc_GeospatialWorld-December2011.pdf
10. National Mapping Agencies, Cadastres, Statistics, Forest, Soil, Hydrographic, Geological Surveys, Land Affairs departments, et cetera
11. See http://govpro.com/technology/gis_gps/gis-geospatial-growth-20110127/
12. See PPgis.net for further details available from http://www.ppgis.net/

3. SUSTAINABLE URBAN–REGIONAL DEVELOPMENT

3.1 The issues

Urbanization is one of the most significant global processes in the world today. With more than 50 per cent of the world's population now living in cities and a trend for further urbanization, particularly in the world's less developed countries, we are witnessing urban development at an unprecedented scale (UN-HABITAT, 2010a). The rapid expansion of existing towns and cities, through both planned and unplanned development, as well as the creation of new towns and cities, is relentless.

Urban regions of all sizes share many basic processes and concerns. Some of these concern the relationships of urban regions with the natural environment on which they depend for water, food, waste disposal and energy or their vulnerability to natural disasters (see chapter 5). There are also common concerns as to how to provide efficiently for the basic needs of the residents and those who visit the city for economic or leisure activities. Adequate and safe shelter, accessible social services, efficient transportation systems, energy and telecom services, business and commercial services and public administration and governance services must all be planned for, delivered and operated in a sustainable manner.

Geospatial information is a vital element in the quest for sustainability in urban and regional development. Planning for future development should be based on a sound understanding of both the current situation and the historical development path of the urban region. Given the scale and speed of contemporary urbanization, this requires three basic layers of geospatial data: (1) the substrata layer, which is mostly the natural environment; (2) the infrastructure networks layer for water, drainage, transport, etc.; and (3) the occupation layer consisting of the buildings and the activities that take place within them, all at multiple scales over extended time periods (Priemus, 2004, 2007). Each of these layers consists of multiple thematic and topographic data sets which need to be updated at regular but different time intervals, according to the appropriate rates of change.

The substrata layer is generally the least dynamic layer. However, when natural disasters occur (see chapter 5), substantial and rapid change may occur to the natural environment due to flooding, erosion, earthquakes, landslides etc. The network and occupation layers require more frequent updating. In a well-planned city, changes to these two layers will be tightly synchronized. New networks should only be created to support new activities, and no buildings should be constructed and occupied if they do not have the required infrastructure connections. Moreover, they should be designed on the basis of a sound understanding of the substrata structures and processes and their implications for the built environment (such as load-bearing capacities, ground and surface water, etc.). Thus, establishing properly synchronized and coherent geospatial connections between the three layers is paramount for sustainable urban development.

GS&T provides useful tools and platforms to realize these connections. It also supports several tasks often associated with planning and development (Webster, 1993a, 1993b). Tasks related to the plan-making tradition of urban management are more ad hoc in nature, while those in the administrative tradition of urban management are more geared to routinized procedures such as development control, land administration or public utility operations and maintenance (Masser and Ottens, 1999).

Urban–regional development tends to be driven from the national/subnational government and community/individual levels, as cities do not cross borders. However, the global level is still relevant to urban–regional development, and attention is being paid to this topic globally as shown in box 3.1.

Box 3.1: GS&T and urban planning at the global level

The GEO Task "Global Urban Observation and Information" in the GEO 2012–2015 Work Plan is designed to improve the coordination of urban observations, monitoring, forecasting, and assessment initiatives worldwide. An international Task Team representing data providers and end users is working together to support the development of a global urban observation and analysis system, producing up-to-date information on the status and development of the urban system and filling existing gaps in the integration of global urban land observations with data relevant to urban structure, ecosystems (including air quality), and socioeconomic indicators.

Source: See task SB-04 at: http://www.earthobservations.org/ts.php

The following sections look more closely at the role of GS&T in three areas of urban management. While not comprehensive, the coverage of the applicability of GS&T in these areas provides insight into the growing range of possible GS&T applications as well as some of the interrelationships between different issues and approaches.

3.2 Urban poverty dynamics

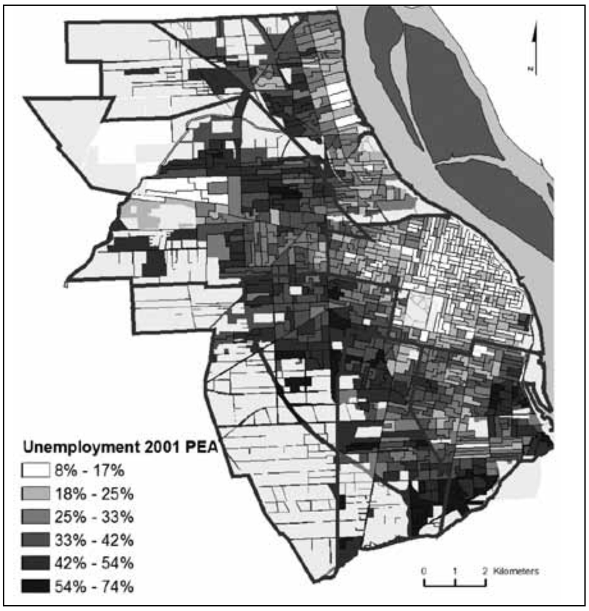
In many developing countries, urbanization means the "urbanization of poverty" and hence higher rates of child morbidity and mortality. Although in general child mortality rates are higher in rural areas than in urban areas, the rates in urban slums may exceed those of rural areas (Martinez et al., 2008; UN-HABITAT, 2003). Urban deprivations (e.g. high infant mortality rates, lack of safe shelter, overcrowding and inadequate water and sanitation systems) in the world's many slum communities are symptomatic of urban poverty. In some cities of sub-Saharan Africa, more than 60 per cent of the population live in so-called informal settlements, often with more than one of these urban deprivations.

Responding effectively to urban poverty dynamics is a major challenge for local and national governments, particularly in the world's poorest countries, whose governments have limited human, technical and financial resources. Key development information and indicators become quickly outdated as a result of rapid urbanization. The lack of current data is an obstacle to understanding the scale, speed and locations of newly developing urban areas, particularly informal development.

Statistics and statistical mapping to study the patterns of urban poverty are well-established ways to provide useful, policy relevant insights into the patterns of urban deprivations for local governance processes (Baud et al., 2009). Routinely collected data on urban poverty may be available through a national census, and can be used to analyse the level and spatial patterns of urban poverty (Martinez, 2009). Figure 3.1 below shows such an analysis, with one measure of urban poverty, in this case unemployment rates from census data, geographically referenced and visually displayed on a map.

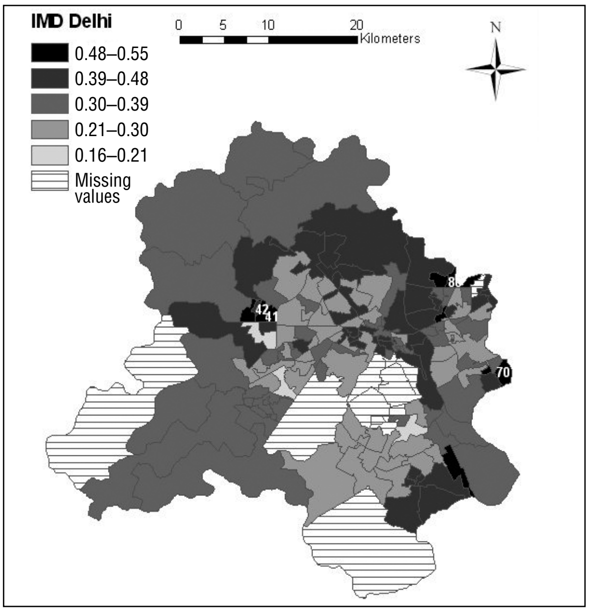
Such analyses can be repeated over time as new census data sets become available to provide an impression of dynamics, albeit at the relatively long time interval of 5–10 years. Data from the official 2001 Indian Census has been used by Baud et al. (2008) to analyse and map urban deprivations based on a livelihoods approach using a set of indices for four types of capital (social, financial, physical, human) to generate an Index of Multiple Deprivation (IMD) (see Figure 3.2). Alternative sources of useful statistical data for poverty analysis may be available

Figure 3.1: Rates of unemployment in Rosario Argentina 2001 Census



Source: Martínez, J. (2009)

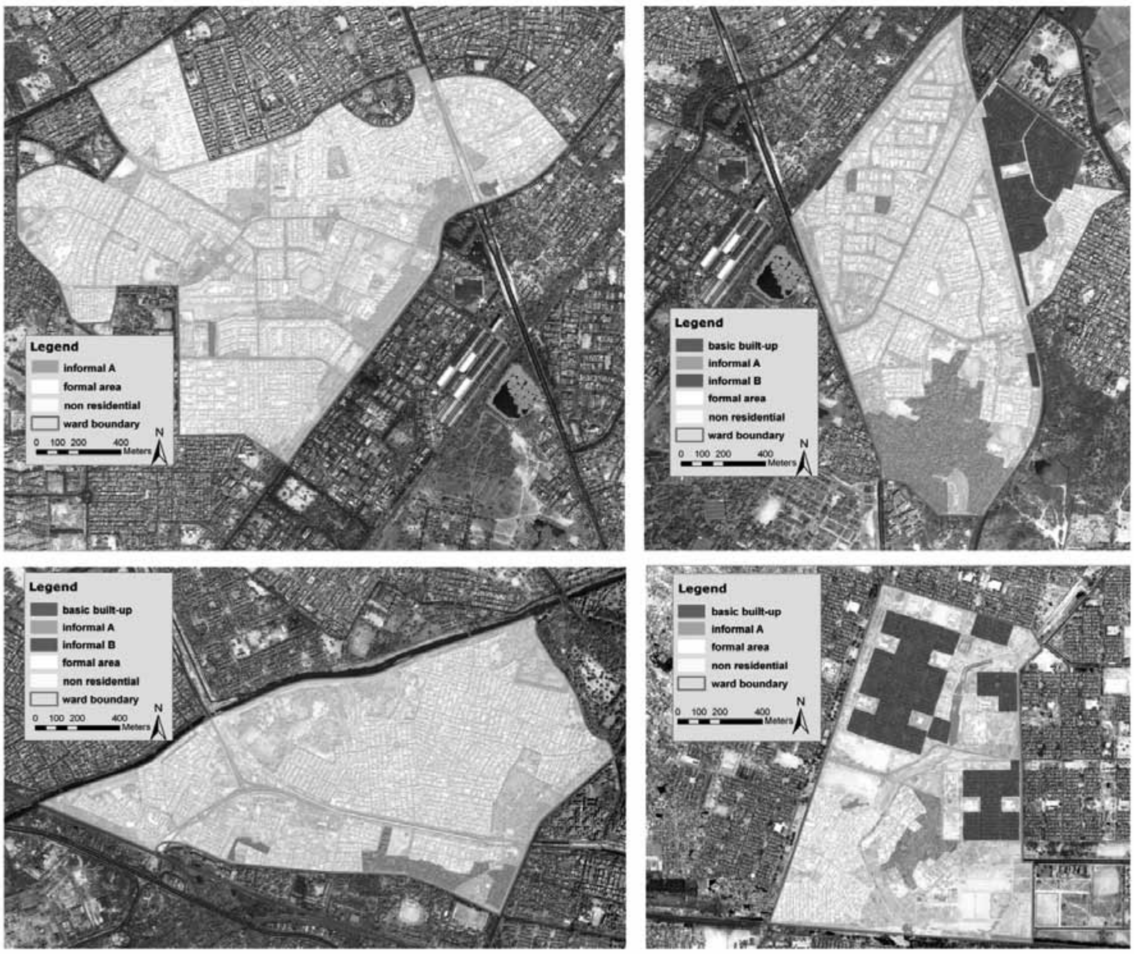
Figure 3.2: Hotspots of poverty in Delhi



Source: Baud, Sridharan and Pfeffer (2008) for some cities through local statistical surveys such as the Demographic and Health Survey (which recently started to georeference its statistics to enable spatial analysis)[13] or the Multiple Indicator Cluster Survey, which covers the health and well-being of women and children.[14] These data are a key source for United Nations reporting on the Millennium Development Goals such as UN-HABITAT's State of the World's Cities series.

However, such methods suffer from significant shortcomings, not least of which are the delays between the collection and release of census data, lengthy planning and implementation procedures, as well as the high cost and relatively high levels of aggregation of census data required to protect the privacy of individuals. A purely statistical approach can however be supplemented by EO, specifically very high resolution (VHR) imagery, which is typically captured from satellites. This technology has been available since approximately 2000. VHR images have been used to provide additional details on the distribution of poverty "hot spots" in Delhi, revealing that the high aggregation level of census tracts conceals substantial diversity in living conditions (Baud et al., 2010). The maps in figure 3.3 show the distribution of different types of formal and informal building typologies in four wards of Delhi. The socioeconomic and physical structures of many wards are very mixed, but this diversity can only be revealed through the use of VHR imagery. The urban poor tend to be concentrated in the two informal housing classes as well as the basic formal type, which are usually so-called resettlement colonies. A purely statistical analysis would not have revealed this diversity.

Figure 3.3: Visual interpretations of different housing typologies in selected wards of Delhi to refine poverty targeting



Source: Baud, Kuffer, Pfeffer, Sliuzas (2010)

Thus, the combination of statistical and geospatial information is both a necessary and a powerful way to examine and monitor poverty dynamics. Unless slums can be identified, policymakers cannot do anything to respond to them.

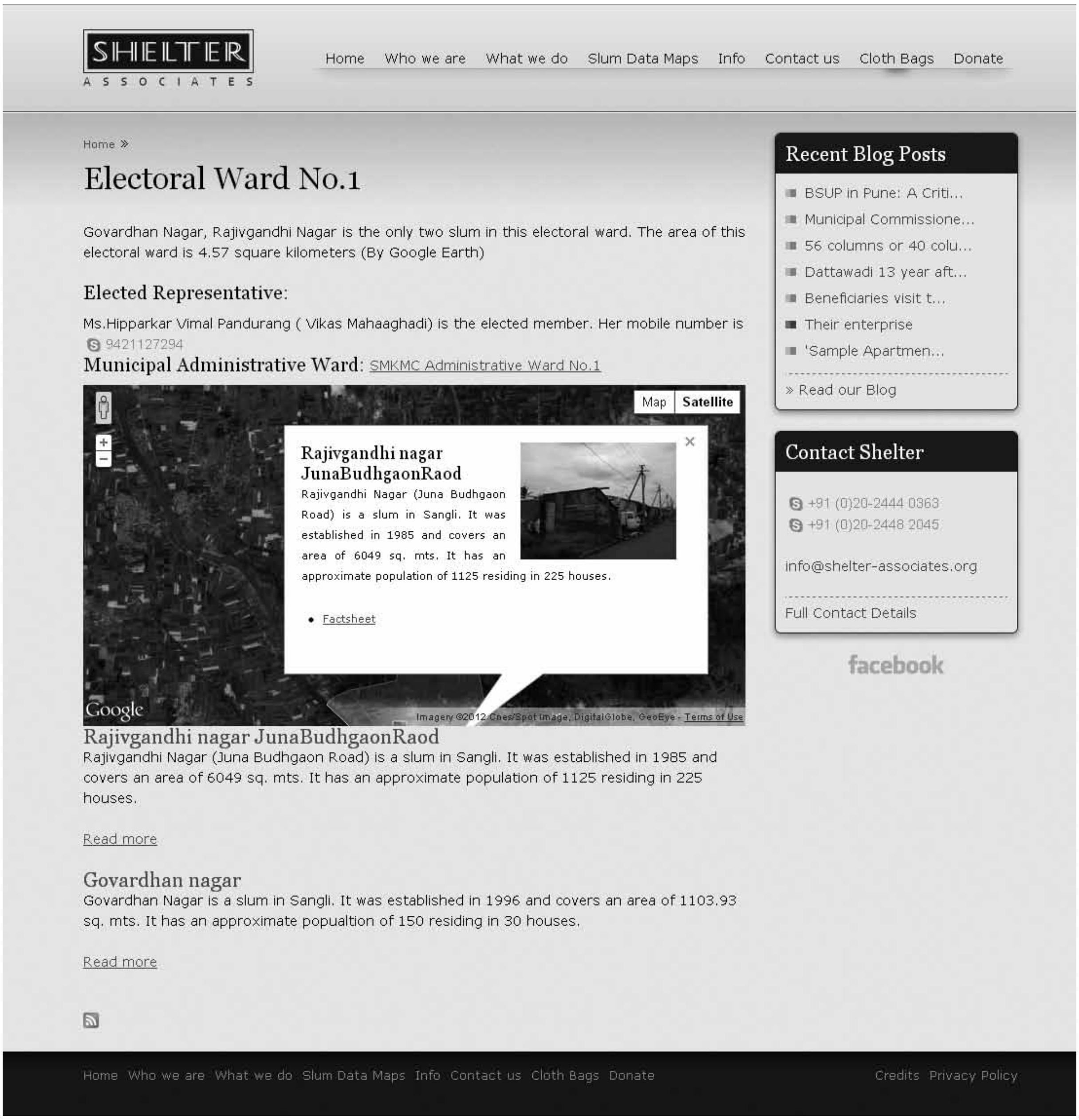
Much research by remote sensing experts on the use of VHR images is concentrated on the use of advanced object-oriented approaches for automatic feature extraction (Blaschke, 2010), and such techniques are also being developed for slum detection and classification (Kohli et al., forthcoming). This type of work is as yet far from operational but will continue to improve. In the meantime, human interpretation of VHR images remains an important means for slum identification and monitoring.

As VHR imagery becomes more widely known through web-based mapping services such Google Earth, Google Map Maker, OpenStreetMap, ArcGIS Online, Microsoft Bing Maps etc., the range of geospatial information users is dramatically expanding. Organizations and individual citizens which or who would have once relied on official maps from a national government mapping agency now have the ability to generate their own maps and even collect, manage and disseminate spatial data on an increasing scale. For example, with the assistance of the German Development Agency, the Greater Cairo Governorates have developed methodologies to create their own detailed urban district level databases of buildings and associated socioeconomic data, sidestepping the traditional government mapping agencies. Their geospatial database is now regularly updated and used to address local poverty and other urban management issues.[15] Their bottom-up geospatial data collection strategy is a key instrument in the building of a sustainable local urban management capacity in Egypt's Governorates. VHR images can be used to bridge the time gap between official census surveys, allowing local planners and engineers to monitor the physical development process in order to make reliable estimates of population data for fast-changing urban districts.

Several NGOs have developed the capacity to collect and use geospatial data extensively in their technical and advocacy work, in which self-reliance and empowerment of community members has a central role. These include Shelter Associates in Pune (India),[16] the Society for Promotion of Area Resource Centres in Mumbai (India),[17] Pamoja Trust in Kenya,[18] and Shack/Slum Dwellers International, which focuses on urban poverty alleviation and slum improvement.[19] The development of their geospatial capability arose from the recognition of the importance of spatial data in expressing community claims for land rights and services. Shelter Associates trained community youth to carry out surveys. They also added qualified land surveyors to their staff to prepare settlement maps from plane table surveys, but this approach has gradually been combined with digital survey tools and satellite imagery. Shack/Slum Dwellers International has a strong desire to promote empowerment and self-reliance, also with regard to GS&T.

In association with UN-HABITAT and the Regional Centre for Mapping of Resources for Development in Nairobi, associated NGOs such as Pamoja Trust have also developed an independent capacity for settlement mapping and enumeration that includes a high level of community participation and engagement. The active involvement of community members in physical and socioeconomic enumeration assists them with individual skill development and in raising their spatial awareness of their community and its environs. The independent generation of detailed geospatial databases of slum areas and slum dwellers is in principle empowering, as it improves the knowledge base of residents and communities and also reduces the information imbalance between communities and the Government (Abbott, 2003; Sen et al., 2003; Sliuzas, 2003). Figure 3.4 is an example of the type of detailed geospatial data that can be collected on slums by NGOs working together with local residents to produce maps.

Figure 3.4: Part of a webpage produced by Shelter Associates showing extent and details of a slum area in Sangli, India



Source: Shelter Associates

Such initiatives demonstrate how accessible and useful geospatial technology has become. While the democratization and popularization of geospatial technology have barely started, it is already creating new opportunities and challenges for traditional government mapping agencies. Two opportunities are the potential to (1) mobilize large numbers of citizen mappers to collect spatial data in order to help fill the spatial or temporal gaps in existing spatial data coverage; and (2) provide near real-time information to the Government and relief agencies in disaster situations (see chapter 5). Establishing working protocols for the collection and delivery of data of acceptable quality, and scrutinizing and using a more diverse range of data sources in an integrated manner are some of the major challenges. Being on “a” map is not equivalent to being on "the" (official) map, and governments may have reservations about the official use of data collected directly by citizens.

It is important that policymakers recognize the changing landscape associated with the democratization of GS&T. Spatial data serves an increasingly wide range of public and private interests but to maximize the benefit from this, appropriate standards and protocols for data collection, management, sharing and dissemination are needed. Chapter 7 sets out recommendations on how officials can more effectively engage with citizens to meet their geospatial data needs.

To conclude this section, recent developments in GS&T can allow for quicker, more accurate data to be generated on dynamic, fast-changing urban landscapes. Further, these data can also be collected more cheaply, especially if crowdsourcing is used. These more accessible data can better provide governments, NGOs and other users with the information they need to respond effectively to the challenges posed by urban poverty.

3.3 Urban infrastructure and services

Clean drinking water, electricity for 24 hours a day, proper sanitation, and good-quality education and health care are important public services that help create the conditions for human well-being and social and economic development. They are provided through both public and privately funded physical and social infrastructure.

Provision of physical infrastructure is guided by principles of equity (ensuring that all segments of society enjoy equal access to appropriate, good-quality and safe infrastructure); affordability (providing infrastructure that people can afford); and efficiency (organizing the development, delivery and operation of infrastructure in the most efficient way). In many developing countries, however, huge challenges exist in catering for the rapidly growing urban population and the spatially dispersed rural population.

Notwithstanding large investments by national governments and international donors, the infrastructure challenge remains real: for example, despite recent improvements, close to a billion people in developing countries lack clean drinking water and over two billion do not have access to improved sanitation.[20] The electrification rate of developing countries averages around 75 per cent but with large variability. Even where the correct infrastructure exists, services may still not reach the population. For example, water may be supplied but not be fit for consumption; an area may be electrified but only actually receive electricity for a few hours a day and so on. The poor are often the least served and also pay high costs for alternative services. These alternatives can be informal and often illegal (see figures 3.5 and 3.6). Due to poor planning, engineering, operations and maintenance, the useful life of infrastructure facilities is often much shorter than the normal design lifetime. This leads to a rapid depreciation of assets and high costs of replacement.

Figure 3.5: Electricity connections in Hanoi

Source: Mark Brussel, ITC

Figure 3.6: Informal and illegal water connections in Dar es Salaam, Tanzania

Source: ITC

The provision and operation of physical infrastructures are complex, as they need to respond to a wide variety of often conflicting demands. The reconciliation of conflicting goals creates many dilemmas: financial sustainability versus technological choice, economic performance versus environmental impacts, short-term versus long-term planning horizons (Sahely et al., 2005), for which trade-offs are inevitable. This balancing act requires the best available strategies and methods and up-to-date information to support decisions.

GS&T has an enormous potential in the infrastructure sector. The geospatial analysis capabilities of GIS help analyse service provision levels and act as a support tool in the physical planning of infrastructure. GIS data analysis capabilities enable organizations to link their traditional engineering drawings and maps of the distribution, transportation and collection networks with a wide variety of information about infrastructure assets to optimize their operations. GS&T offers important functionalities for managing infrastructure assets, from relatively simple tasks such as being able to quickly locate an underground pipe or cable (thereby reducing the cost of unnecessary damage and service disruption) to more complex operations of maintenance optimization or service planning and distribution adjustment.

This is why the infrastructure industry has been one of the first and major driving forces behind GS&T application worldwide. For most utility companies in Europe and the United States, GIS has been the major innovation of the last 25 years and is at the core of their business processes. Governments and utility companies in both the UK and the Netherlands, for example, cooperated intensively in the development of common spatial data frameworks and databases that today are the basis for their GS&T applications. In many developing countries, the infrastructure sector has been one of the first to use GIS routinely in day-to-day operations, and the opportunity for governments to partner with infrastructure companies to jointly develop and maintain their spatial databases is therefore obvious.

Infrastructure asset management is a “combination of management, financial, economic engineering and other practices applied to physical assets with the objective of providing the required level of service in the most cost-effective manner” (CIRIA, 2009). It is the most important contribution of GS&T in the infrastructure sector. Typical infrastructure assets are buildings, pipelines, pumps, valves, switches, or any infrastructure object that forms a vital part of the system and can be represented along with its attribute information in a geospatial database. Both public and private organizations may own and/or operate infrastructure assets. GIS-based tools are used to register their location and other characteristics for strategy development and decision-making. Typically, asset management takes place through the integration of several geospatial databases that provide simultaneous access for users to update facilities and work orders. Since the 1980s, many GIS packages with such capabilities have appeared on the market. Recent advances in mobile technology and global positioning systems have made it possible for field crews carrying out inspection and repair tasks to consult the geospatial database in real time, based on their location, and to produce dedicated maps or engineering drawings on the basis of which repairs are made. Changes made to the infrastructure can also then be uploaded to update the database.

Developments in GS&T therefore provide governments and other operators and owners of infrastructure with tools to both better manage existing urban infrastructure and better plan for future needs and developments. Better management and planning of infrastructure can ultimately help to alleviate some of the problems discussed at the beginning of this section (such as unavailability of clean drinking water and intermittent electricity supply), producing a wide range of benefits to society.

3.4 Urban transport and mobility

People take part in activities such as employment and education that are connected to specific locations. Urban transport facilitates the movement of people and freight. The attractiveness of locations of work or leisure depends on how accessible they are, which is influenced by the performance of the transport system. The transport system is composed of various types of more or less integrated infrastructure networks; roads, bus lanes, railroads etc. These networks may be used by different transport modalities—cars, buses, motorcycles, bicycles and pedestrians—depending on the preferences of travellers and their socioeconomic profiles.

Sustainable transport is increasingly promoted as an alternative to the traditional transport model (Newman and Kenworthy, 1999). In terms of policy, planning and implementation, the traditional model has been dominated by the paradigm of the automobile. The “predict and provide” approach of building on forecasted demand has led to ever higher expansion of roads and facilities, use of space and urban sprawl (Schiller et al., 2010). Many cities in developed and developing countries alike are grappling with how to manage their urban growth, land use and transport. These cities are already confronted with high levels of congestion and pollution, mainly caused by the “predict and provide” approach that has led to inefficient land use and transport systems. This has threatened the quality of life, reduced the economic growth potential and aggravated the massive problem of climate change.

Similar to the previous discussion on urban infrastructure, the key to promoting sustainable transport is to restructure the way urban mobility is organized. Sustainable transport provision emphasizes accessibility rather than mobility (therefore compact development) and promotes multi-modality (with a much bigger role for public and non-motorized transport) while internalizing all environmental and social costs (Blanco et al., 2009; Dimitriou, H. T., 2006; Preston, J., and Rajé, F., 2007; World Bank, 2002).

GS&T can play a pivotal role in the development of sustainable transportation. Geospatial technologies are already widely used in the transport sector. Several GIS applications have been developed in transport planning and management, traffic control, logistics and intelligent transport systems. The use of geospatial tools in sustainable urban transport systems and infrastructure provides insights into spatial accessibility, equity and environmental sustainability in urban areas. This is because GIS systems combine three main information sources:

(i) Infrastructure information, with all its characteristics associated with the geospatial features allowing for proper operation and maintenance;

(ii) Movement information, allowing for data on flows, modalities, energy use, pollution etc. to be modelled and analysed; and

(iii) Physical, social and environmental contextual information, allowing for spatial analysis of access, equity, and environmental externalities.

Consequently, GS&T can provide information and analysis to support evidence-based, sustainable urban transport policies in a way that would not otherwise be possible. Such policies can improve accessibility, reduce congestion and limit environmental damage resulting from transport.

3.5 Challenges

There is much unrealized potential when it comes to the application of GS&T in the field of sustainable urban and regional development. State-of-the-art GIS software that runs on simple personal computers allows even small organizations such as district municipalities or small infrastructure providers to use GIS. Software and hardware are no longer major issues, but effective application is often still limited.

Effective use of GS&T is generally hampered by a number of overarching challenges which are discussed in chapter 6. However, there are also a number of challenges specific to the use of GS&T in the context of sustainable urban–regional development, which are set out below.

Problems with image data: Although data availability at a general level has considerably improved over the last decades, especially since the availability of VHR satellite images, many problems remain. Image data is raw data and to be useful, information must be extracted in a way that is efficient and consistent with existing data. Moreover, official access to VHR images is quite expensive, and even though partnerships and group licenses can help save substantial sums, institutional barriers often make it difficult to implement such arrangements despite the substantial cost reductions. Government agencies often buy expensive high-resolution satellite images but do not share them with other government agencies, unless there is pressure from above. In many developed countries, the Treasury or budgetary offices can coerce government agencies into sharing expensive data by threatening to cut funding if data are not shared. In developing countries, a donor from country X may finance satellite data for Ministry A and another donor from country Y may finance Ministry B for the same data. The major institutional barrier is the lack of coordination in cost-sharing. For developing countries, the problem may be solved by either better coordination within the country or better coordination among donors in the new aid architecture.

Difficulties with locating underground infrastructure assets: In the infrastructure sector, data acquisition is complicated by the fact that infrastructure assets

Box 3.2: Abbott's 10-step plan for the management of infrastructure assets

The key infrastructure assets to be captured are water supply systems, sanitation systems, solid waste management systems, roads and other transport networks, drainage systems and street lighting. Establishing a spatial database of these assets with GIS will create a spatial data infrastructure for planning and management. Such a spatial database can be based on the available sketch maps if that is the best available material. In other words, thematic and spatial coverage is initially prioritized above spatial accuracy. The 10 Steps for Asset Management are:

1. Define infrastructure categories and subcategories
2. Build spatial and tabular database templates
3. Compile an inventory of assets
4. Assess the condition of the assets
5. Cost and value the assets
6. Measure assets against strategic goals and objectives
7. Develop plans for new assets
8. Develop a maintenance plan for each asset
9. Create a budget for each asset

Source: Abbott, J. (2006) Asset Management, Manual Series on Infrastructure, GTZ-IS, Ethiopia are often underground and hard to locate. Satellite images will not be able to find underground assets, and in the absence of accurate records locating these assets will likely require costly and disruptive digging. On the other hand, this challenge also points to the need to establish a GS&T approach to ensure that sufficient information for operations and decision-making is available. Often, setting up a GIS is considered complicated and challenging under the circumstances of limited resources of developing cities, but GIS does not have to be highly sophisticated to be effective. One example of a relatively simple GIS is a 10-step plan developed for infrastructure asset management in Ethiopian cities described in box 3.2. This simple approach would enable essential infrastructure information to be captured in a GIS in a straightforward way and could be applied in other resource-constrained environments.

3.6 Summary of benefits

Table 3.1: Summary of GS&T-enabled benefits in sustainable urban–regional development

GS&T Enabler	Direct Benefit	Societal Benefit
Web-based mapping services	Allows the public to fill gaps in existing maps and information.	Provides public with choice of potential service providers which are continuously updated.
	Allows maps to be updated and created and shared more quickly and cheaply.	Spatial data readily available via mobile devices, including smart phones.
Advanced object-oriented approaches for automatic feature extraction	More rapid and effective urban mapping (including slum identification and classification).	Lower costs for urban mapping and map updating.
Infrastructure management tools	Better managed and maintained infrastructure assets with increased lifespans.	Lower costs for operation and maintenance; less disruption of services due to breakage.
	Better informed planning decisions on future infrastructure development.	Synchronization of operation and maintenance works leading to less disruption of usage.
Transport GIS applications	Provides insights into urban accessibility.	Reduced travel times through integrated land use and transport.
	Better informed planning decisions on future transport development.	Cleaner, safer and more livable cities; Reduced urban sprawl.

NOTES

13. See http://www.measuredhs.com/
14. See http://www.unicef.org/statistics/index_24302.html
15. See http://egypt-urban.net/ for details including English and Arabic guidelines and publications.
16. See www.shelter-associates.org
17. See www.SparcIndia.org
18. See http://www.pamojatrust.org/
19. See http://www.sdinet.org/
20. See http://www.unicef.org/wash/

4. LAND ADMINISTRATION

4.1 The issues

Land administration is a proven enabler of economic, social, and environmental development (UN-FIG, 1999; Dale and McLaughlin, 1999; Williamson et al., 2010). GS&T is at the heart of land administration systems. However, successful implementation involves overcoming a range of technical, legal, institutional, and social impediments.

Land administration systems collect, maintain and disseminate information about land tenure, land use and land value (UN-ECE, 1996). The bases of the systems are also known as land registers and/or cadastres. They include both textual and geospatial information. The textual part contains information about people, land tenures, land uses, and land values. The geospatial part relates to the location of that textual information, and is often visualized as a map of land parcels or cadastral map. Both types of information are collected through processes of adjudication, demarcation, surveying and recordation. The information is brought together in an information system: land parcel identification codes and geospatial coordinates are used to create links between the different types of information. It is usually Government that manages the system, often with the help of private professionals, such as land surveyors or notaries. The information is often publicly available, although fees and some restrictions apply. The land administration system should be accurate, authoritative, verified, unambiguous and available (Williamson et al., 2010).

Land administration systems support social development in a number of ways. For individuals and citizens they secure land tenures; enable access to credit; facilitate cheaper and faster land dealings; and reduce land disputes (Henssen, 2010; de Soto, 2001). For governments, the systems facilitate the assessment and collection of land tax; provide a land inventory to support land reform, land consolidation, or land readjustment (UN-HABITAT, 2007); facilitate controls on land transactions (e.g. maximum amount of property ownership per individual); support many other government activities (e.g. environmental management); and reduce information duplication by acting as an authoritative base register for Government (Besemer et al., 2006; Henssen, 2010). However, these benefits only materialize if financial services and adequate institutional capacity exist within a society (FAO, 2007).

All countries are at various stages of establishment, maintenance, and renewal of their land administration systems (Henssen, 2010). GS&T offers opportunities for increasing the efficiency and effectiveness of these processes. Emerging geospatial tools can deliver cheaper, faster or higher-quality spatial information with respect to collection, maintenance, and dissemination. This is of particular importance for governments in developing countries, because systems must be (a) faster and (b) cheaper to establish and maintain.

The primary objective when establishing a cadastre (or land administration system) is to finish it (Henssen, 2010). Currently in many countries, this objective is not being met. Establishment of land administration systems in the developing world is progressing far slower than required (Deininger, 2003). At current rates, it will take decades, if not centuries, to achieve full registration. Internationally, land administrators agree that faster and cheaper approaches are needed. In addition, high-level tenure security should not be attempted in a "big bang": a staged approach is necessary (UN-HABITAT, 2008). A staged approach provides for more immediate land tenure security, of some sort, and also affords the required time for growth of strong land institutions.

Realization of the staged approach requires new ways of thinking about adjudication, demarcation, surveying and recordation (Van der Molen and Lemmen, 2005). The following paragraphs explain these four processes and how they are traditionally performed, before sections 4.2 and 4.3 set out new ways of thinking about them.

Adjudication is the process of investigating existing rights in land for recording purposes. The conventional way to perform adjudication is through lengthy legal checks of existing documentation, drawn-out consultation with interested parties, numerous on-the-ground visits, drafting of legal rights, community approval, and final recordation. Lengthy dispute resolution processes should also run in parallel.

Surveying is the process of measuring and mapping the location of those land interests. It is conventionally performed through a full on-the-ground cadastral survey using plane tables, optical squares, total stations, or some other form of ground-based surveying technology. The latter tools give higher accuracies (Jing et al., 2011).

Demarcation is the physical marking of a boundary (Zevenbergen, 2009). The choice is often described as being between “fixed” or high-accuracy boundaries, and “general” or more approximate boundaries. In many countries, a mixture of both is used, but one method will tend to dominate the other. The decision takes into account the value of land, the risk of land disputes, and the information needs of the users of the cadastre (Henssen, 2010). Fixed boundaries tend to be more expensive: greater amounts of labour, materials, methods and expertise are required. However, general boundaries also present challenges: physical features such as walls, hedges, ditches, or trails must already exist and be respected as boundaries.

Recordation is the process of entering the textual and graphical information about tenure, use and value into the information system. A unique identifier is attached to each parcel or property object, and this becomes the primary organizing tool of the land administration system. Modern land administration systems tend to make use of geographic information and database technologies to perform this task.

In summary, each of the four processes is traditionally complex, time-consuming, and expert-labour intensive. New approaches to adjudication, demarcation, surveying and recordation must be rapid in application, low in cost per unit, with appropriate accuracy, and simple in procedure. They should also be amenable to higher accuracy and registration, readily adaptable to further modernization, not rendered useless when more refined work occurs later on, and should allow for the inclusion of new types and better-quality information over time (Augustinus, 2005; Henssen, 2010). However, low-cost, rapid approaches do not necessarily equate with low-tech solutions. Modern GS&T can assist in delivering these progressive land administration solutions. Applications of GPS and two alternative methods of collecting VHR images, high-resolution satellite imagery (HRSI), and low-altitude remotely sensed imagery (LARSI), are now explored in relation to these processes.

4.2 High-speed adjudication and surveying

GNSS technologies such as GPS can support high-speed adjudication and surveying. GPS receivers use the signals from a number of satellites to calculate the coordinates of a location. GPS can be used in the high-speed establishment of a ground control network for a jurisdiction or country. A ground control network is a collection of on-the-ground points with precisely known locations. The network of points are used as anchors or “points of truth” to relate all other survey data that is subsequently collected. The GPS version of a ground control network uses continuously operating GPS receivers or continuously operating reference stations (CORS) as the precisely known points. With a CORS network in place, the accuracy of collected GPS data points can go from metres to centimetres: the accuracy requirements of traditional cadastral surveys are attainable. Because GPS surveying is generally less labour- and time-intensive than traditional surveying methods, there is great potential for increasing the speed of surveying by establishing a dense ground control network. Many countries now have at least one, if not multiple, CORS networks under development (c.f. Abidin et al., 2011; Janssen et al., 2011). As an alternative, where accuracy requirements are lower, such as those generally in rural areas, lower-grade GPS receivers can be used to calculate boundary locations or identify parcel centres without a local GPS control network being in place.

At the parcel level, GPS can be used for determining the coordinates of fixed boundary markers. These coordinates can be collected rapidly with or without a CORS network in place. For example, in Turkey 120 cadastral points were collected over a 3–4 hour period using precise GPS positioning. The same points took 5–6 hours to collect using more conventional approaches. Office processing times were also cut in half: from 30 to 15 minutes (Pirti et al., 2009). While this was only a pilot, if these results were extrapolated across an entire jurisdiction, the time reductions could be quite significant: years could be saved from project timelines. GPS receivers could also be used as support tools in adjudication and surveying tasks.

Box 4.1: Indonesia, surveying, and GNSS

In Indonesia, over 50 per cent of the country's 87 million parcels remain unregistered. In an effort to speed up registration, solutions using GNSS technologies are being investigated and applied. Since the 1990s, geodetic reference stations and cadastral ground control points have been established with GNSS technologies. More recently, the country has embarked on the densification of its GPS CORS networks. The official national CORS network, the Indonesian Permanent GPS Station Network, now includes some 100 stations. The utilization of GNSS has expedited the establishment of the National Cadastral Reference Network. The aim is to begin utilizing GNSS in the survey and registration of individual parcels. This is currently done using traditional surveying tools and techniques such as total stations, trilateration or traversing.

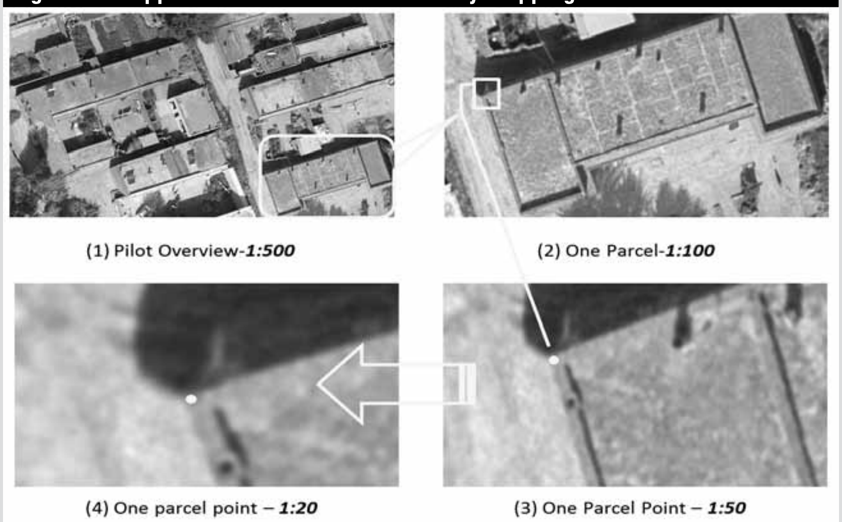
Pilots show that using GNSS to establish and re-establish boundaries could simplify and accelerate the surveying processes. A range of data capture techniques, including real-time (RTK), post-processed and hybrid (including both terrestrial and GPS data capture), are under development. The different methods are needed to overcome the limitations of GNSS in some contexts, such as signal obstruction caused by terrain and topography. An added benefit of using GNSS for parcel surveys is that all boundaries would be established within a single unified national reference coordinate system. The problematic experiences of using GNSS technologies to re-establish the cadastre in Aceh following the 2004 tsunami could have been overcome if more than just a local coordinate system had been in use. At any rate, GNSS tools were used in these re-establishment exercises and have subsequently gained recognition across the country.

Source: Abidin et al. (2011)

Box 4.2: China, Boundaries, and LARSI

In the Chinese city of Yan'an in the province of Shaanxi, an assessment of LARSI for cadastral mapping purposes was undertaken. This occurred as part of the Second National Land Survey Project in China, which ran from 2007 to 2009. LARSI uses smaller remotely controlled unmanned aircraft equipped with imagery sensors for data collection. The low, slow-flying aircraft are able to capture larger quantities of higher resolution imagery per run. As they are unmanned and light, operation costs are lower. Imagery is considered easier to interpret and provides for higher accuracies. Streamlined processes for fieldwork meant that labour costs were decreased and the process was quicker. However, resultant cadastral maps were still not considered adequate for urban applications (~21cm accuracy). (Jing et al., 2011).

Figure 4.1: Application of LARSI for boundary mapping in China



Source: Jing et al. (2011)

Another example of high-speed land registration using GNSS in Indonesia is described in box 4.1

Photogrammetric methods, including use of orthophotos (geometrically corrected aerial images) or enlarged photo prints, also offer the potential for high-speed land administration. This is especially the case when a systematic countrywide adjudication project is being undertaken. Imagery is collected from sensor-equipped manned aircraft, unmanned aircraft (LARSI) or high-resolution sensors mounted on satellites (HRSI).

Manned aircraft techniques can generally achieve resolutions in the order of 25 to 50cm. However, in many cadastral applications 25 to 50cm accuracy is still not considered good enough (Jing et al., 2011). Consequently, LARSI has emerged as a new technique capable of increasing the speed of adjudication and surveying processes. Box 4.2 gives an example of how LARSI was used in one Chinese city to undertake cadastral mapping at high speed.

Satellites can also be equipped with imagery sensors. Until recently, the application of satellite imagery was limited for land administration purposes: image resolutions were not good enough for determination of potential cadastral features such as fences, hedges or even buildings. Cadastral maps require larger scales, in the order of 1:500 through to 1:10,000, depending on the size of parcels. Application of imagery from these satellites was limited to areas with large parcel sizes, open terrain, and scales smaller than 1:25,000 (Henssen, 2010).

A range of new commercially owned satellites and constellations equipped with high-resolution sensors are now in operation: GeoEye's GeoEye-1 satellite; Digital Globe's WorldView-1 and Quickbird satellites; SPOT's range of satellites; RapidEye's constellation of five satellites; and ImageSat International's EROS satellites. The market is competitive. Image resolutions under 50cm are technically possible: buildings, plants and certainly many parcel boundaries can now be identified on the image. However, legal restrictions, driven by concerns about individual privacy, currently impede the sale and use of lower resolutions for civilian purposes in many country contexts. Rules are regularly under review; however, the United States of America, India and Russia provide prominent examples of countries where these legal restrictions are in place. The application of HRSI for high-speed adjudication in rural areas is already recognized, and Box 4.3 provides an example of this from Ethiopia.

Box 4.3: Adjudication and HRSI in Ethiopia

Figure 4.2: Trialing HRSI for boundary identification in Ethiopia - World Bank Study

Source: ITC

In Ethiopia, conventional land titling is progressing well, but the programme is limited to textual certificates. Geospatial land parcel mapping is not common yet. In a World Bank study, Quickbird satellite imagery was used to establish a parcel index map for a region (Lemmen and Zevenbergen, 2010). Large plots or prints of HRSI images were taken in to the field: local villagers, rights holders and local officials were asked to sketch in the boundaries of their lands (Fig 4.2). The 1:2000 plots were of high enough quality to allow all parties to understand the images, contribute input and sketch boundaries. Back in the office, the images were rescanned, georeferenced, the boundaries digitized, and organized in an information system. The process appears to be very useful in places where high-speed coverage takes precedence over survey accuracy, as is often the case in rural areas.

Source: Lemmen and Zevenbergen (2010)

Meanwhile, in urban areas, where highly precise boundaries are used, current HRSI resolutions are not considered adequate (c.f. Ahin et al., 2000). The trend towards higher imagery resolution and lower cost may change this situation. The benefits of using HRSI for cadastral applications, even in urban areas, should become increasingly apparent for some contexts.

Developments in GS&T therefore allow land adjudication and surveying to be performed more quickly and cheaply than was previously possible with traditional methods, although not always to the same levels of accuracy. However, as these technologies develop further their level of accuracy will continue to improve.

4.3 Low-cost demarcation and recording

The drive for cheaper land administration solutions has resulted in new thinking about demarcation. In some cases, the lack of progress in establishing systems with highly sophisticated methods is leading to new, low-cost approaches (Henssen, 2010). The idea is that cheaper and less accurate solutions can eventually be upgraded when Government and citizens find it essential to do so. Contemporary geospatial technologies offer more innovative low-cost solutions, as reflected by the usefulness of GPS and imagery for virtual boundaries, point cadastres and crowdsourcing.

In the case of general boundaries, the concept of the "point cadastre" offers an innovative low-cost solution. Point cadastres use a single geographic location or "point" to symbolize a land parcel or tenure object. The approach provides a cheap and quick solution in places where land information is missing or in need of renewal (Fourie, 1994; Burke, 1995). The point becomes a "stand-in" for the parcel or tenure polygon. The concept is also known as "single point cadastre", "dots for plots", or "geocoded address files". Adjudication of actual boundaries can take place at a later time when suitable drivers and finance can be found. Even without boundaries, general or fixed, multiple applications become available: identification of parcels for simple property taxation, basic tenure recordation, rudimentary land use planning, and management of other activities such as education and health. The approach can also be used to complete gaps in pre-existing parcel-based land administration systems (Griffith, 2011): the points can later be renewed into parcel boundaries. International standards for modelling the land administration domain, including the Social Tenure Domain Model and Land Administration Domain Model, are already equipped to deal with point representations (Oosterom et al., 2006; FIG, 2010). Currently, Kadaster International is working to demonstrate the utility of the concept in Guinea-Bissau.

As discussed in chapter 2, crowdsourcing is a significant recent development in GS&T, enabled by modern technologies. In the context of land administration, crowdsourcing provides another opportunity for low-cost demarcation and recordation. Crowdsourced data comes from citizens, often in a volunteered fashion. Individuals collect the data in an active or passive fashion. The potential for land administration to collect and use crowdsourced data is under construction (RICS, 2011). Citizens could potentially adjudicate, demarcate and survey their own boundaries. The bypassing of the State or privately-run surveying establishment could help citizens quite significantly, especially the poor and marginalized. The information would be lodged in some form of registry, potentially even without government involvement. Much is still to be determined: issues of assuredness, ambiguity, accuracy, authenticity, and availability need clarifying. These characteristics are the heart of conventional systems, and crowdsourced data appears limited on these fronts. However, crowdsourced land administration might help land administration development in places where official systems do not exist or are inadequate.

In summary, GS&T can be used to provide quick, low-cost land demarcation and recording where high levels of accuracy are not required. These technologies can therefore allow countries with minimal financial resources to quickly and cheaply establish basic land registries and reap the corresponding benefits.

4.4 Challenges

The land administration processes of adjudication, demarcation, surveying and recordation are essential for economic, social, and environmental development. The differences in standards of living between those countries that successfully maintain land administration systems and those who do not are well documented (de Soto, 2001). GS&T can support land administration systems but there are a number of challenges to using GS&T in this way. As with chapter 3, only challenges specific to land administration will be discussed below. Overarching challenges which apply to a variety of areas will be covered in chapter 6.

Technological limitations: The performance of GPS receivers falls off in highly urbanized or densely forested areas. Buildings, trees and other structures can block or bounce signals, distorting measurements. With respect to HRSI and LARSI, the key issue is available accuracies. For urban land administration applications, achievable accuracies are still not considered adequate. In addition, issues of cloud and vegetation cover inhibit HRSI use in many cases. Moreover, HRSI and LARSI cannot replace the need for in-field checks, surveys, and more importantly, agreement on where boundaries lie. Consequently, traditional methods cannot be entirely replaced.

Cost of CORS networks: Land administration systems are expensive to establish and maintain, meaning that some level of cost to society is unavoidable. Even with reductions in price due to technological advancement, equipment costs for both ground control and boundary surveying can still be high, particularly when the high accuracies of traditional cadastral surveying are sought. Continuously operating GPS nodes are still relatively expensive to set up in terms of equipment, maintenance and power supply requirements. They also require adequately trained staff for ongoing maintenance, and entail all the costs associated with such maintenance.

Rural complexities: Another set of challenges facing the application of GS&T in land administration concern complications with administering rural land tenure systems. In large parts of the world, people seek resources that are seasonal, changeable and spatially dynamic. This includes people benefited by social forestry, semi-nomadic grazing rights and tribal leases on land. Land tenure systems in these instances feature a wide range of rights, leases, ownerships, transfers and other types of holdings. Mapping these customary features is far more complex than conventional cadastral mapping that can be used in urban environments. A new range of institutional norms need to be understood and incorporated into any administrative approach. This additional complexity requires more flexibility in geospatial tools if all the features of rural land administration are to be covered (Dalrymple et al., 2004; World Bank, 2003).

The need for a new reference datum: GPS also often requires the adoption of a new reference datum if implemented on a scale such as in a national land administration system. This will most likely differ from the old reference datum within a country. While technically solvable, it is an issue and is often used as a blocking mechanism by various interest groups.

Legal and institutional arrangements: Despite all this, technology is often not the main issue. Legal and institutional arrangements often play a far greater role in obstructing innovative low-cost implementations. Successful projects, especially in the developing or newly industrialized context, are generally found in places with strong political leadership and a sustained focus on building technical capacity. Developments in Malaysia, Singapore, Thailand, South Korea, Japan, and more recently Rwanda provide examples (Henssen, 2010). Where impediments do exist, they generally relate to social or political contexts. Rivalries between different government land administration agencies often inhibit implementation. This is particularly the case when one agency is given the lead in a project. Two agencies may be unwilling to share data or cooperate with each other. Creating the collaborative environment required for integrated recordation is a major hurdle for development. Other stakeholders including professionals, the private sector, and educational sectors, also have vested interests. New approaches often challenge the status quo, meaning that incomes and jobs are potentially at risk. Additionally, new geospatial technologies frequently require training and equipment costs that the existing workforce must bear.

Other impediments relate to existing bureaucratic processes or red tape. For example, application of HRSI, LARSI and GPS could already be much wider if not for legislation and institutional norms prescribing higher accuracies than feasible (Jing et al., 2011). Drafting new legislation is a lengthy process, and regardless of goodwill, the tools cannot be used before the legislation is enacted.

4.5 Summary of benefits

Table 4.1: Summary of GS&T-enabled benefits in land administration

<table>
<tr><th>GS&T Enabler</th><th>Direct Benefit</th><th>Societal Benefit</th></tr>
<tr><td>GNSS ground control networks</td><td>Faster and cheaper establishment of cadastral ground control at jurisdiction level</td><td rowspan="6">• Secured land tenures
• Access to credit
• Facilitation of cheaper and faster land dealings
• Reduction of land disputes
• Facilitation of the assessment and collection of land tax
• Provision of a land inventory to support land reform
• Land consolidation or land readjustment
• Controls on land transactions
• Support for many other government activities
• Reduction of information duplication through its role as an authoritative base register</td></tr>
<tr><td>GNSS receivers</td><td>Faster surveying and demarcation at parcel level</td></tr>
<tr><td>LARSI</td><td>Faster adjudication and surveying, potentially in urban areas</td></tr>
<tr><td>HRSI</td><td>Faster adjudication and surveying in rural areas</td></tr>
<tr><td>Point cadastres</td><td>Lower cost adjudication, surveying, demarcation, and recording in urban and slum areas</td></tr>
<tr><td>Crowdsourced geospatial data</td><td>Lower cost surveying and recordation</td></tr>
</table>

5. DISASTER RISK MANAGEMENT

5.1 The issues

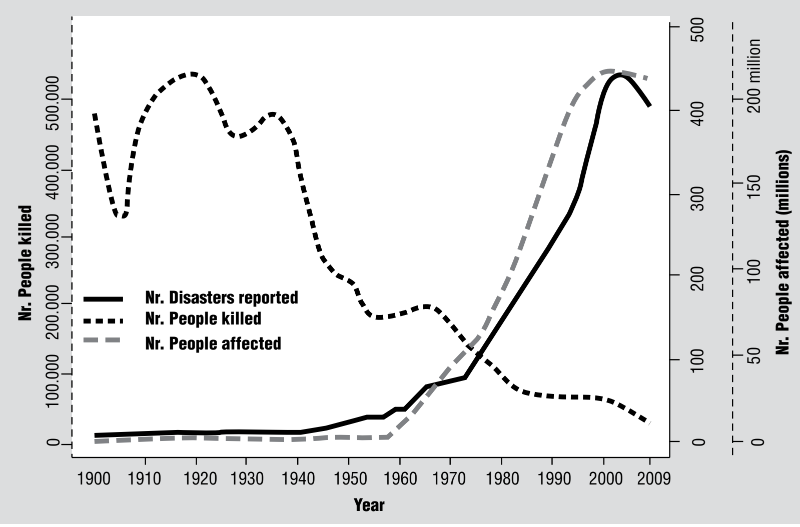
Disasters are headline news almost every day. They often take the form of sudden events causing widespread losses and human suffering, such as earthquakes, tsunamis, hurricanes and floods. Recent examples are the Indian Ocean tsunami (2004), the earthquakes in Pakistan (2005), Indonesia (2006), China (2008), Haiti (2010) and Japan (2011), and the hurricanes in the Caribbean (2005) and the USA (2008). Other hazards, such as the recent drought in the Horn of Africa (2011), soil erosion, land degradation, desertification, glacial retreat, sea-level rise, loss of biodiversity etc, have a slow onset. These processes also cause local, regional, and global impacts, but do so in the long run rather than immediately.

The United Nations International Strategy for Disaster Risk Reduction (UN-ISDR, 2004) defines disasters as "a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources". Although the term "natural disasters" in its strict sense is not correct (as disasters are a consequence of the interaction between hazards and vulnerable societies), the term is used extensively in both literature and practice. It is also important to distinguish between the terms "hazard" and "risk".

Hazards are potentially dangerous phenomena, substances, human activities or conditions that may cause loss of life, injury or other health impacts, property damage, loss of livelihood and services, social and economic disruption, or environmental damage. Risk results from the combination of hazards, conditions of vulnerability, and insufficient capacity or measures to reduce the potential negative consequences of risk (O'Keefe et al., 1976). Disasters can therefore be prevented even where natural hazards occur. If steps are taken in advance to limit the damage and loss of life caused by a hazardous event, a disaster will not have occurred.

Hazardous events have been on the rise in recent decades (Figure 5.1). In the past decade, the number of natural disasters increased by a factor of 9 compared with the decade 1950–1959 (EM-DAT, 2011). In terms of monetary losses, earthquakes have produced the largest amount of losses (35 per cent of all losses), followed by floods (30 per cent), windstorms (28 per cent) and others (7 per cent). Earthquakes are also the main cause of fatalities, estimated in the order of 1.4 million lives during the period 1950–2000 (47 per cent), followed by windstorms (45 per cent), floods (7 per cent), and others (1 per cent) (MunichRe, 2011; EM-DAT, 2011). On the positive side, the number of human fatalities due to natural disasters shows a decreasing trend. This may be due to better warning systems and improved disaster management, but the number of affected people follows the increasing trend of the number of events (see Figure 5.1).

Figure 5.1: Summary of natural disasters, showing the numbers of reported disasters, people killed and people affected between 1900 and 2009



Source: EM-DAT (2011)

About 85 per cent of disaster-related casualties occur in developing countries, where over 4.7 billion people live. The greater loss of life is due to a number of reasons, including:

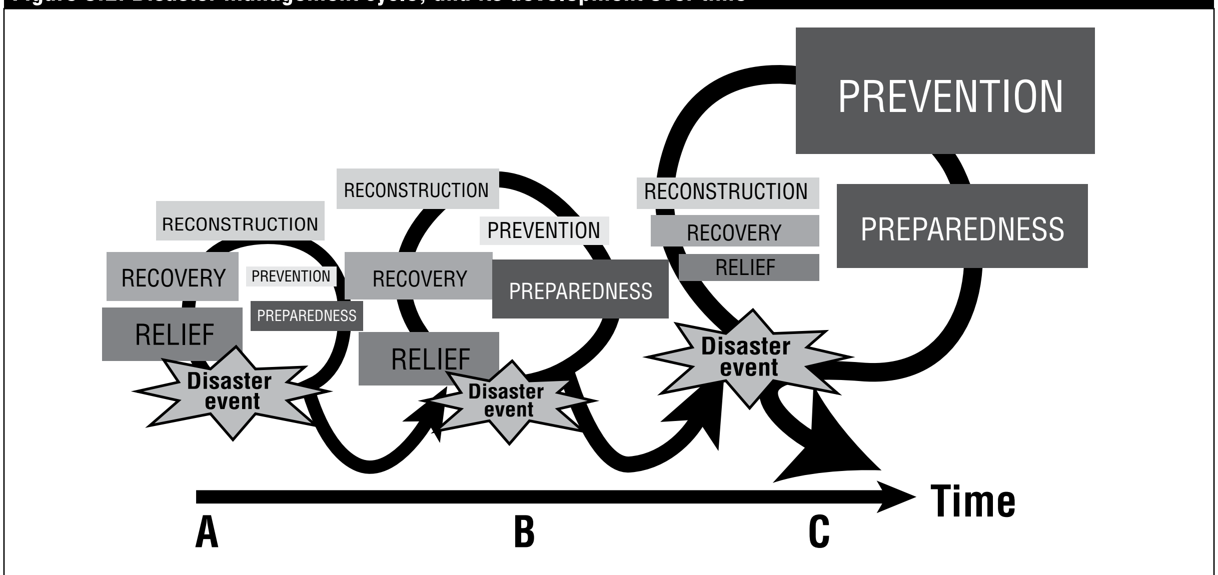
- Construction of buildings and settlements in hazardous areas due to lack of land use planning and regulation (urban sprawl);
- Lower awareness and disaster preparedness (lack of community resilience);
- Lack of political capacity to intervene on the structural and organizational causes of disasters (e.g., building codes or their enforcement, raise awareness on mitigation and prevention);
- Missing or non-effective early warning systems;
- Lack of disaster risk management plans, including evacuation planning and facilities for search-and-rescue operations and medical attention.

Although 65 per cent of the overall losses occur in high-income countries (with gross national income, or GNI above $12,000 per capita) (World Bank, 2011), and only 3 per cent in low-income countries (with GNI less than $1000 per capita), the effect in the latter group is devastating, as such losses may represent as much as 100 per cent of their GNI (UN-ISDR, 2009). Economic losses in absolute terms (billions of dollars) show an increase with the level of development, as the absolute value of elements at risk that might be damaged during a disaster increases with development. In relative terms, however, the trend is reversed, showing a decrease in the losses expressed as a percentage of GDP with an increasing level of development (MunichRe, 2011). The effects of hazardous events are therefore felt disproportionately highly in the developing world.

In the past few decades, the focus has slowly shifted from disaster recovery and response to risk management and mitigation, and ways to reduce the vulnerability of communities by strengthening their capacity to develop coping strategies (Blaikie et al., 1994; Birkmann, 2006). The decade 1990–2000 was declared by the United Nations the International Decade for Natural Disaster Reduction (IDNDR). As the impact of disasters increased dramatically during that decade, the international community decided to continue this effort after 2000 in the form of an International Strategy for Disaster Reduction (ISDR).

Figure 5.2 shows how disaster risk management has been portrayed differently over time. The size of the boxes indicates the importance given to each of the phases. The size of the circles indicates the time between two successive disaster events. Initially (Figure 5.2A), most emphasis was on disaster relief, recovery and reconstruction, thereby getting into a cycle where the next disaster was going to cause the same effects or worse (e.g. Haiti which has been affected by a series of hurricanes and a major

Figure 5.2: Disaster management cycle, and its development over time



earthquake, and where most of the focus is on relief). Later on (Figure 5.2B), more attention was given to disaster preparedness by developing warning systems and disaster awareness programmes (e.g. Bangladesh, where emphasis was given to the development of an early warning system for tropical cyclones, leading to a large reduction in human casualties). Currently (Figure 5.2C), efforts are focusing on disaster prevention and preparedness, thus enlarging the time between individual disasters and reducing their effects, requiring less emphasis on relief, recovery and reconstruction. The aim of disaster risk management is now to enlarge this cycle, and only reach the response phase to extreme events with very low frequency (e.g. Cuba which has focused on disaster risk management (see section 5.4 for details).

Disaster risk management (DRM) is defined as "the systematic process of using administrative decisions, organization, operational skills and capacities to implement policies, strategies and coping capacities of the society and communities to lessen the impacts of natural hazards and related environmental and technological disasters". This comprises all forms of activities, including structural and non-structural measures to avoid (prevention) or to limit (mitigation and preparedness) adverse effects of hazards (UN-ISDR, 2004).

Geospatial data and technologies are now an integral part of disaster risk management because both hazards and vulnerable societies are changing in space and time. In real-time emergency and response phases, Earth observation (EO) can be coupled with meteorological forecasts to monitor events, evaluate their magnitude and expected impacts and, most importantly, define near real-time event scenarios to support decision-makers in managing resources and organizing emergency plans. For example, hazards such as cyclones move and change in location, speed and direction, which means they need to be tracked using GS&T. Similarly, the people who need to be evacuated or the emergency response resources of a society also move, and this movement needs to be directed in response to changes in the hazard. GS&T therefore contributes greatly to the various phases of disaster risk management, as summarized by Table 5.1. New methodologies for applying GS&T to DRM

Table 5.1: Main contributions of geospatial science and technology

DRM Phase	Activity	Main GIScience and Earth Observation contribution
Relief	Damage assessment	Satellite-based damage assessment, spatial data infrastructure, automatic classification, high-resolution images, InSAR, crowdsourcing, mobile GIS applications, collaborative web-mapping, GIS databases, web-GIS, telecommunication, planning, GIS analysis
	Humanitarian assistance	
	Resources analysis	
	Logistics	
Recovery	Clean-up, restoration of services	High-resolution EO data, collaborative web-mapping, mobile GIS, Global Positioning Systems
	Rehabilitation of damaged infrastructure	
Reconstruction	Reconstruction planning	High-resolution EO data, land administration, GIS analysis, multi-hazard assessment, map updating
	Revitalization of affected sectors	
Prevention	Disaster databases	EO-derived input data, Digital Elevation Models, magnitude-frequency analysis, linking of advanced modelling tools with GIS analysis, EO-derived assets data, mobile GIS, Spatial Multi Criteria Evaluation, probabilistic risk assessment, participatory GIS, cost-benefit analysis, decision support systems, environmental impact assessment, risk atlases, web-GIS
	Hazard assessment	
	Vulnerability	
	Risk assessment	
	Physical/ structural mitigation works	
	Land use planning & building codes	
	Education, training and awareness	
Preparedness	Community planning	Participatory GIS, measurement networks, satellite measurements, change-detection, telecommunication, spatial data infrastructure, web-GIS, remote sensing
	Early warning	
	Monitoring	
	Emergency planning	

can be developed and fully explored (Kaiser et al., 2003), and are regularly reported in scientific journals and conferences (e.g. in the proceedings of the International Symposium on Geo-information for Disaster Management). Sections 5.2 to 5.4 will now illustrate some of the key applications of GS&T in the main phases of disaster management.

The following sections examine the applications of GS&T to the phases of DRM set out in table 5.1 in more detail.

5.2 Disaster relief, recovery and reconstruction

GS&T plays a major role in rapid damage assessment after the occurrence of major disasters. Automatic and manual classification methods, based on optical, thermal or microwave satellite images, have been developed to extract hazard-related features (e.g. flooded areas, burnt areas, landslides) or damaged infrastructure from satellite images. For instance, for flooding, EO satellites can be used to map inundation phases, including the duration, the depth of inundation, and the direction of water flow (Smith, 1997). Information about the damage of physical assets can be obtained using medium-resolution optical satellite data (LANDSAT, SPOT, IRS, ASTER), high-resolution optical data (QuickBird, IKONOS, WorldView, GeoEye, SPOT-5, Resourcesat, Cartosat, Formosat and ALOS-PRISM) and microwave radar satellites (RADARSAT1, 2, CosmoSkyMED). Satellite-derived information is one of the key contributions of GS&T to disaster risk management.

Box 5.1: Crowdsourcing combined with satellite technology: Haiti earthquake

The 2010 Haiti earthquake demonstrated how many organizations are involved in post disaster damage mapping. The International Charter "Space and Major Disasters", set up by various space agencies, has been activated over 350 times (see section 5.2). When the Charter is activated, these agencies generate initial satellite images on the disaster area. Subsequent data processing and damage mapping are then done by a number of different organizations, including the DLR Centre for Crisis Information (DLR-ZKI), UNITAR, and the Service régional de traitement d'image et de télédétection (SERTIT, based at Strasbourg University, France) among many others. Moreover, commercial players, such as the ExpressMaps service by SPOT Imaging and Infoterra France, provided reference maps.

In addition to the maps produced by traditional agencies, there were two other prominent approaches to post-disaster mapping in Haiti. The first approach involved crowdsourcing and the use of Google Map Maker and Open Street Map to rapidly map Port-au-Prince. Hundreds of volunteers with local knowledge created a comprehensive basemap of the disaster area within a few days, working on image data but often also using ground knowledge. This local knowledge was an advantage that the largely European-based map production of the Charter process lacks.

The second approach was done under the Global Earth Observation-Catastrophe Assessment Network (GEO-CAN) initiative led by the World Bank and the Global Facility for Disaster Reduction and Recovery (GFDRR). Over 500 individuals used remote sensing data to map damage visually, using an image-based collaborative mapping tool called Virtual Disaster Viewer developed by ImageCat. In contrast to the first approach, this one relied on experts and controlled access to its development.

Such extensive mapping is in principle welcome. In the aftermath of the Haiti earthquake, up to 10,000 NGOs were estimated to be active, so there was clearly strong demand for data. However, the more than 2,000 damage maps for Haiti suggest considerable duplication and a lack of coordination. It is not clear which of those maps were actually used and whether they were useful to emergency workers on the ground.

Despite these qualifications, the response to the Haiti earthquake demonstrated that non-professionals have significant potential to contribute to post-disaster information gathering. The response also showed that there is a great willingness by volunteers to contribute to such efforts.

Source: Kerle, N. (2011)

An important initiative focused on the provision of space-based data for disaster response is the International Charter ‘Space and Major Disasters’ (Disaster Charter, 2011). The Charter mobilizes 14 space agencies around the world and benefits from their satellites and expertise through a single access point that operates 24 hours a day, seven days a week at no cost to the user. The International Charter aims to provide a unified system of space data acquisition and delivery to those affected by natural or man-made disasters. The satellite images of affected areas provided by the Charter are analysed by other bodies and used to inform disaster responses (see Box 5.1). As of today, the Charter has responded to over 350 calls acquiring over 3000 images by around 20 different imaging satellites, and the number of times it is activated is growing steadily year after year.

The United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER, 2011) has been established by the United Nations to ensure that all countries have access to and develop the capacity to use space-based information to support the disaster management cycle. In Europe, the Global Monitoring for Environment and Security (GMES) initiative of the European Commission and the European Space Agency (ESA) actively supports the use of satellite technology in disaster management (GMES, 2011). The GMES Initial Operations Emergency Management Service – Mapping in Rush Mode, launched in April 2012, is the first service implemented within the framework of the GMES initial operational phase. This service is provided on a 24/7 basis, covering the on-demand and fast provision of geospatial information supporting worldwide requests coming from authorities in charge of crisis management in the aftermath of major events such as earthquakes, floods, tsunamis, wind storms, industrial accidents and humanitarian crises.

Systems have also been developed for fast assessment of damage directly after the occurrence of major events. For instance, the PAGER (Prompt Assessment of Global Earthquakes for Response) system, developed by the United States Geological Survey, is an automated system that rapidly assesses earthquake impacts by comparing the population exposed to each level of shaking intensity with models of economic and fatality losses based on past earthquakes in each country or region of the world (PAGER, 2011).

In addition to these top-down institutional initiatives which are often based on EO, several bottom-up crowdsourcing initiatives are emerging for collaborative mapping in emergency situations or for the collection and updating of topographic information. Some examples of platforms for disaster response are Ushahidi (2011), Sahana (2011) and Virtual Disaster Viewer (2011). The Virtual Disaster Viewer is a tool for collaborative disaster impact and damage assessment, and has proven its effectiveness after the Haiti earthquake in 2010. Hundreds of earthquake and EO experts were assigned specific areas (tiles) of the affected regions to review and to assess. They compared “before” and “after” high-resolution satellite images which became available on many platforms immediately after the disaster and engaged in collaborative mapping of the damage. Such collaborative mapping applications might become a very important tool in the future.

The use of geospatial information in damage assessment is an extensive topic which has only been explored briefly above. More detailed overviews on this topic can be found in CEOS (2003), IGOS (2007) and Joyce et al., (2009). Examples of initiatives that focus on spatial data infrastructures for disaster relief are Reliefweb (2011), Alernet (2011), HEWSweb (2010), and GDACS (2011).

The geospatial technologies and data collection methods described in this section help provide essential information rapidly to aid responses to disasters. This information can be disseminated to and used by a wide range of organizations on the ground to improve their effectiveness in delivering assistance to those in need.

5.3 Disaster prevention – hazard and risk assessment

GS&T contributes significantly to disaster management through supporting hazard and risk assessments. These assessments require a multitude of data from different sources, including many types of geospatial data depending on the type of hazard and the area covered.

Hazard assessment using GIS can be carried out at different geographical scales, depending on the objectives of the study, the availability of geospatial data and the size of the study area (Van Westen, 2012). These scales range from global to a community level. For hazardous events, such as windstorms, drought, earthquakes, and tsunamis, which affect large areas, hazard assessments must use a global or international mapping scale. For example, the Global Seismic Hazard Mapping Project (GSHAP, 1999) produced regional seismic hazard maps for most parts of the world, and is now followed up by the Global Earthquake Model (2011). Digital Elevation Models (DEMs) measure differences in elevation of the earth. This is important for several hazard models, because small changes in elevation can have a big impact on whether a certain area will be effected or not. Models for assessing floods are one example of this. The main sources for global DEMs used in hazard and risk analysis are Shuttle Radar Topographic Mission and ASTER-derived DEMs. In the near future, the TanDEM-X satellite mission will provide a global DEM for the entire Earth, with relative height accuracy of 2m, and a spatial resolution of 12m (Zink et al., 2008). This higher-resolution DEM will allow a much better analysis of the areas that are potentially at risk. Other GS&T applications (such as sonar measurements and high spectral and spatial resolution satellite images coupled with a non-linear machine learning technique) can be used to obtain detailed tsunami hazard maps.

Interferometric Synthetic Aperture Radar (InSAR) is another powerful GS&T tool for assessing hazards. InSAR can be used for detecting changes in topographic heights, due to various hazardous processes, such as land subsidence, slow-moving landslides, tectonic movement, ice movement and volcanic activity (Ferretti et al., 2001; Farina et al., 2008). For detailed measurement of tectonic plate movement, Differential Global Positioning Systems at fixed points are used extensively, e.g. for mapping strain rates and tectonic plate movements (Vigni et al., 2005), volcanic movements (Bonforte and Puglisi (2003), and landslides (Gili et al., 2000).

Hazard assessments are often conducted on a global scale with multiple actors from across the world working together. One example of such global collaboration is the GEO Geohazard Supersites and Natural Laboratories collaboration, which is described in box 5.2.

In many instances, accurately assessing hazards requires complex mathematical models that consider multiple factors. For example, mapping of forest fires with GS&T is done by mapping the fires themselves using thermal sensors, or through the mapping of burnt areas. But to accurately predict how fires will spread and produce effective early warnings, many other inputs are needed. For instance, vegetation conditions play a critical role: the expected rate of spread and energy released depend to a large extent on hourly variations in fuel moisture conditions. In this case, vegetation indices for qualitatively and quantitatively evaluating vegetative covers using spectral measurements

Box 5.2: Global cooperation in hazard assessment

The GEO Geohazard Supersites and Natural Laboratories (SNL) is a membership-based consortium of universities, research institutions, national agencies responsible for geohazard observations, and space agencies. The aim is to systematically acquire, and provide access to, remote sensing and in situ geophysical data for areas exposed to geological threats (“Supersites”). SNL provide a platform allowing fast, easy and free access to complete geospatial datasets from multiple sources and disciplines. This interdisciplinary approach has the potential to reduce the uncertainty of future disastrous events and provide essential information to policymakers in endangered areas.

There are four earthquake Supersites (Tokyo, Vancouver-Seattle, Los Angeles and Istanbul) and three volcano Supersites (Vesuvius/Campi Phlegreii, Mount Etna and Hawaii). In addition, there are event Supersites for earthquake and volcanic disasters. The Geohazard Supersites can provide critical scientific information about the nature of the geologic events to civil defence authorities. The initial objectives of the Geohazard Supersites are to establish a free multi-satellite online data repository for the selected Supersites and to dramatically enhance the scientific community’s access to remote sensing and in situ data. The long-term objective is to develop an international, sustainable and integrated approach to geohazards, optimally utilizing the remote sensing and in situ resources of GEO members.

can be assimilated within models to better estimate phenological stage and, in turn, moisture content and biomass of fuels. These parameters can be used to feed fire behaviour models coupled with meteorological forecasts to produce medium-range fire weather prediction.

Another example of a complex geospatial hazard assessment model is the MARSOP-3 project on crop yield forecasting. This includes the management of a meteorological database, an agrometeorological model and database, low-resolution satellite information, statistical analyses of data and crop yield forecasting. It also publishes bulletins containing analysis, forecasts and thematic maps on crop yield expectations using a Web-GIS application (Reidsma et al., 2009). The application of such types of crop forecasting systems allow national governments, NGOs and international organizations (e.g. FAO, WFP, WHO, UNOCHA) to better plan their response actions for hazardous events.

The geospatial tools described above all allow scientists and policymakers to better understand and predict natural hazards. However, assessing hazards is only one part of the issue, in order to understand the risks posed by each hazard, another set of tools are needed to help assess how these hazards will interact with societies. Many such geospatial risk assessment tools have been developed by specialized companies, but these are proprietary and are mainly used in the insurance sector. The best publicly available software tool for estimating potential losses from hazards is HAZUS (which stands for ‘Hazards U.S.’). HAZUS was developed by the United States Federal Emergency Management Agency (FEMA). It is a nationally applicable standardized methodology that contains models for estimating potential losses from earthquakes, floods, and hurricanes. HAZUS uses GIS technology to estimate physical, economic, and social impacts of disasters (FEMA, 2004). Although the HAZUS methodology has been very well documented, the tool was primarily developed for the USA, and all data formats, building types, fragility curves and empirical relationships cannot be exported easily to other countries. Notwithstanding, several other countries have been able to adapt the HAZUS methodology to their own situation, e.g. in Bangladesh (Sarkar et al., 2010). The HAZUS methodology has also been provided a basis for the development of several other open source software tools for potential losses from hazards.

Another prominent risk assessment tool is the regional CAPRA initiative developed in Central America in collaboration with the World Bank. This tool is an excellent example of the regional level of GS&T application, and is described in box 5.3.

Box 5.3: CAPRA – regional disaster risk in Central America

The Central American Probabilistic Risk Assessment Initiative (CAPRA) aims at increasing understanding of disaster risk in the Central American countries. It does this by developing a system which utilizes state-of the-art technology in Web-GIS and disaster models. These are used to generate an open platform for disaster risk assessment, which allows users from the Central American countries to analyse the risk in their areas and be able to take informed decisions on disaster risk reduction. CAPRA is an initiative by the World Bank, together with the Central American Coordination Centre for Disaster Prevention (CEPREDENAC), in partnership with Central American governments. The initiative is supported by the United Nations International Strategy for Disaster Reduction Secretariat (UNISDR), the Inter-American Development Bank (IDB), and the World Bank.

CAPRA aims to develop probabilistic risk analysis techniques to quantify the future impact of hazards in monetary and population losses. The methodology focuses extensively on the development of probabilistic hazard assessment modules for earthquakes, hurricanes, extreme rainfall, and volcanic hazards, and the hazards triggered by them, such as flooding, windstorms, landslides and tsunamis. The methodology also includes a component for the generation of exposure databases, working at three levels, from using proxies and indicators at the national level up to a detailed inventory of assets using Google Earth software applications. The vulnerability module allows creating and managing vulnerability curves for physical vulnerability assessment. Actual risk assessment is carried out using a tool called CAPRA-GIS, which combines the hazard data exposure data and vulnerability curves.

Source: www.ecapra.org

The geospatial technologies and data collection methods described in this section allow scientists to better model the areas that might be affected by hazards and their intensities, at different scales of analysis. The methods also allow for better estimation of the possible losses of these events, which are the basis for policymakers to design risk reduction strategies.

5.4 Disaster preparedness

GS&T plays a major role in disaster preparedness by monitoring and forecasting hazardous events. This can be done in different ways. The most straightforward is by directly measuring the phenomena, using networks of stations, e.g. earthquake strong-motion data, flood-discharge stations, meteorological stations, coastal tide gauge stations, or wave measurement buoys. Seismic networks have been formed globally (e.g. GSN, 2011), and a tsunami warning system has been developed for many parts of the world after the tragedy of the 2004 Indian Ocean tsunami. Several GS&T-based early warning and monitoring systems are operational. The most relevant ones monitor tropical storms and cyclones, volcanic eruptions, gas emissions and ash clouds, forest fires, and drought.

Disaster risk reduction (DRR) can be achieved if science is successful in providing society with clear and detailed information on the potential risk it is facing. Objective and reliable information on hazards, vulnerability and exposure, presented through an analysis of expected impacts for given scenarios, can trigger and sustain the political will and economic commitment needed to achieve adaptation and mitigation. Within this framework, GS&T has the powerful capacity to represent and describe complex dynamics and processes by means of detailed, objective and up-to-date risk assessment maps. Additionally, GS&T has an important role to play in supporting the scientific community through the development of large-area vulnerability modelling and mapping.

The hazard and risk assessment tools described above and in section 5.3 can help science to provide clear, critical information about hazards and risks earlier and more simply than was previously possible. Policymakers can then use this information to prepare for the hazardous event and reduce its impact. If such preparations are sufficiently effective, a potential disaster resulting from a natural hazard can be prevented altogether. However, in order to effectively prepare for potential disasters, two key steps are required. First, the information must reach policymakers; second, policymakers must be able to use the information to respond quickly and effectively.

In fact, the economic and societal impacts of disasters are weakly related to society's capacity to respond to extreme events after they occur. Instead, they depend to a large extent on the vulnerability of the infrastructure and the preparedness of the society. Within this framework, GS&T and GIS can make a difference, since the use of satellite imagery, combined with all the available in situ data, makes it possible to dramatically improve the management of risk in all phases: before, during and after a disaster. This vision was captured in the GEOSS 10-Year Implementation Plan, which clearly defines its role in advancing the Societal Benefit Area of Disasters: "GEOSS implementation will bring a more timely dissemination of information through better coordinated systems for monitoring, predicting, risk assessment, early warning, mitigating, and responding to hazards at local, national, regional, and global levels" (GEOSS, 2005).

In support of this aim, GEONETCast has been developed as a global network of satellite-based data dissemination systems providing a wide and growing range of environmental data and products to a worldwide user community (Mannaerts et al., 2009). Also, as discussed in section 5.2, UN-SPIDER works to give all countries access to space-based information to support the full disaster management cycle. This includes early warnings and risk and hazard assessment as well as post-disaster damage assessments. Another system for disseminating this information is the Sentinel Asia programme, an initiative for sharing disaster information in the Asia–Pacific region on the Digital Asia platform by making the best use of Earth observation data for disaster management in the Asia–Pacific region (Sentinel Asia, 2011).

Once policymakers have the information they require, they can attempt to manage the risks they face. Risk management cannot take place without proper risk governance. Risk governance has been promoted in the ISDR, Hyogo Framework for Action (see box 5.4) to: "Promote and improve dialogue

Box 5.4: The Hyogo Framework for Action (HFA)

Following the risk governance guidelines of the HFA 2005–2015, a 10-year plan was made to make the world safer from natural hazards. It was adopted by 168 Member States of the United Nations in 2005 at the World Disaster Reduction Conference, which took place just a few weeks after the Indian Ocean tsunami. The HFA is the first plan to explain, describe and detail the work that is required from all different sectors and actors to reduce disaster losses. It was developed and agreed on with the many partners needed to reduce disaster risk–governments, international agencies, disaster experts and many others–bringing them into a common system of coordination. The HFA outlines five priorities for action, and offers guiding principles and practical means for achieving disaster resilience:

1. Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation;
2. Identify, assess and monitor disaster risks and enhance early warning;
3. Use knowledge, innovation and education to build a culture of safety and resilience at all levels;
4. Reduce the underlying risk factors;
5. Strengthen disaster preparedness for effective response at all levels.

The HFA goal is to substantially reduce disaster losses by 2015 by building the resilience of nations and communities to disasters. This means reducing loss of lives and social, economic, and environmental assets when hazards strike.

Source: http://www.unisdr.org/we/coordinate/hfa

and cooperation among scientific communities and practitioners working on disaster risk reduction, and encourage partnerships among stakeholders, including those working on the socioeconomic dimensions of disaster risk reduction" (UNISDR, 2005). Governance depends on political commitment and strong institutions. Good governance is identified in the ISDR framework for disaster risk reduction as a key area for the success of effective and sustained disaster risk reduction (IRGC, 2005).

One of the important processes in risk governance is risk communication, the interactive exchange of information about risks among risk assessors, managers, news media, interested groups and the general public. An important component of this is risk visualization. Since risk is a spatially varying phenomenon, GIS technology is now the standard approach for the production and presentation of risk information.

An example of effective risk governance in practice from Cuba is given in box 5.5. In this example, it is important to note that the hazard and risk assessments provided by GS&T are just enablers. What actually prevents disaster is effective risk governance. Consequently, without effective risk governance in place, the use of GS&T gives little direct benefit on its own in the field of disaster risk management.

As discussed in section 5.2, PGIS can play a significant role in disaster relief but it can also have an impact in disaster preparedness and prevention. The concept of community-based disaster risk management (CBDRM) has emerged during the past two decades in many countries. The promoters have included NGOs, citizen's organizations, humanitarian agencies and government departments in different countries in the region. Despite this rapid expansion in application, the great majority of CBDRM practitioners lack opportunities for skills development and capacity-building. One of the main organizations involved in capacity-building is the Asian Disaster Preparedness Centre (ADPC), which actively works towards the realization of disaster reduction for safer communities and sustainable development in Asia and the Pacific. It has organized many training courses and implemented local programmes on good governance and disaster risk management systems development (Abarquez and Murshed, 2004).[21] As in other areas, PGIS and crowdsourcing may have a growing impact on the use of GS&T in disaster preparedness.

The geospatial technologies and data collection methods described in this section allow stakeholders involved in early warning and disaster preparedness (such as civil defence organizations, NGOs,

Box 5.5: Cuba as an example of best practices in disaster risk reduction

Between 1998 and 2008, Cuba was struck by more than 20 tropical storms, of which 14 became hurricanes and seven were of great intensity. During this time period, a total of 11 million people were evacuated. Disaster risk reduction is a priority for the Cuban government, as can be seen in its vast legal framework and structural and educational actions that positively impact social, economic and safety indicators of the population. After assessing risk in a municipality, the Government establishes an order of priorities to reduce identified vulnerabilities. This implies planning the necessary material and financial resources for the gradual reduction of risk, until it reaches a level considered acceptable for all. To facilitate this work at the local governmental level, the Cuban Civil Defence created the Risk Reduction Management Centre strategy and prioritized its implementation for the most vulnerable municipalities.

The Cuban model of Risk Reduction Management Centres, which have been supported by UNDP Cuba through diverse initiatives, establishes the possibility of mitigating disaster impacts through an informed, coordinated, multidisciplinary and decentralized approach which focuses on identifying hazards and acting pre-emptively to reduce risks. This approach has contributed to the excellent track record in Cuba of protecting human life and livelihoods through preparedness and institutional capacity-building at a local level.

In order to establish the basis for the national disaster management activities, the Cuban Civil Defence, together with national expert organizations, carried out a comprehensive multi-hazard risk assessment, taking into account all types of hazards that may affect the country. For this project, GS&T has been essential in determining the historical databases of hazard events, generating maps of factors that control the hazards, modelling the potential areas affected and the intensities expected, mapping the exposure of buildings, population and other elements at risk, and eventually in determining risk scenarios.

Source: http://www.preventionweb.net/english/professional/publications/v.php?id=14963

national and local governments, and international organizations) to better predict the time, place and intensity of disaster events. This enables them to ensure that the population is better prepared, so that the consequences of the imminent disaster can be reduced.

5.5 Challenges

GS&T can contribute significantly to understanding, modeling and monitoring natural hazard processes, at various scales and using a range of techniques. GS&T findings and tools have been used successfully in analysing the risk to vulnerable societies, and the results have been communicated to stakeholders who have often used them in appropriate disaster risk reduction strategies. However, with both extreme events and the numbers of vulnerable people on the rise, several challenges will need to be overcome to better estimate future hazards and risks. As with chapters 3 and 4, challenges particular to the application of GS&T to DRM are discussed below, while general challenges will be covered in chapter 6.

Aligning the scientific community with disaster stakeholders: Scientific advances in hazard and risk assessment and demands of stakeholders/ end users are still not well aligned. In many cases, scientific findings do not leave the confines of the scientific community (IRGC, 2005). One cause of the gap between the science and stakeholders/ end users is the complexity of human–environment interactions. This has led to the development of a diversity of approaches, often difficult to implement by the end user community.

Taking a multidisciplinary approach to the impacts of natural hazards: Impacts of natural hazards on the environment and on the society are still tackled using monodisciplinary approaches. Monodisciplinarity is evident in scientific research (single approach and tools for each type of hazard). Management tools, models, and local-to-regional technical solutions have been proposed by numerous projects for single hazards. Only a few of them have tackled the issue of risk assessment and management, however, from a multi-hazard perspective. The integration of geoinformation systems and local community knowledge relevant to hazards, vulnerability and risk modelling is still in an initial stage (Maskrey, 1998; Ferrier and Haque (2003); Zerger and Smith, 2003). Systematic collection of data from significant events using public participation can provide a very useful component for the development of data sets to be used as input for risk studies at community level, and as a basis for risk management and community planning.

One programme which could help address both of these challenges is the Integrated Research on Disaster Risk (IRDR).[22] IRDR is a decade-long, interdisciplinary research programme sponsored by ICSU in partnership with the International Social Science Council (ISSC), and UNISDR. The IRDR Science Plan envisages an integrated approach to disaster risk management through a combination of natural and social sciences. It could help build a bridge between the scientific community and policymakers in this area as well as encouraging more multidisciplinary research.

5.6 Summary of benefits

Table 5.2: Summary of GS&T-enabled benefits in disaster risk management

GS&T Enabler	Direct Benefit	Societal Benefit
Crowdsourcing	Rapid damage assessment, where many people (experts in many locations, and people in the affected areas) can rapidly collect a lot of information.	Faster and more accurate assessment of damage of disasters allows for more effective disaster response, leading to less loss of lives.
GEOSS	Improved use of and access to observations and information related to disasters and risk and hazard assessments.	Better informed policies, decisions and actions associated with disaster preparedness and mitigation. More effective access to observations and related information to facilitate disaster warning, response and recovery.
UN-SPIDER	Dissemination of space-based information for disaster responses.	Coordination of the multitude of organization involved in DRR results in better and faster disaster response, leading to less loss of lives.
CAPRA, HAZUS and other hazard risk assessment tools	Hazard risk assessments indicate where hazard may occur, how frequent, and how much damage is expected.	Estimation of possible losses due to disasters, allow the society to adopt measures to reduce their effects in terms of loss of lives and economic damage.
Various early warning systems	Early warning of impending hazard events.	Early warning gives the society the time to prepare response operations, evacuate people, and stop activities that would cause more damage.

NOTES

21. http://www.adpc.net/pdr-sea/publications/12Handbk.pdf
22. See http://www.irdrinternational.org

6. CHALLENGES TO UTILIZING GS&T

Chapters 3 to 5 have demonstrated some of the powerful ways that GS&T can aid development in the areas of sustainable urban development, land administration, and disaster risk management. However, it will not be easy for the benefits described above or in any areas to be realized. The previous chapters addressed some specific challenges in each area, but several general challenges must also be overcome before GS&T can deliver its potential development benefits.

This chapter considers the wide variety of challenges to implementing GS&T under seven headings: global strategy and vision; national strategy and vision; infrastructure and data; participatory GIS and crowdsourcing; cost and cost-efficient access to GS&T systems; capacity-building of human resources; and research.

Chapter 7 then discusses proposed recommendations of how to overcome these challenges.

6.1 Global strategy and vision

As discussed in chapter 2, the cross-border nature of Earth processes and GS&T systems mean that countries must work together to approach the provision of geospatial data globally. In developing such a global strategy, there are two key challenges that must be overcome.

First, there is a challenge of coordination. There is significant redundancy in EO systems resulting from a lack of coordination where different organizations observe and monitor the same processes. Conversely, there are areas of the globe and some thematic topics of interest where data is lacking or non-existent (GEO, 2005). The goal of using one observation to serve a number of different users is often not realized, and this duplication prevents resources from being used as efficiently as they could be.

Linked to the challenge of coordination is one of interoperability and data sharing. To eliminate duplication of observations, different organizations will need to share information with each other (GEO, 2005). There are technical challenges to this, such as incompatible data structures and policies, as well as cultural and institutional challenges, with some organizations reluctant to share their data or make it public. While progress has been made at the global level in terms of developing common standards, there is no way of ensuring that these are always followed. It is also difficult to apply these standards retroactively to existing databases and systems.

6.2 National strategy and vision

Chapter 2 introduced the concept of a national geospatial strategy or SDI. At the national level, there are many challenges to implementing an SDI and developing a clear strategy and vision for the use of GS&T. This study has provided examples of some of the ways that GS&T can support development, and there are many other potential applications of GS&T which have not been covered. Selecting which of these areas to focus finite resources on is therefore the first challenge at the national strategy level. Further, in each area there may be several different available technological tools ranging from free and open source software programmes to expensive proprietary ones. Policymakers will need to decide not only what opportunities to pursue but what tools to pursue them with, based on a cost-benefit analysis of alternative options. This will require a level of knowledge of the different available tools, which may be lacking, as well as a detailed understanding of the country’s needs.

Second, national strategies must take account of a number of different stakeholders. Stakeholders will need to be identified and engaged with, but new technologies mean that the set of people who use and are affected by GS&T is rapidly expanding. Providers and users of GS&T may now include government ministries, local and regional governments, NGOs, geospatial scientists and researchers, foreign governments, the United Nations and other international bodies, local communities and increasingly individual citizens themselves (see section 6.4). In developing countries, many programmes may be funded directly by donors who will also be key stakeholders. All the groups listed above will have diverse and sometimes contradictory priorities and objectives, yet they are all important for a well-functioning SDI.

A further stakeholder challenge is that user and use follow-up and feedback are essential for improving geospatial models and software products. This requires continued engagement with end users to get their constructive feedback. In other words, it will be necessary to establish a community where all the key stakeholders are able to exchange ideas and stay in regular contact. This will take time and effort, and require a critical mass of stakeholders to be engaged. Therefore, identifying and engaging with these various stakeholders will prove a significant challenge for governments as they attempt to develop a clear strategy for GS&T.

Third, there are also institutional challenges that will need to be overcome at national level. Given that GS&T will have application across several government ministries, it is not clear who should have overall responsibility for it. In many countries, ministries may not have previous experience of working together and a cultural change may be required. Governments will need to find a way to allow all ministries to access data and have input into the GS&T strategy. Any changes to the institutional and policy framework will need to overcome inertia and other constraints and develop new business models to enable public and private customers to adopt GS&T solutions. They will also need to be locally driven, making use of local dynamics and organizational structures.

Fourth, there may also be legislation required to free data for sharing. Typical legal issues that may impact the application of GS&T include intellectual property rights governing access to and use of geospatial data (such as copyright and patenting of software and algorithms), privacy and data protection law, and liability law. The example from chapter 4 of privacy laws preventing the use of HRSI for adjudication and surveying of land in certain countries illustrates this point. Existing legislation may unintentionally create obstacles to the use of geospatial technologies created after the legislation was written. Countries implementing an SDI should therefore consider whether any existing legislation requires updating to take into account the GS&T applications they intend to implement. However, any strategy that requires the implementation of legal changes increases complexity and risk, as delays or disagreements in the legislative process can impact timelines.[23]

Finally, there is the need to keep abreast of global and regional developments to ensure that the SDI being developed will be compatible with other countries and allow for interoperability. Given that global coordination of GS&T is in its infancy and still evolving, this may not be straightforward.

6.3 Infrastructure and data

Implementing the SDI will require good-quality data to be collected, analysed and disseminated as well as the necessary physical structure to support this. However, studies have identified several challenges in both these areas, which while largely overcome in developed countries are still a significant factor in the developing world (Craig et al., 2002).

In terms of infrastructure, problems include the security of buildings where equipment is stored, reliability of the power supply, speed and availability of internet connections and various problems with hardware (Stuart et al., 2009). Any of these problems can significantly reduce the viability of an SDI, as they limit the ability to store, analyse and disseminate data.

Once these challenges are overcome, data of sufficient quality needs to be collected to be fed into the infrastructure. However, a recent study by GEO identified several common problems with data that can undermine their usefulness (GEONetCab, 2011):

- The information cannot be found, cannot be accessed or is otherwise not available;
- The information is accessible, but not usable or reliable for forecasting or scenario development on different subjects;
- Appropriate models and product generation cannot be identified;
- The information cannot be processed in a way that supports the decision-making process;
- The information is shareable, but not timely delivered or up to date: inadequate quality of the information to support the decision-making processes.

Which of these problems apply will be determined by the type of data sought and the collection and analysis methods available. What is clear is that the technology itself is of no use without the necessary data, and that often it may be challenging to collect data to the required standards.

6.4 Participatory GIS and crowdsourcing

As previous chapters have highlighted, participatory GIS and crowdsourcing have vast potential to improve the timeliness, cost-effectiveness and accuracy of data collected for use in GS&T as well as empowering local communities. However, several challenges present themselves to any government or other organization attempting to harness the power of crowdsourcing.

First, there is the challenge of verifying the accuracy and authenticity of data supplied by the crowd. Many crowdsourcing platforms such as Open Street Map have their own verification process built in, and independent studies have verified the quality of their data in certain areas (Haklay, M., 2010). However, other areas, such as needs requests during a disaster or crowdsourced land registration data, can be more problematic. In such instances, the people submitting the data may have vested interests that will raise questions about the data they provided. If you rely on crowdsourcing to inform you of the needs in a disaster zone, you risk only responding to people with smart phones. If you rely on crowdsourcing for land registration, you risk giving legal rights to land to whoever claims it first.

The other side of this argument is that if policymakers and geospatial scientists treat all data from the crowd as suspicious until verified, then many of the benefits of crowdsourcing will be negated. Crowdsourcing is quicker and cheaper than existing methods, but if the users of crowdsourced data seek to verify all such data before using then, then these advantages disappear. Striking a balance between these two opposing views is therefore a key challenge to effectively using crowdsourced data.

A second set of challenges with crowdsourcing relate to the diffuse and diverse nature of the crowd. First, it may be difficult to ensure that only relevant and useful data are submitted by the crowd. Consumers of data such as emergency response coordinators on the ground face the challenge of communicating to the diffuse crowd exactly what information they need. There is therefore a risk that volunteers in the crowd will spend a significant amount of time and effort producing data that are subsequently of little use. Another consequence of the crowd's diverse nature is that some members may lack the technical skills required for certain tasks. How to engage with and upskill the crowd is a significant challenge for the GS&T community and policymakers seeking to collaborate with the crowd.

A third key challenge is how to best mobilize the crowd. While high-profile disasters such as the Haiti earthquake attract an instant response from significant numbers of people eager to help, it is more difficult to mobilize the crowd for lower-profile disasters or for proactive work. How to turn the crowd into more of a community that can be engaged with and coordinated in a structured way is a significant challenge, but can open up a whole new world of citizen involvement.

6.5 Cost and cost-efficient access to geospatial data

Geospatial technologies all have costs associated with them to varying degrees. While there are a variety of open source software packages available, often the best products in particular areas are proprietary and come with software licence costs. Using open source software also requires highly knowledgeable software developers, who may well be lacking in certain countries. Also, in many instances the effective adoption and use of GS&T requires the development of applications that are tailored to the specific needs of the organization. This means that software development or customization may be required, which will have associated costs.

In addition to software costs, GS&T relies on infrastructure and hardware, as discussed in section 6.3. Many technologies require easy and fast Internet access to be used effectively. This is particularly the case for crowdsourcing-enabled processes, which rely on the public to submit information using Web 2.0 technologies. For locations without fast and easy Internet access, achieving some of the potential benefits of GS&T will not be possible without significant investment in Internet infrastructure. Infrastructure investment will also be needed to ensure that sufficient data storage and processing power is available at the level of the end user.

In many developing countries, priority for limited resources is often given to supposedly more pressing development activities instead of GS&T. This frequently happens without a clear understanding of how dependent most development activities are on the availability of timely, accurate and reliable geoinformation resources. Consequently, the high costs involved act as a major barrier to using GS&T for enabling development.

6.6 Capacity-building of human resources

Another challenge concerns the ability of governments, NGOs, private sector and other stakeholders to develop the skills to effectively use and maintain geospatial technologies. Insufficient capacity-building resources to provide a sustainable human resource base have been identified as a significant bottleneck to implementing GS&T (GeoNetCab 2011). A survey of GIS professionals in Africa identified limited human resource capacity, particularly a lack of trained staff, as the factor reported to be the most significant in limiting the wider use of GS&T (Stuart et al., 2009). There is a regular need for professionals in geoinformation, both in the technical disciplines[24] and in applied disciplines.[25] This need ranges from the vocational/technologist level to the Masters/PhD level.

While human resource challenges vary from region to region, and while all regions have at least some GS&T capacity, there are generally not enough experts in GS&T to meet potential demand. The low rate of the introduction and incorporation of GS&T courses into the regular curricula of higher learning institutions and universities will exacerbate this problem. Also, as the technologies and science involved develop at a fast pace, there is a continuous need for refresher training to ensure that experts' skills do not become outdated.

There is also currently a lack of performance indicators or standards for accreditation and certification procedures for education in the field of EO (and for the use of GS&T in general). This means that there is no global standard for the quality of courses available. Employers are unclear of the relative value of certification from different institutions, and prospective students are similarly uninformed.

In developing countries, there are further challenges to capacity-building. Many programmes and research projects are short-term and fail to leave any legacy behind when they are completed. GIS systems are often built deployed by non-local human resources. Where projects do have strong capacity-building aspects, there remains the risk that local staff trained in geospatial sciences by the project will leave as soon as it finishes. Trained local professionals often leave to join the private sector within their own countries or to move to a new job outside their country. This can hinder efforts to build a critical mass of experts within a specific country.

Human resource capacity-building challenges are not limited to training a sufficient number of experts. There is also an issue with general awareness of GS&T. Many managers and policymakers in areas that could benefit significantly from the use of GS&T do not understand what GS&T can contribute and what conditions would be required to enable its adoption. Therefore, because of a lack of understanding among potential customers of GS&T it is not utilized as often or as effectively as it could be. Finding a way to educate policymakers and potential customers of geospatial data and analysis about GS&T is an equally important and challenging area of capacity-building.

6.7 Research

Significant research is still needed in a number of areas to understand more fully the interactions between GS&T and citizens and those between GS&T and policymakers. Current gaps in research also include collaborative research for and in developing countries, capacity-building, the crowdsourcing phenomenon, and research on how to develop prototypes of geospatial operational models and software products.

Geospatial scientists conducting research in these areas will face two distinct challenges. The first is to ensure that their research is multidisciplinary and includes insights from the social sciences and economics as well as from geography, engineering and the physical sciences. Such a multidisciplinary approach will be essential to understand not just how GS&T can be improved technically but also how its application and use can be improved as well. This understanding will enable the benefits of GS&T to be more easily and more fully realized.

Linked to this challenge and some of those described in section 6.6, future research and discussions within the GS&T community need to find a way to better communicate with decision-makers. Until the GS&T community is able to clearly and simply explain the benefits and applications of GS&T to decision-makers, the take-up of its findings will be limited.

NOTES

23. SDI Cookbook, chapter 8, Legal and Economic Policy, available at http://www.gsdidocs.org/GSDIWiki/index.php/Chapter_8 (accessed on 2 May 2012)
24. Such as cartography, surveying, visualization, geospatial database management, geospatial data handling and geo-statistics.
25. Such as water and natural resources management, agriculture, urban planning, earth sciences, meteorology, oceanography and land administration.

7. RECOMMENDATIONS AND CONCLUSION

In order to address the challenges set out in Chapter 6 and to realize the benefits identified earlier in this report, this chapter makes a number of recommendations under the same headings used in chapter 6.

7.1 Global strategy and vision

To address the challenge of global coordination, governments and governing bodies of international and regional organizations should consider joining the Group on Earth Observations (GEO). They could also facilitate participation of their experts in implementing the GEOSS Implementation plan, in terms of achieving strategic targets in architecture, data management, capacity-building, science and technology, and user engagement. By participating actively in GEO, governments would collectively address current shortcomings in the following ways:

- Improve coordination of strategies and systems for GS&T and identification of measures to minimize data gaps, with a view to moving towards a comprehensive, coordinated, and sustained GS&T system of systems;
- Coordinate the effort to involve and assist developing countries in improving and sustaining their contributions to observing systems, as well as their access to and effective utilization of observations, data and products, and the related technologies by addressing capacity-building needs related to GS&T systems; and
- Exchange observations recorded from in situ, aircraft, and satellite networks in a full and open manner with minimum time delay and minimum cost, recognizing relevant international instruments and national policies and legislation

Institutional interoperability and fostering a culture of data sharing can also be facilitated by membership of GEO and participation in implementing GEOSS. To address the challenges of technical interoperability, governments and other organizations working with geospatial data should follow the SDI implementation guide from the GSDI,[26] which is a frequently updated, living document available publicly online. This contains guidance on the most recent ISO common standards for metadata, on how to build geospatial data for multiple uses, what metadata to use, how to make geospatial data discoverable, and how to facilitate open access to data.

Another global forum working towards interoperability of data is the Committee on Data for Science and Technology (CODATA). CODATA is an interdisciplinary Scientific Committee of the International Council for Science (ICSU) that works to improve the quality, reliability, management and accessibility of data of importance to all fields of science and technology. It has a specific task group working on Earth and space science data interoperability, which has been running since 2008.[27] Also, as discussed in chapter 2, the GGIM initiative is another forum where technical and institutional interoperability can be promoted.

These global forums and institutions all bring together practitioners from around the world in an effort to align their data. If everyone uses the same data standards, then technical interoperability will become much easier, allowing for more exchange and sharing of data.

7.2 National strategy and vision

To decide which areas of GS&T to prioritize, governments should match the geospatial technologies to the goals of their national institutions, and their society. A long-term view is needed among governments, especially in developing countries: champions are needed and political will must be maintained at all levels. Governments will need to develop a vision of the desired future and a clear sense of how SDI components could serve that future and help to realize it. This will require decisions to be made on the priorities of different societal benefit areas and GS&T enablers that will be focused on. To help achieve this, governments could organize a workshop with key stakeholders and define a national coordinating body, with working groups and/or committees. In countries where GIS implementations are highly dependent on donor involvement in terms of funding and technical expertise, donor representatives should be considered as key stakeholders and included in the process of building an SDI.

Once a vision is defined and agreed upon, an assessment of the current position should be undertaken. From a data perspective, the initial focus should be on documenting those geospatial data sets that have current or anticipated future use, data sets that form the framework on which others are based, and data sets that represent the largest commitment in terms of effort or cost. The current position assessment should also inventory available systems and software, levels of skilled individuals and what skills they have, and existing courses offered in the region that are relevant. Once both the current position and the desired position are understood, a plan of how to move from the former to the latter can be developed. Potential bottlenecks and challenges in realizing the vision should be identified in advance and steps taken to address them.

This plan and strategy should include a detailed assessment of the available tools and technologies that can help achieve the desired position and a well-researched business case for the preferred option that considers the strengths and weaknesses of all the alternatives. It should also include an assessment of whether any legislative changes would be required and set out what these would be.

For the SDI vision to be achieved, it is important that all key stakeholders are identified and engaged with through both the visioning and implementation phases. The stakeholders will include not only people and organizations that use GS&T but also people and organizations that will be impacted by its applications. From an academic perspective, researchers from a range of disciplines, both technical ones such as cartography, surveying, visualization, geospatial database management, geospatial data handling and geostatistics, and broader ones such as economics and political science, should be included in discussions. For specific aspects of SDI which require particular expertise, governments should organize formal working groups of interested parties and experts. Such areas could include standards (metadata, exchange), national geospatial data sets, policy, legal /economic policy and capacity-building, and approaches on how to assimilate existing technological solutions into the local context.

With regard to institutional challenges, governments should avoid locating the SDI within one of the many ministries that rely on geospatial data and analysis. To do so would risk the SDI being seen as something specific to that ministry when it is in fact applicable to several ministries. Therefore, rather than the SDI being part of the Ministry of Agriculture or the Economy, it should be separate. This would better enable the geospatial scientists and other staff to collect and analyse data for a variety of equally important purposes rather than serving a single ministry or a narrower set of objectives. The Netherlands provides an example of how this can be achieved. In the Netherlands, the national mapping and land administration agency, Dutch Kadaster, maintains a map base which is mandated as an “authentic register” for the country: all government agencies must use it for administrative purposes. Moreover, agencies must send errors and corrections directly to Dutch Kadaster for updating. In return they are provided access to the data set. This approach ensures that each agency has access to the data that it needs and also that it shares its data with other agencies. It also reduces costs for all government users of topographic data (van der Molen, 2005).

To ensure that national strategies remain aligned with global developments, governments should, wherever possible, pursue an incremental approach. This reduces the risk that significant work is done quickly which later ends up being incompatible with what other countries and organizations are doing.

An incremental approach also has other advantages. Meaningful, cost-effective applications can be developed on the basis of a rudimentary data set that can be progressively improved over time according to a carefully considered information strategy. Many improvements in both spatial data handling use can be made by rethinking current practices and actively seeking opportunities for greater collaboration between all stakeholders—public, private and civil society. Geospatial tools support gradual improvement. Initially, systems should be simple to create with appropriate accuracies, but flexible and enable scaling and refinement of accuracy over time.

7.3 Infrastructure and data

Minimum infrastructure is essential for effectively implementing an SDI, and some investment may be essential. If Internet access is a challenge, installing GEONETCast could be considered as a low-cost alternative method of receiving data (see section 7.5). For other infrastructure needs (such as secure buildings, reliable electricity supply and databases) investment, either from the country or from donors, will be essential. Without the minimum infrastructure requirements in place, it will not be possible to use GS&T effectively.

Data quality issues are complex and diverse. The specific challenge will vary depending on the type of data requirement, the collection methods and the level of accuracy needed. However, for general support with data issue, government representatives and other interested parties should consider joining the GSDI association which was discussed in Chapter 2. By providing best practices, suggested policies and data standards GSDI can help its members to tackle specific data issues that they may be facing.

7.4 Participatory GIS and crowdsourcing

There is no single rule for verifying the accuracy of crowdsourced data. In some instances, consumers of data will have worked with the same organizations multiple times and will be able to trust the accuracy of the data based on past performances. In other instances, data may be provided by an unknown individual or organization and may be more questionable. Just because data come from the crowd and have not been verified does not mean they are false, and it may be wrong to assume that such data are false until proven otherwise. However, consumers of geospatial data should always think critically about the reliability of their data, whether it comes from crowdsourcing or more traditional means. They should be aware of the possibility that unverified data may be inaccurate, and acknowledge this in their analysis and outputs.

The solutions to the other challenges with PGIS and crowdsourcing discussed in chapter 6 (ensuring data relevance, lack of specific skills in some members of the crowd, means of mobilizing the crowd for non-high profile events) are all related. Essentially, the solutions to each of these challenges can be achieved through collaborating with the crowd to turn it into a community, increasing communication within the crowd and between it and the GS&T community. This can also help address concerns over the accuracy and authenticity of crowdsourced data by building long-term relationships of trust between organizations in the crowd and consumers of their data. Through such communication, the GS&T community can clearly articulate to the crowd what it needs, help train the crowd and build its capacity, and mobilize the crowd in a more structured and predictable way.

A number of communities already exist within the crowd such as Open Street Map[28], the Standby Taskforce,[29] Map Action[30] and GIS Corps,[31] among others. The Digital Humanitarian Network is a recent initiative to coordinate the crowd by acting as a "network of networks". It aims to "to provide an interface between formal, professional humanitarian organizations and informal yet skilled-and-agile volunteer and technical networks."[32] It includes a standard form for formal organizations to request the services of the crowd, which coordinators process and disseminates through the network. As initiatives such as this and the existing organization develop, the crowd will continue its development into a community. This in turn will make it easier for professionals to interact with the crowd, gaining the data they need in the time frames and to the standards that are required.

With PGIS more generally, a number of recommendations can be made about how to best work with communities to collect geospatial data and information. These recommendations also have relevance to crowdsourcing and are listed below:

- ***Define the purpose of PGIS activity:*** Analytical and operational clarity about the purpose of the PGIS exercise is a key element. There are many purposes and justifications behind P-Mapping. It is important to establish from the start whether the purpose is to satisfy Government or community objectives.
- ***Ownership is key:*** Ownership of the outputs as well as the knowledge inputs is vital. Ownership determines who sets the purpose, and what that purpose is. It decides on priorities and establishes the extent of the practice in terms of technology, information sources and spatial extent.
- ***PGIS facilitators should avoid raising expectations:*** Ownership creates expectations. Any process or project facilitated by an outsider is liable to raise expectations of some benefits to the community, even if clearly nothing concrete may follow from the activity. If the purpose lies outside of the participating community, the risk of this is greatest.

- ***Clearly define outputs:*** It must be clear from the start what the geospatial outputs or products are going to be, and for whom they will be relevant. PGIS products should be simple, clear, understandable, testable, and convincing, as well as relevant, reliable, logical, replicable and coherent.
- ***Anticipate conflicts:*** Every collaborative or participatory process elicits conflict. Conflicts result from misunderstandings or false expectations, and can be mitigated by transparency. By discussing collaboratively what might be the (negative) impacts of the outputs, local people can become more aware of discrepancies in terms of resource allocation or negative environmental conditions. Providing a platform for discussion can prevent conflicts from escalating.
- ***Not all knowledge should become public knowledge:*** Each community has a right of confidentiality to the geospatial data it produces. Community members in a PGIS exercise may be "illegal" squatters. Local authorities do not want to publicize neighbourhood crime maps that give a bad impression or would lower real estate values. Ownership by the community would allow them to decide who can access the data and under which conditions.
- ***Research the crowdsourcing phenomenon:*** The novelty of crowdsourcing applications for better governance is proportional to the difficulty of understanding and explaining their success or failure. Little is known about the behaviour of public officials towards information volunteered by ordinary citizens and their willingness to grant legitimacy to citizen-generated data on their core business: the provision of public services.

7.5 Cost and cost-efficient access to geospatial data

If a country or organization lacks high-speed Internet access to receive geospatial data, it should consider installing GEONETCast as a low-cost alternative (see box 7.1). Also, if financial constraints limit the ability to purchase commercially available software, GEO has an inventory of open source programmes for relevant tools that can be accessed through the GEO Portal.[33] This extensive inventory is frequently updated with a range of open source tools which are free of charge.

However, as discussed in section 6.5, even where software is free, customizing it for specific needs often requires finance and highly skilled software developers who may be lacking. New deployment types such as the cloud (for software and/or services and/or data maps) can significantly reduce the maintenance cost of a platform while increasing the potential number of users, opening up a new dimension in system design and sizing. Technological advancements can therefore drive down the costs of establishing an SDI. In addition, the private sector provides tools and functions for freely sharing and accessing data over the web, such as Esri's ArcGIS Online. Data sets can be searched and retrieved; communities of interest can be built for data and knowledge sharing.

Despite these possibilities, ultimately developing countries may well need support from donors if they are to overcome the basic cost challenges described in chapter 6. There is a strong record of donor involvement in GS&T in developing countries.

Almost all government ministries using geospatial technologies in Africa received the initial impetus for GIS usage from projects funded by foreign donors or international financial institutions (Conitz, 2000). While it is impossible to put a number on the amount of foreign aid invested in Africa in the geospatial sector, for land administration alone, at least $715 million was invested for the period 2002–2012 (Johnson 2011). Other significant areas of donor spending of GS&T includes climate for development in Africa (ClimDev) at $136 million, the West African Science Service Center on Climate Change and Adapted Land Use (WASCAL) at €100 million, and the Central Africa Regional Programme for the Environment (CARPE) at $53 million (Lance et al., 2005). Donor targets have shifted over time from Government, to the private sector, to NGOs and civil society organizations (Lance, 2012).

It is clear then that international donors can play a significant role in helping developing countries to overcome the financial and cost challenges they face in implementing geospatial technologies. Challenges remain for all parties concerned such as how to coordinate initiatives between ministries, recipients and donors to avoid a silo approach or unnecessary duplication. However, developing countries should continue to explore the potential for donors to help them overcome financial challenges when implementing SDIs.

Box 7.1 GEONETCast - low-cost access to geospatial products, services and satellite data: practical opportunities for capacity-building

GEONETCast is a near real-time global network of satellite-based data dissemination systems designed to distribute space-based, airborne and in situ data, metadata and products to diverse communities. GEONETCast is a task in the GEO Work Plan and is led by EUMETSAT, the United States, China, and the World Meteorological Organization (WMO). Many GEO Members and Participating Organizations contribute to this Task. Currently, GEONETCast applications are available for all societal benefit areas. Prime application areas are weather, water and disasters.

GEONETCast is a low-cost dissemination system with the additional advantage that it can be used in areas without fast and reliable Internet services, conditions which prevail in many African countries. The system is already well anchored in the meteorological community.

Processing tools are needed to exploit the full potential of GEONETCast for use by non-meteorological organizations. Several initiatives are ongoing to sustain the development of more applications. One example is the GEONETCast toolbox developed at ITC, which builds further on EUMETSAT software and enables users to import data into ILWIS GIS for further analysis. ILWIS is open source GIS software under GPL license available at 52north (http://52north.org/). At this site, the GEONETCast toolbox can also be downloaded. The number of downloads of the toolbox by interested users is steadily growing. The GEONETCast applications based on the toolbox require little resources, while all knowledge to customize applications to local needs is accessible online at no further cost.

As a result, a new community is emerging, promoting the use of free near real-time environmental and earth observations data (in situ, airborne and space-based) and derived products for worldwide use. Using inexpensive, off-the-shelf equipment, the data can be directly received from communication satellites. This capability, in conjunction with data from freely accessible archives, provides the possibility of obtaining a multitude of environmental and EO-related data. This information is highly relevant for various application domains, such as weather, atmosphere, oceans, land, vegetation, water and environment.

To allow the user community to grow spontaneously as an open network, anyone can join by using own resources to set up the system and by acquiring knowledge on how to install and operate the system and set up specific applications. With online tutorials and manuals, exchange platforms, a distance education system is available enabling anyone with basic knowledge of GS&T to engage in setting up a receiving station and start with applications.

7.6 Capacity-building of human resources

Chapter 2 discussed some of the benefits for human resource capacity-building at regional level. This is particularly the case for developing countries, which may have strong financial constraints, as regional capacity-building allows resources to be pooled and economies of scale to be realized. The first step in establishing a regional capacity-building plan should be the prioritization of societal benefit areas, by examining Earth processes and institutions in the region. For example, in some regions disasters may be the SBA of most concern, whereas in other regions disasters may be of little concern and the focus could be on other areas such as health or biodiversity

The next step should then be the creation of an inventory of capacity in the region with regard to GS&T, in terms of research institutions, universities offering GS&T education, space expertise and private sector expertise. The advantage of a regional approach is the ability to share education and research capacity across nations. For instance, one university programme in GS&T could cater to the needs of the entire region; not all nations in the region need to be space-faring and launch their own remote sensing satellite to access the data which they need.

The third step involves the identification of regional opportunities and bottlenecks. The science, engineering and technology capacity required may exceed the combined capacity of all existing research institutions and government departments in the region. This being so, cooperation and partnerships across the public–private sector divide are an absolute necessity. The final step involves the actual development of the regional strategic plan via a network of regional organizations to contribute to and benefit from GEO capacity-building initiatives; identify existing programmes; and involve the geospatial community.

Capacity-building packages depend on the priorities relevant for the region/nation. A "one-size-fits-all" approach to capacity-building will not offer an optimal solution. From the variety of capacity-building interventions, the optimal package for a region or nation will depend on the SBAs relevant for that region and the related target groups. Capacity-building is a long process. Experience shows that about 10 years may be needed before a capacity-building programme with (joint) research starting from scratch can become truly sustainable (GeoNetCab, 2011).

At the global level, issues such as certification of training, cross-border recognition of diplomas and certificates, and quality assurance across nations in a region are crucial. Within the framework of GEO, various workshops are being organized to address issues of cross-border recognition. A first step would be the certification of international short courses in GS&T. This would allow countries, organizations or universities that already have systems in place, or strong vested interests, to keep or establish their own capacity-building systems while ensuring coordination and compatibility.

As discussed in section 6.6, there is a danger that when capacity-building programmes in developing countries are completed, locally trained staff immediately leave, taking their skills with them and undermining the capacity-building objectives. Two possible alternatives are available to deal with this issue. One is to train more staff than will be needed. This will clearly be reliant on funds but has its advantages. First, it will ensure that a sufficiently sized dedicated local team will remain in place to meet ongoing needs after the project team has left. Second, where trained staff do leave for the private sector but stay in their country, this should also be seen as a benefit. People trained in GS&T will still be in the country and will remain part of the country's GS&T capacity. Alumni networks can be used to keep in touch with former students and ensure that their skills can still be used. The other alternative is to place restrictive covenants in the terms and conditions of training. These restrictions could include an obligation to pay back any tuition fees if the trainees leave their position within a certain period of time.

The preferred method will depend on the specific programme, but the key issue is that in any development programme, capacity-building should be considered as one of the main aims from the beginning. Organizations conducting geospatial projects in the developing world should always look to collaborate with local staff and build capacity as they go, rather than arrive, perform a service and then leave.

In order to raise awareness and educate policymakers and managers about GS&T, opportunities and achievements need to be promoted and disseminated to various levels of decision-makers. There is a need for short courses at all levels to familiarize professionals of all types with GS&T applications. These range from short courses for engineers or geographers with different backgrounds, to seminars and workshops for decision-makers. The potential demand for this type of capacity-building is huge, as the benefits of GS&T applications become more and more apparent. The number of different subjects is also substantial. This demand can be partly addressed by the regular educational system and partly by specialized organizations and/or special initiatives in a project or programme format.

7.7 Research

To address current gaps in knowledge, significant research challenges need to be tackled at the nexus of GS&T and citizens' knowledge. Crowdsourcing applications are new, and understanding and explaining its successes and failures so that these can be learnt from will be challenging. A better understanding of the incentives for citizens to contribute and ways to validate the quality of citizens' reports is needed. Little is known about the behaviour of scientists to citizens' contributions (e.g. in environmental monitoring) and of public officials towards information volunteered by ordinary citizens.

Research is also needed at the nexus of geospatial science and policymakers. Science and public policy are not distinct domains. Their interdependence is so strong as to spark processes of co-production of relevant knowledge. Analysis is needed of the social, policymaking and knowledge production processes through which varying types of knowledge (scientific, practical expertise, administrative and citizen/lay knowledge) are co-produced by scientists, policymakers, stakeholders and citizens. This analysis should cover areas including spatial planning, environmental policy, land administration and disaster risk management. The focus should be on the body of scientific, cultural, pragmatic and lay knowledge which, in different political regimes, informs decision-making.

Interdisciplinarity is essential in GS&T research. Overcoming legal, institutional, and broader social issues requires geospatial scientists, land administrators, spatial planners to work with scholars from public administration, economics, law, and political science. Studying Earth processes and organized human activity in disaster risk management is only possible with interdisciplinary approaches.

Finally, researchers should consider the audience for their work to be not just the GS&T community but also the wider community of Government, NGOs and other users of geospatial data and findings. The GS&T community should therefore seek to reach beyond its traditional audience and disseminate its work more widely. Conferences and other GS&T community events could become more outward-looking, and in some instances include policymakers as speakers or guests so that the technical community could hear the policymakers' perspective on GS&T.

7.8 Conclusion

This study has demonstrated some of the ways in which GS&T can be used to support development in a variety of areas. GS&T is a powerful tool that can provide several benefits and as it develops, the range and scope of benefits its application can provide will continue to increase. GS&T experts have predicted that in the next five to ten years, geospatial data are likely to become more ubiquitous and technological evolution will continue to accelerate, leading to cheaper and more accurate geospatial technologies. Previously niche technologies may become mainstream, and the proliferation of geospatial technologies in everyday products such as smart phones is likely to fuel growing use of crowdsourcing.

However, it is important to note that no matter how advanced geospatial tools become, they are not a panacea and do not solve all problems. Geospatial science only provides tools and enablers. These in themselves do not solve issues relating to existing legal frameworks, institutional blockages, social arrangements or any of the development challenges discussed in this study.

This study has provided a number of examples where GS&T has been used by policymakers and other actors to address specific development needs. It would not be realistic for a single country to attempt to develop capacity in every application of GS&T covered in this study. Instead, an assessment should be made of what the specific needs of a particular society are and which of those needs GS&T can help to address. National SDI strategies should therefore focus on the priority areas where GS&T can have a significant impact. Not all benefits will be equally important to all countries, and therefore it should be expected that national SDI strategies will vary significantly.

To fully realize these benefits, several challenges need to be overcome. These range from the specific challenges discussed in chapters 3, 4 and 5 (such as difficulties in locating underground infrastructure assets or the technological limitations of GPS in busy urban areas) to the more overarching challenges discussed in chapter 6. Governments will not be able to effectively address these challenges by acting on their own. With regard to the levels discussed in chapter 2 (global, regional, government and citizen), it is important to note that action at each level is required and that the different levels are all interdependent on each other. National SDIs would not be nearly as effective without global initiatives to agree common data standards allowing countries to exchange information more easily. Regional collaboration would not be possible without national or subnational governments collecting data and providing resources. Citizens collecting geospatial data individually rely on globally available tools such as Google Earth, Open Street Map or ArcGIS Online to provide data on a global scale. Therefore, governments will need to collaborate with each other, with global institutions and companies, and with individual citizens if they are to fully harness GS&T to support development.

All of this will require significant investment in both time and resources. However, the scale of the potential benefits of successful application of GS&T in development means that this investment should be more than worth it.

NOTES

26. SDI Cookbook, available from http://www.gsdidocs.org/GSDIWiki/index.php/Main_Page>. (accessed on 2 May 2012), See also http://www.gsdi.org/gsdicookbookindex.
27. See http://www.codata.org/index.html
28. See http://www.openstreetmap.org/
29. See http://blog.standbytaskforce.com/about/
30. See http://www.mapaction.org/
31. See http://giscorps.org/
32. See http://digitalhumanitarians.com/
33. The GEO Portal is available from http://www.geoportal.org/web/guest/geo_home
34. United Nations Committee of Experts on Global Geospatial Information Management, (2012), “Future trends in geospatial information management: The five to ten year vision” available from http://ggim.un.org/docs/meetings/Netherlands/Future%20trends%20in%20geospatial%20information%20management%20summary_12April.pdf

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