# Spatial Information for assessing Land Issues in Disaster Risk Management

**Jaap ZEVENBERGEN, Norman KERLE and Arbind TULADHAR, the Netherlands**

**Key words**: disaster risk management, spatial information, land issues

## SUMMARY

Disasters are occurring frequently around the world, and their impacts on people's life and livelihood are very large and rising. The increasing amounts of spatial information being collected around the globe can contribute towards mitigating disasters and reducing their impacts to some extent. However, the effective use of spatial information in the different phases of Disaster Risk Management (disaster risk assessment, risk reduction, emergency response, and recovery and reconstruction) is always challenging and variable. While positive examples do exist, there is also ample room for improvement.

Satellite images have become the most visible, and overall arguably the most useful form of spatial data employed following disaster events. In the emergency and early recovery stages after a disaster, when time is crucial, especially tasked satellite images are made available to a number of processing agencies through the International Charter 'Space and Major Disasters'. In the recovery and reconstruction phase, the satellite images (and not open format data) that were made available early on can often not be reused for later steps, due to licensing restrictions and Charter legal agreements. The utilization of crowdsourcing and volunteered geographic information has been making an increased impact after disasters (especially the Haiti 2010 earthquake), but are also hard to keep up in the next phase. Overall the impact of spatial information shortly after a disaster is still limited by many hindrances, e.g. satellites orbits, expertise needed to work with the data, and limited field validation of damage assessment results. In the next recovery and reconstruction phase, the fact that spatial data are normally (in non-disaster circumstances) not easily shared between agencies, not freely available and come with a number of restrictions and difficulties for their uses starts to play an important role as well. Other aspects like land tenure issues also become important and call for different types of spatial information on land and properties.

Little, though increasing, effort is being made before a disaster hits to acquire and process information on the hazards and the elements at risk, and spatial information on land tenure relations. A large gap remains in many parts of the world, especially where people lack security of tenure, adding to their vulnerability to disaster.

Despite the clear realization of the value of readily available current and usable spatial data – acquired both prior and in a timely manner following a disaster event – for an effective response, much remains to be done. The paper highlights this for each of the phases in DRM.

# Spatial Information for assessing Land Issues in Disaster Risk Management

**Jaap ZEVENBERGEN, Norman KERLE and Arbind TULADHAR, the Netherlands**

## 1. INTRODUCTION

Disasters are occurring frequently around the world, and their impacts on people's life and livelihood are very large and continue to increase. Especially people with limited access to resources and political support are extra vulnerable to disasters; they are often struck by them, and the relative consequences on their livelihood are often large. Many publications indicate that spatial information and the uses of spatial analysis tools can be effectively used in each of the stages of Disaster Risk Management (DRM), i.e. disaster risk assessment, risk reduction, emergency response, and recovery and reconstruction. If appropriately used, the increasing amounts of spatial information being collected around the globe contributes to reducing disaster risk, as well as the impacts of disaster events to some extent, and even increase community resilience during the disaster period.

The overall use of spatial information for the support of government activities, including for example land administration, physical planning, housing development, and transport, has been receiving a lot of attention over the last two decades. UNECE (1996) clearly shows that spatial information supports effective land administration, and is a basic requirement for the growing need of secured land tenure and to support management of land based activities such as DRM from the social, environmental and economic perspectives to achieve sustainable development (Tuladhar, 2004). During most of this time the attention was focused on the supply side of the spatial information, and how to share it among different stakeholder, in a field that became known as 'spatial data infrastructures (SDI)', also known as National Geographic Information Systems in some countries.

Despite the clear realization of the value of readily available current and usable spatial data – acquired both prior and in a timely manner following a disaster event – for an effective response, much remains to be done. The paper highlights this for each of the phases in DRM, after starting with a section on access issues for spatial information.

## 2. SPATIAL DATA INFRASTRUCTURE, CROWDSOURCING AND VOLUNTEERED GEOGRAPHIC INFORMATION

Margareta Wahlström, the United Nations Assistant Secretary-General for Disaster Risk Reduction, wrote in the preface to the book 'Geo-information for Disaster and Risk Management: Examples and Best Practices' the following:

> "Each year, disasters arising from storms, floods, volcanoes and earthquakes cause thousands of deaths and tremendous damage to property around the world, displacing tens of thousands of people from their homes and destroying their livelihoods. Developing countries and poor communities are especially vulnerable. Many of the

deaths and property losses could be prevented if better information were available on the exposed populations and assets, the environmental factors in disaster risk, and the patterns and behavior of particular hazards. Increasingly, this information is becoming available with the help of technologies such as meteorological and earth observation satellites, communication satellites and satellite-based positioning technologies, coupled with hazard modeling and analysis, and geographical information systems (GIS). When integrated into a disaster risk reduction approach, and connected to national and community risk management systems, these technologies offer considerable potential to reduce losses to life and property. But this requires a solid base of political support, laws and regulations." (JB GIS, 2010).

Issues around access to spatial data are discussed next, followed by the developments around crowdsourcing, especially linked to disasters.

### 2.1 Spatial data infrastructure and spatial data sources

The biggest challenge for the disaster risk management is timely availability and accessibility of reliable, current and accurate spatial information. The notion of SDI is meant to share and improve access to spatial information in a consistent manner for effective uses of variety of geo-datasets in application domains such as DRM. These dimensions include spatial data (such as topography, elevation models, administrative boundaries, geographical names (gazetteering), certain thematic data sets, cadastral data sets), standards, access and service technology, institutional framework and policy including costs and pricing policies (Groot and McLaughlin, 2000). Although progress has been made at the conceptual level of SDI, the number of countries with an actually well working SDI in place is limited, and more work is still needed there, for instance on focusing much more on the use and demand side of the spatial information, e.g. on striving towards Spatially Enabled Government and Society (Steudler and Rajabifard 2012).

Until Geo-ICT emerged as a concept around 1990, maps were considered the principal source and repository of spatial data. Many different types of maps existed, each focusing on a different set of phenomena, such as geographic, geological, geomorphological, topographic, road, city, or cadastral maps. In the past aerial photogrammetry has helped early on to map visible features and changes in land covers. Now, with an increasing amount of platforms (e.g. geostationary satellites, low orbit satellites, airplanes, unmanned aerial vehicles (UAVs)) and variety of sensors (visible, thermal, infrared and radar), an increasing number of the features of the earth surface can be remotely sensed. But certain features can still not be seen from space, especially social-economic information (on land tenure relations, size of household, financial situation, etc.). The use of physical proxies has allowed non-directly visible social phenomena to be assessed, such as social vulnerability (Ebert et al., 2009). Field verification improves the reliability of such information.

Geo-ICT does not only help to collect information, but also to analyze the data, by allowing integration of different types of spatial information (structured in layers) within geographical information systems (GIS). However, this requires that all the information is brought in relation to the same geodetic reference system. Satellite-based navigation systems such as GPS have made it much easier to do so. For a first rough cut, e.g. whether a bridge is still standing or not, or a house has collapsed or not, even a handheld GPS and many mobile devices already provide enough accuracy to support DRM activities. Increasingly complex models allow combining information and make it possible to estimate and predict a growing number of phenomena from a distance in a GIS environment. Damage assessment modeling (for terrain and esp. buildings) is a very useful tool after disasters. However, the impact of spatial information has been constraint due to data limitations, like satellites orbits, data costs, expertise needed to work with the available data, lack of pre-disaster maps, lack of damage map standards, and limited field validation of for example damage assessment models.

Many of the countries that are most often hit by disasters have less developed economies and usually also less spatial data and very rudimentary data sharing arrangements such as SDI. Groot and McLaughlin (2000) indicates that having a facility or organization that acts as 'broker' between data users and the suppliers can improve the integrity, timely accessibility and sharing data for the applications in the domain. A lot of spatial data at different scales are being generated via both national and commercial satellite operators and data processors. Such data, certainly the high resolution ones, are normally not freely available and come with a range of copyright restrictions. In the emergency and early recovery stages after a disaster, when time is crucial, specific images are made available to a number of processing agencies via the International Charter 'Space and Major Disasters' (Stryker and Jones, 2009).

## 2.2. Crowdsourcing and volunteered GI

Over the last years, the ordinary citizens have been increasingly collecting spatial information with handheld devices (like smartphones and handheld GPS), or contributing through web-based data collection portals, in what is called neo-geography, crowdsourcing or volunteered geographic information (Goodchild, 2007). While the concept goes back more than 100 years, the tools and Web 2.0-based approaches are new, and are having an increasing impacted on disaster response, including damage mapping. Beginning after the 2008 Wenchuan (China) earthquake, in particular following the 2010 Haiti earthquake disaster crowdsourcing in different shapes became a prominent approach (Kerle, 2013; Kerle and Hoffman, 2013). At its most basic, crowdsourcing can be divided into passive and active contributions. For example, by aggregating active mobile phone profiles clues about the situation on the ground (e.g. power outages quickly leading to a decline in active phones) can be obtained, while an analysis of geotagged (based on IP addresses) search term use can demarcate disaster hotspots. Such passive volunteering of information has become a valued source of disaster-related intelligence, and the behavior of the masses has been shown to be surprisingly quick and accurate in terms of revealing trends and emerging incidents. In addition, following major disasters typically a huge willingness to help is evident, including by people entirely unaffected by the given event. A meaningful contribution is the provision of geotagged incident reports and photos, for example on Ushahidi, the most prominent disaster reporting website. Following the 2010 Haiti earthquake Google Map Maker and OpenStreetMap also drew the support of thousands of lay volunteers, who mapped roads and landmarks in Port-au-

Prince and environs in great detail in a few days (Heipke, 2010), providing a much needed base map for all subsequent disaster response and rehabilitation work. In addition to mapping roads also many crisis field reports were generated using social media platforms. The growing strength of the citizen mapper is also well reflected in the Crisis Mappers community (http://www.crisismappers.net) that now has nearly 5,000 members, and that largely took charge of coordinating the unofficial Haiti damage mapping. Following the Haiti earthquake this community also showed how a direct engagement between distributed volunteers and both affected people and volunteers on the ground is possible.

Recent disasters, also starting with Wenchuan and peaking with Haiti, have also seen attempts at image-based damage mapping by volunteers trained in image analysis, a more advanced form of active crowdsourcing. In the Global Earth Observation-Catastrophe Assessment Network (GEO-CAN) some 600 experts mapped damage based on satellite and aerial images, with this information later serving as the basis for the post-disaster needs assessment (PDNA). While GEO-CAN has been largely seen as a success (e.g. Barrington et al., 2011), also substantial limitations of the approach have been highlighted (Kerle, 2011; Kerle and Hoffman 2013).

## 3. EMERGENCY RESPONSE

Following an incident leading to the damage that exceeds the coping capacity of the affected place or area, i.e. a disaster by definition, a rapid understanding of the nature, extent and severity of the consequences is needed. The principal reason is that because of the insufficient ability to deal with such an amount of damage, external assistance is needed to address the disaster consequences, the type and scale of which can only be determined by adequate intelligence about the disaster.

Similarly, spatial information is needed for evacuation and siting of emergency shelters. With power outages, patchy or conflicting field reports, infrastructure typically affected by the event and access to the site impeded, rapid generation of a clear picture of the damage is very difficult. Remote sensing images seem a natural solution as they have additional advantages:

- a synoptic perspective that potentially covers the entire affected area,
- excellent cost-per-area-unit characteristics,
- standardized acquisition parameters (repeat visits always at the same time of day and, in standard configuration, with the same viewing angle), allowing for effective multi-temporal monitoring,
- provision of an objective record of the disaster scene, ideally augmented with pre-event reference imagery, and
- availability of a suite of different instruments to address a wide range of disaster situations and information needs

Disasters are hugely variable in type and, consequently, their physical characteristics. Those can be expressed as spatial (e.g., shape, extent), temporal (e.g., onset, duration, dynamics) and spectral (e.g., visible, thermal) characteristics (e.g., Kerle et al., 2008; Zhang and Kerle, 2008). A suitable remote sensing solution needs to match those disaster parameters, meaning that a high spatial resolution instrument is needed to map detailed structural damage or to identify markers for property boundaries, while an instrument with less detail but wider coverage is more suited to map the extent of vast disasters. Similarly, images in the visible domain show the situation as a human would see it, while a thermal sensor is needed to pick up heat signals. Radar data are suited to detect structural information or ground subsidence, and to penetrate cloud clover, while data in the infrared part of the electromagnetic spectrum can detect consequences such as changes in vegetation health. This ability to customize a remote sensing-based response is a strong asset. However, it also means that for a given information need only few instruments may exist that, due to orbital restrictions, are not always immediately available, leading to data acquisition delays of days or even weeks. Furthermore, the vast range of instruments results in very specific data that often require expert knowledge and specialized tools to process and interpret.

To ensure maximum data availability and suitable processing after a disaster, the International Charter 'Space and Major Disasters' was established in 2000 by three major space agencies (the European (ESA), French and Canadian Space Agencies), and has subsequently grown to include virtually all civilian operators of satellites (currently 22 organizations). The Charter gets activated primarily for rapid onset hydrological or geophysical disasters (e.g., floods, landslides, earthquakes). Complex humanitarian disasters (e.g., civil unrest, famine) and technological disasters (with the exception of significant oil spills) are not included (see www.disasterscharter.org). The Charter gets activated by a standardized procedure, and satellite image data suitable for a given event type are acquired on a priority basis. The images have traditionally been processed, also on a priority basis, by professional analysts at UNOSAT, the German Aerospace Center' Center for Crisis Information (DLR-ZKI) and SERTIT (based at the University of Strasbourg, France). Typical results are print-optimized PDF maps showing information such as flood extent, landslide location, wildfire scars, or structural damage distribution. Recently it was announced that the Charter is now offering 'universal access' to the data for emergency response purposes (Geospatial World, October 2012). The Charter is generally seen as a successful case of international cooperation, though some limitations in the process have also been identified. The high number of annual Charter activations, currently around 40, together with frequent absence of reliable field information, means that results are rarely validated (Kerle, 2010). In recent years other organizations have become involved in image-based damage mapping, including Information Technology for Humanitarian Assistance, Cooperation and Action (ITHACA, based at Torino University, Italy), the United Nations Cartographic Section (UNCS), the European Union Satellite Center (EUSC), the Information Management & Mine Action Programs (iMMAP), and the Joint Research Centers of the European Commission (JRC). This has led to a confusing situation as to who provides authoritative disaster information, as well as to substantial duplication of damage assessment work (Kerle, 2011). Some national mapping agencies or national remote sensing centers act as project managers for a Charter activation and do some of the mapping as well. Since the actual satellite images are typically not made available by the processing organizations, they cannot easily be used to address additional questions, such as to detect property boundaries in support of an adjudication process.

While civilian satellite images, which now achieve spatial resolutions of approximately 40 cm, have become a standard tool in damage mapping (e.g., Voigt et al., 2011), airborne data played a more important role. It was shown that about 10 times more damage could be mapped with 15 cm resolution aerial images compared to the satellite-based results (Lemoine, 2010). Also airborne Pictometry data (imagery with 4 oblique views and a vertical image) were used to map damage, with façade views providing extra information (Gerke and Kerle, 2011). In principle such image data are also useful to help preserve information on the immediate post-disaster situation related to property boundaries (before cleanup operations or secondary disasters alter the scene) that can later aid in the adjudication process. However, very little work has been done on the extraction of actual cadastral information from imagery. An example is Ali (2012), who used participatory methods to extract parcel information from satellite data. Anderson (2000) had previously shown how local participation together with simple aerial images can be used to map land rights (see also Lemmen and Zevenbergen, 2010). In crisis situations pre-event images should be used to extract property boundaries to support the post-disaster response and reconstruction process. However, for those situations where no suitable data exist, better conceptual frameworks and methods are needed to derive the maximum amount of information possible from the post-event imagery to settle ownership or property location/boundary disputes. As was done by Ali et al. (2012), involving the stakeholders in the analysis is one option, and many participatory GIS approaches have been developed. This collaboration based on face-to-face interaction can be considered as one end of the collaborative mapping spectrum

## 4. RECOVERY AND RECONSTRUCTION

Availability of a variety of both pre-disaster maps and post-disaster imagery will help to plan for camps, and ideally even for emergency shelter (although that will be needed immediately depending on the climate). Satellite data proves to be useful to detect, quantify and monitor refugee and IDP camps (e.g., Kemper et al., 2011), and are routinely used to map hazards. The latter is needed to ensure that camps are not permanently located in hazardous area (often amongst the few vacant spaces). Especially when housing is severely damaged or totally destroyed, it will take a longer term to rebuild them, and thus the sites of camps become important since they will be around for quite some time. It is not unusual for certain camps to even become permanent new settlements. Suitability of the site relates to numerous topographic issues (size, sloping, drainage, access to water, link to road system, etc.), but also whether the area may be considered safe, and is not prone to (another) disasters (after an earthquake one does not want to end up in floodplain). Finally, the pre-existing land tenure situation is important, since it regularly happens that emergency shelter and camps are put up without consulting the host communities, which might lead to land disputes later when the site starts to turn permanent.

The phase moves then to the planning and building of new housing, and eventual dismantling of temporary shelters. Rebuilding in situ has to be carefully considered for a number of perspectives. In general there is an aim towards ‘building back better’. First of all the area should be (re)considered from a hazard perspective. It is not unlikely that (large) parts of the affected area had already been identified as falling within hazardous zones, but people lived there anyway because of lack of knowledge, lack of alternatives or due to livelihood choices. For example, in Aceh an extensive non-building zone along the coast was suggested, which would create long commutes for e.g. fishermen.

If no hazard maps have been prepared yet, they should be prepared at this stage, and existing hazard maps need to be revisited. The disaster might shed new light on the models used during hazard mapping, or the situation has changed after the disaster. Different sets of spatial data contribute to these analyses, although of course appropriate models are at least as important. Finally, remote sensing data are ideally suited to provide a basis for a detailed assessment of reconstruction progress (Guo et al., 2010) by monitoring the speed and quality of, for example, house rebuilding.

As emphasized before, a careful selection of data and processing type is needed for an effective assessment of different hazards (Joyce et al., 2009; Kerle et al., 2008). Access to the appropriate spatial information, however, becomes a problem again during the recovery and reconstruction phase. The images (and not open format spatial data) that were made available early on in the emergency response phase can often not be reused for later steps. The 'normal' fees and conditions start to apply again. Other aspects such as land tenure issues become important and call for different types of information.

As part of reconstruction, the land tenure arrangements of the affected people become increasingly important. In certain settings, funds to rebuild a house are only released if formal land documentation can be supplied. This is always a challenge, but certainly unrealistic in areas where the formal land sector only had a limited impact before the disaster, and the people's land tenures were customary, informal or otherwise extralegal. Spatial data showing land use cover can support claims as far as they show which land was in use (and even which type of use), and show the general, visible boundaries as well. It cannot help to determine which person was using, let alone owning, the land or house. However, aerial images can be a powerful tool in a broader enumeration or participatory mapping project or community driven adjudication. Figure 1 shows the integrated map of land use and flood zones in Chitwan district of Nepal (Chaorenlynyuta, 2011).


Figure 1: Present land use conditions and flood affected zone in Chitwan, Nepal (taken from Charoenkalunyuta, 2011)

In areas with good coverage of land documentation, including cadastral maps, issues may still occur when some of the land has been lost (e.g., to the sea) or when severe, regional and local, displacement has taken place. A first issue that needs attention is to re-establish the survey control points that have been lost or severely damaged. New marks may need to be placed and re-surveyed using GPS or conventional surveying techniques. Although GPS (or other GNSS) approaches are increasingly used for cadastral work in a setup with Continuously Operating Reference Station (CORS) stations, land administration systems, including cadastral maps, are legacy systems that contain a lot of information collected in the past with technology appropriate at that time. With restored survey control points, ground based techniques can be used for surveys to demarcate boundaries and for positioning of all rebuilding activities. It can also be used for ground truthing of aerial data sets. In case of seismic induced disasters, there is also the need to deal with deformation of the earth crust, leading to displacement of buildings, roads, local survey control points and even regionally the whole survey control network.

After the 2011 East Japan Great Earthquake and Tsunami, post-seismic deformation mapping of survey control network showed enormous movement. 44,000 official survey points were affected, with horizontal movements of up to 5.6 meter. Even the origin of the network in Tokyo had moved 20 cm. With specific geodetic techniques (including a Very-long-baseline interferometry station and GPS), 600 were re-established. The Ministry of Justice had ruled that the boundaries moved with the land, except for the effect of local landslides, and thus made the coordinates relative to the terrain objects, which we see as a wise and practical approach. The relevant geodetic authorities (GSI) created software for coordinate transformation to restore the boundaries. Control points were re-established to aid the resurveying of boundaries, especially in locally distorted areas with landslides and liquefaction (Sekine and Nanjo, 2012). Furthermore, the Ministry of Land re-surveyed the boundaries of public properties first so that they will be referred to as reliable known boundaries when private properties start to come in. The nearly complete digital data of the land registries and cadastral maps in the area had been backed up in the central database (Kaidzu, 2012). Similar issues needed attention in Christchurch after the 2011 Earthquake (Donnelly et al., 2011).

## 5. DIASTER RIKS REDUCTION

It is widely accepted that resources invested in disaster risk reduction are eclipsed by the cost incurred if disasters do occur, yet too little effort is being made to access and reduce risk. The last decade progress has been made to shift the attention to disaster risk reduction, especially since the Hyogo meeting, and the resulting Hyogo Framework of Action. Increasingly, hazard maps are being prepared that show where and with which intensity the different hazards are likely to occur, and with which elements at risk (e.g., people, infrastructure, economic or environmental processes) and which hazard-specific vulnerabilities exist. The latter includes information on land tenure relations, such as where people work and live. In combination all these data serve to quantify risk. Mitigation measures can then be put in place where needed the most, such as placing buildings on shock absorbers, strengthening dykes and damns, breakwaters, hurricane shelters, installing early warning systems, evacuation routes and drills, educating people, etc.. Very hazardous areas, once identified, can even be rezoned to less intense or near human free land use types.

However, it remains much more difficult to have all the necessary spatial information available in the disaster risk reduction phase (ideally before a disaster hits and to be revisited after one). Even though increasingly work is being done on hazard mapping, as well as on documenting land tenure relations, a large gap remains in many parts of the world. Especially people with little money and other resources who lack security of tenure are extra vulnerable to disaster; they are more often struck by them, and the relative consequences for them are also larger.

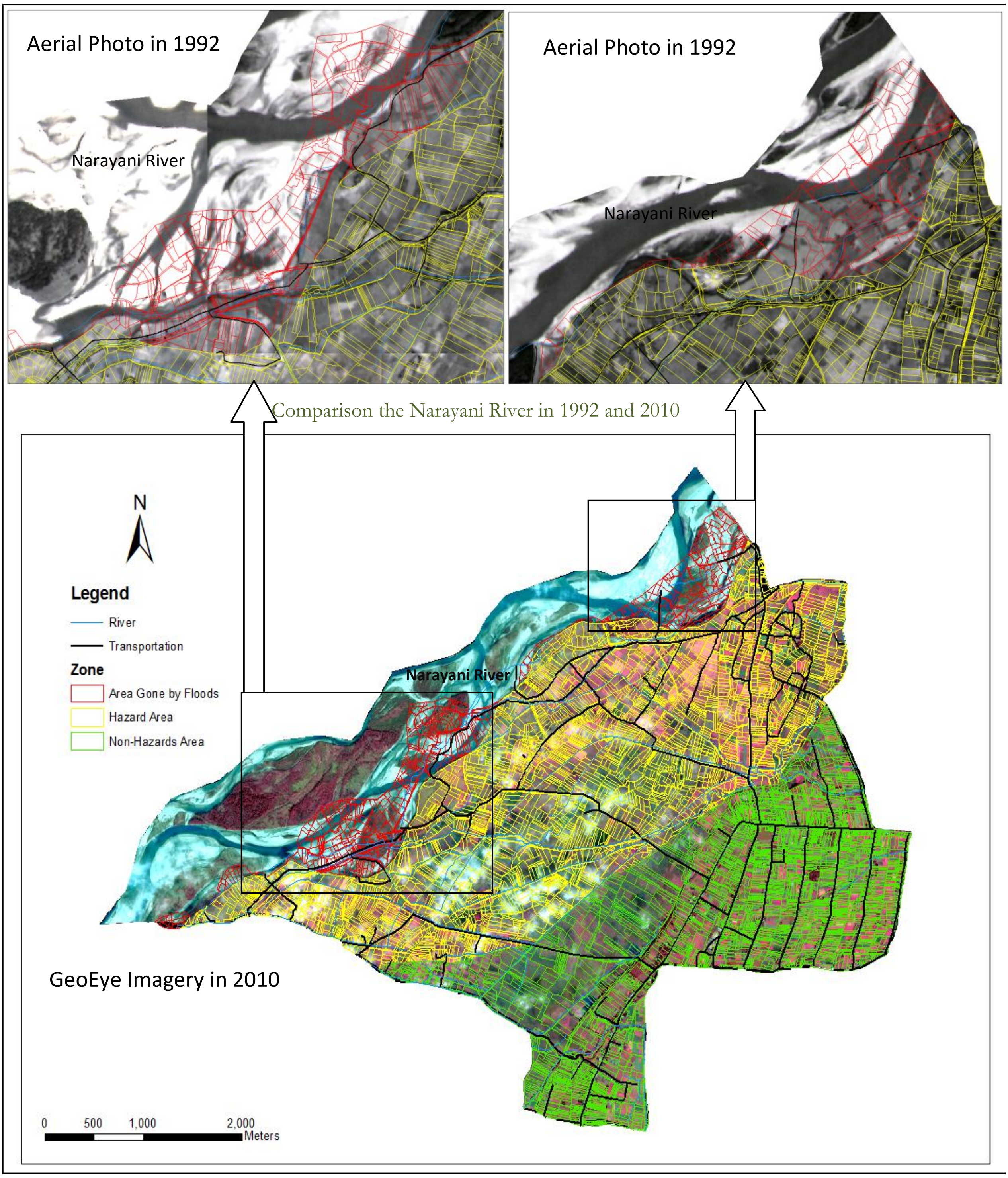


Figure 2: Land parcels (in red) flooded in Narayani River in Chitwan, Nepal (taken from Charoennkalunyuta, 2011)

In the meantime a lot of countries, partly with support from donors, are working very hard on preparing hazard maps and disaster risk atlases for specific areas. Sometimes it involves a city or region, sometimes an entire country. A quick look through some of the geospatial magazines in the 2nd half of 2012 shows many examples. For instance UNDP funded hazard maps of the whole of Sri Lanka, focusing on coastal hazards, landslides, cyclones, droughts and floods (Geospatial World, September 2012). Another example is the 'Risk Atlas Georgia' prepared as part of the project 'Institutional Building for Natural Disaster Risk Reduction (DRR) in Georgia' by ITC and the Caucasian Environmental NGO Network (CENN). Due to Georgia's geographic location between the higher and lower Caucasian mountains, it is exposed to a number of different natural hazards. A main result was the national scale hazard and risk atlas of Georgia that was made together with national expert organizations. The main goal of the "Atlas of Natural Hazards and Disaster Risks" is to provide national and local governments, businesses and the local population with information about existing and potential natural hazards, risks and socioeconomic vulnerability. The atlas will also assist governmental institutions in the improvement of the disaster risk management and reduction policies currently in place, the development of a relevant strategy of effective planning, and in the efficient implementation of different development projects. Any interested person or organization will therefore have the opportunity to evaluate the risks and relevant challenges faced by the local communities of Georgia by utilizing the information contained in this Atlas. The maps included in the atlas have been developed on the bases of modern, international and national research and assessment methods. The atlas is dealing with 10 types of hazards (earthquakes, flooding, landslides, mudflows, rockfall, snow avalanches, drought, wildfire, windstorm, hailstorm), and 8 types of elements at risk (population, buildings, GDP, roads, pipelines, forest, crops and protected areas). Databases were generated of past hazard events, exposure maps, created physical, social, economic and environmental vulnerability maps, and risk maps for all combinations of hazard and assets. Three different levels of administrative units were used for aggregation of the exposure and risk results: regional, districts and community. Both a paper and a web-based risk atlas were developed (http://drm.cenn.org/index.php/en/).

The focus on vulnerable people will also benefit from spatial data, including cadastral and land use maps, which can help identify areas with small parcels, many dwellings, limited routes out in case of evacuation and many other vulnerability criteria. Especially in combining the hazard maps with such spatially enabled information on vulnerability will help to prioritize areas that need attention from a disaster risk reduction perspective (see Charoenkalunyuta et al., 2011).

## 6. CONCLUSIONS

Spatial data are increasingly available in many formats and through many services around the world. This applies clearly to the disaster risk management sector where, in every phase of the disaster cycle, spatial information has much to offer. Like in any other sector, a well-tuned spatial data infrastructure with appropriate policy and tools can be of great help. The International Charter allows for spatial data to support emergency interventions, and also national and other stakeholders are very willing to help on this issue. Ideally, pre-disaster spatial information and newly acquired spatial data come together to really help determine the hotspots that need immediate assistance and the size of the damage. However, despite growing enthusiasm in recent years about the utility of increasingly more detailed and sophisticated remote sensing data to assess structural damage, in particular the Haiti event has demonstrated the severe limitations to map what is a very complex 3D building situation in largely vertical, 2D imagery. Even highly detailed aerial imagery (Pictometry) only insufficiently revealed damage (Gerke and Kerle, 2011).

Official spatial data can further be improved in term of reliability and quality by combining data obtained via crowdsourcing and volunteered GI. Spatial data collected for specific recovery and reconstruction projects can be made part of the emerging national spatial data infrastructure.

Another set of layers in such an infrastructure can deal with the different land tenure arrangements (how people hold their land), which ideally includes at least an inventory or enumeration of people in actual occupation in informal and often vulnerable areas that are outside the official land registration system and very often disaster prone.

Lastly, land professionals play an important role in collection, processing, using and sharing this information and are to be more aware of the specific needs of the disaster management sector. Sometimes a small thing can mean the difference between saving or losing the life of a potential disaster victim, so it is worth trying.

## ACKNOWLEDGEMENT

This paper is based on the report 'Spatial Information for Addressing and Assessing Land Issues in Disaster Risk Management' prepared for and with financial support by FAO, the Food and Agricultural Organisation of the United Nations as part of a broader cooperation between FAO and FIG in the field of land and disaster.

## REFERENCES

Ali, Z., Tuladhar, A., and Zevenbergen, J., 2012, An integrated approach for updating cadastral maps in Pakistan using satellite remote sensing data: International Journal of Applied Earth Observation and Geoinformation, v. 18, p. 386-398.

Anderson, P.S., 2000, Mapping land rights in Mozambique: Photogrammetric Engineering and Remote Sensing, v. 66, p. 769-775.

Barrington, L., Ghosh, S., Greene, M., Har-Noy, S., Berger, J., Gill, S., Lin, A.Y.M., and

Charoenkalunyuta, C., 2011, Land tenure in Disaster Risk Management: Case of Flooding Nepal, Msc. research, University of Twente, Enschede, the Netherlands, 2011

Charoenkalunyuta, C., Tuladhar, A. and Zevenbergen, 2011, Community Resilience in disaster prone areas based on Land rights/ownerships, presented at Asian Conference for Remote sensing (ACRS), Taipei, Taiwan, 2011

Donnelly, Nic, Mark Smith, Mack Thompson and Don Grant 2011, Re-establishment of Cadastral Boundaries Following the 2010 Earthquake in Canterbury, New Zealand, FIG Working Week Marrakech.

Ebert, A., Kerle, N., and Stein, A., 2009, Urban social vulnerability assessment with physical proxies and spatial metrics derived from air- and spaceborne imagery and GIS data: Natural Hazards, v. 48, p. 275-294.

Gerke, M., and Kerle, N., 2011, Automatic structural seismic damage assessment with airborne oblique Pictometry imagery: Photogrammetric Engineering & Remote Sensing, v. 77, p. 885-898.

Goodchild, M., 2007, Citizens as sensors: the world of volunteered geography: GeoJournal, v. 69, p. 211-221.

Guo, H.D., Liu, L.Y., Lei, L.P., Wu, Y.H., Li, L.W., Zhang, B., Zuo, Z.L., and Li, Z., 2010, Dynamic analysis of the Wenchuan Earthquake disaster and reconstruction with 3-year remote sensing data: International Journal of Digital Earth, v. 3, p. 355-364.

Groot, R. and McLaughlin, J., 2000, Geospatial Data Infrastructure: Concepts, Cases and Good Practice. Oxford University Press. 2000, p.1 -11.

Heipke, C., 2010, Crowdsourcing geospatial data: ISPRS Journal of Photogrammetry and Remote Sensing, v. 65, p. 550-557.

JB GIS 2010 (Joint Board of Geospatial Information Societies (JB GIS) and United Nations Office for Outer Space Affairs (UNOOSA)), Geo-information for Disaster and Risk Management: Examples and Best Practices, 2010.

Joyce, K.E., Belliss, S.E., Samsonov, S.V., McNeill, S.J., and Glassey, P.J., 2009, A review of the status of satellite remote sensing and image processing techniques for mapping natural hazards and disasters: Progress in Physical Geography, v. 33, p. 183-207.

Kaidzu, Masaru, 2012, 2011 East Japan Earthquake, unpublished training material for FIG Commission 7, WG 2 (send 6 January 2012).

Kemper, T., Jenerowicz, M., Gueguen, L., Poli, D., and Soille, P., 2011, Monitoring changes in the Menik Farm IDP camps in Sri Lanka using multi-temporal very high-resolution satellite data: International Journal of Digital Earth, v. 4, p. 91-106.

Kerle, N., Heuel, S., and Pfeifer, N., 2008, Real-time data collection and information generation using airborne sensors, in Zlatanova, S., and Li, J., eds., Geospatial Information Technology for Emergency Response: London, Taylor & Francis, p. 43-74.

Kerle, N., 2010, Satellite-based damage mapping following the 2006 Indonesia earthquake--How accurate was it?: International Journal of Applied Earth Observation and Geoinformation, v. 12, p. 466-476.

Kerle, N., 2011, Remote sensing based post - disaster damage mapping: ready for a collaborative approach?, Earthzine: fostering earth observation and global awareness.

Kerle, N., 2013, Remote sensing based post-disaster damage mapping with collaborative methods, in Zlatanova, S., Peters, R., Dilo, A., and Scholten, H., eds., Intelligent Systems for Crisis Management: Lecture Notes in Geoinformation and Cartography, Springer Berlin Heidelberg, p. 121-133.

Kerle, N. and Hoffman, R.R., 2013, Collaborative damage mapping for emergency response : the role of Cognitive Systems Engineering. In: Natural Hazards and Earth System Sciences, 1 pp. 97-113.

Lemmen, C.H.J. and Zevenbergen, J.A., 2010, First experiences with high - resolution imagery - based adjudication approach in Ethiopia. In: Innovations in land rights recognition, administration and governance : joint organizational discussion paper issue 2 : proceedings from the annual conference on land policy and administration / K.
Deininger, ... [et al.]. - Washington D.C. : The World Bank, 2010.

Lemoine, G., 2010, Validation of building damage assessments based on post-Haiti 2010 earthquake imagery using multi-source reference data, Proceedings of VALgEO 2010 - 2nd International Workshop on Validation of Geo-information Products for Crisis Management: Ispra, Italy, p. 33-34.

Sekine, Ichizo and Masatake Nanjo, 2012, Readjustment of the Cadastral Map in the East Japan Earthquake Disaster Area, FIG Working Week Rome.

Stryker, T., and Jones, B., 2009, Disaster response and the International Charter program: Photogrammetric Engineering and Remote Sensing, v. 75, p. 1342-1344.

Tuladhar, A.M., 2004, Parcel-based Geo-information System: Concepts and Guidelines, PhD dissertation Technical Universiteteit Delft, ISBN 9061642248, the Netherlands

UNECE (United Nations Economic Commission for Europe), 1996, Land Administration Guidelines with Special Reference to Countries in Transition, ECE/HBP/96, Geneva, 1996

Voigt, S., Schneiderhan, T., Twele, A., Gahler, M., Stein, E., and Mehl, H., 2011, Rapid damage assessment and situation mapping: learning from the 2010 Haiti earthquake: Photogrammetric Engineering and Remote Sensing, v. 77, p. 923-931.

Zhang, Y., and Kerle, N., 2008, Satellite remote sensing for near-real time data collection, in Zlatanova, S., and Li, J., eds., Geospatial Information Technology for Emergency Response: London, Taylor & Francis, p. 75-102.

## BIOGRAPHICAL NOTES

**Prof.dr. Jaap Zevenbergen** obtained his doctorate from Delft University of Technology (TU Delft) in Systems of Land Registration and is currently holding the position of professor of Land Administration Systems at the department of Urban and Regional Planning and Geo-Information Management (PGM), Faculty of Geo-Information Science and Earth Observation (ITC) of the University of Twente in the Netherlands. He is also director of the UNU School for Land Administration Studies ran by ITC and Ducht Kadaster, and sits on the international advisory board of the Global Land Tool Network. He is co-chair of FIG Commission 7 Working Group 2: Land Administration, Natural Disasters and Climate Change.

**Dr. Norman Kerle** received a Ph.D. degree in geography (volcano remote sensing) from the University of Cambridge, U.K., in 2002. He is currently an Assistant Professor in disaster geoinformation management with the Department of Earth Systems Analysis, Faculty of Geo-information Science and Earth Observation (ITC), University of Twente, Enschede, The Netherlands. His principal research interests include the utility of geoinformatics for disaster risk management, particularly questions of assessment of vulnerability, risk and post-disaster structural damage, and object-oriented image analysis methods.

**Dr. Arbind Tuladhar** obtained his doctorate from Delft University of Technology (TU Delft) in Parcel-based Geo-Information Systems and is currently holding the position of assistant professor of Land Administration and Geo-Information Science at the department of Urban and Regional Planning and Geo-Information Management (PGM), Faculty of Geo-Information Science and Earth Observation (ITC) of the University of Twente in the Netherlands. Currently Dr. Tuladhar is also visiting professor in Land Administration at Chang'an University, Xi'an (China) as well visiting professor at Kathmandu University (KU), Kathmandu, Nepal. His current research interests focus on integrated systems comprising land governance, land tenure, land administration, cadastral system, Geo-ICT system modeling and development, and spatial data infrastructure in support of sustainable development.

## CONTACTS

Prof. Dr. Mr. Ir. Jaap Zevenbergen
Faculty of Geo-Information Science and Earth Observation (ITC),
University of Twente,
PO Box 217
7500AE Enschede
THE NETHERLANDS
Tel. +31 (0)53 4874351
Fax + 31 (0)53 4874575
Email: j.a.zevenbergen@utwente.nl
Web site: www.itc.nl

Dr. Norman Kerle
Faculty of Geo-Information Science and Earth Observation (ITC),
University of Twente,
PO Box 217
7500AE Enschede
THE NETHERLANDS
Tel. +31 (0)53 4874476
Fax + 31 (0)53 4874336
Email: n.kerle@utwente.nl
Web site: www.itc.nl

Dr. Arbind Tuladhar
Faculty of Geo-Information Science and Earth Observation (ITC),
University of Twente,
PO Box 217
7500AE Enschede
THE NETHERLANDS
Tel. +31 (0)53 4874312
Fax + 31 (0)53 4874575
Email: a.m.tuladhar@untwente.nl
Web site: www.itc.nl