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LAND ADMINISTRATION AND GEOSPATIAL INFORMATION FOR RESILIENCE

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Abstract

Land administration and geospatial information play an important role in all stages of disaster risk management, including prevention and risk mitigation, emergency response, and reconstruction and recovery through the provision of accurate data to stakeholders when required. The contrasting abilities of countries with strong land and geospatial systems to respond to disaster events compared with those with weak systems demonstrates how critical these are. Yet many vulnerable countries lack accurate land registry information, maps that reflect reality on the ground, valuation systems able to assess the impact of disaster events and compensation, or effective town planning, building control and land management systems able to prevent development taking place in unsuitable locations, inadequate standards of construction, or activities that contribute to vulnerability. Based on research undertaken for a World Bank publication, the paper sets out how countries can improve the contribution land and geospatial systems can make to resilience.

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Key Words:

Build Back Better, disaster events, disaster risk management, Land and geospatial systems, resilience

Land administration and geospatial information for resilience

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1. INTRODUCTION

On 12 January 2010, Haiti was struck by a force 7.0 M_w earthquake approximately 25 kilometres west of the capital Port au Prince. It is estimated that over 225,000 people were killed and over one million displaced. It is thought that 40 per cent of Haiti's civil servants were killed or injured and most government buildings were damaged or destroyed (GFDRR, 2010). On 4 September 2010 Christchurch, New Zealand, was struck by a 7.1M_W earthquake that caused no fatalities but a second earthquake of 6.3 M_w on 22 February 2011 resulted in 185 people being killed and over 7,000 casualties. There were 18,000 aftershocks from the first earthquake, including over 34 events of 5 M_W or greater. The series of Christchurch earthquakes resulted in widespread damage to land, including liquefaction. Approximately 167,000 homes (90 per cent of Christchurch's housing stock) were damaged. Air quality was affected, and silt and other contaminates were deposited in waterways. Most of Christchurch's underground pipes and 52 per cent of its sealed roads were damaged, at an estimated cost of NZD$2.7 billion (approximately US$1.75 billion). In some areas damage was so severe that the properties could not be fixed without large-scale remediation over entire areas (Greater Christchurch Group, 2017).

These two countries were struck by earthquakes of similar magnitude causing widespread devastation, but the scale of the casualties was very different, as was the resulting longer term impact and recovery trajectories. Relief work in Haiti was hampered by the poor state of mapping, requiring volunteers from throughout the world to create maps by crowdsourcing from satellite images. Reference and record systems were often unclear, incomplete or out of date. By contrast, the population of Christchurch initially fell by 3 per cent due to migration but has since returned to pre-earthquake levels. The earthquakes were a significant shock to the local economy with disruption to businesses, pressures on the labor market, shifts in the value and uses of land, and loss of capital, but businesses proved to be resilient and adaptable, with business and consumer confidence quickly returning. House prices recovered to above the pre-earthquake level, with growth faster than that of the country as a whole.

The reasons why the impact of these two disasters of similar earthquake magnitude should have resulted in such vastly different impacts is complex but one of the key differences between New Zealand and Haiti is the quality of their land administrations and geospatial information. New Zealand had a mature, reliable land administration system and an advanced authoritative National Spatial Data Infrastructure prior to the Christchurch earthquakes so that it could make informed decisions about which areas properties could be repaired and which should be abandoned. There was support for the insurance industry so that most owners had private insurance cove. New Zealand has a valuation infrastructure that enabled compensation for those who had lost homes and businesses to be calculated. Its building codes and town planning systems had learned lessons from earlier earthquakes and minimized earthquake damage and casualties. By contrast, in Haiti land administration and geospatial information were poor. The recording of property rights was weak and there were problems with proof of title. "Often there was no reliable way of obtaining enforceable documented guarantees of land title. Overlapping, invalid, or improperly documented titles were a frequent source of conflict, making land disputes common, and no fast or reliable formal process existed for settling such disputes" (GFDRR, 2010). The land titling system, managed by the Directorate of Revenues (*Direction Generale des Impots)*, was not computerized. Banks could not use contested properties as guarantees. Possession was often the only tool available to defend property rights. Land administration, land-use planning, zoning, building codes, and property valuation all needed strengthening before the earthquake. No town planning boards or other land-use planning entities existed. While Port-au-Prince and other urban areas did have relatively reliable land survey and cadastre systems, these were complicated by the extensive development of informal settlements (GFDRR, 2010). Crowdsourced maps from satellite images compiled after a disaster can help relief workers find their way around in the immediate aftermath of a disaster but do not provide the level of engineering accuracy, elevation, and slope needed for reconstruction of basic infrastructure such as water supplies, drainage, and the disposal of sewage.

A clear implication of the differing impacts of these two disasters is that geospatial information and effective land administration systems are critical to disaster prediction, prevention, planning, and mitigation strategies, preparedness, emergency response, and post-disaster reconstruction and recovery. Comprehensive and resilient land administration and authoritative geospatial information infrastructure supports more rapid recovery of citizens' normal lives, livelihoods, social and community well-being, and the quick recovery of economic activities by providing accessible and immediate data on demand on the impact, the value of losses and the losers, as well as levels of appropriate compensation and required recovery investments. At its most basic, if those trying to undertake relief work lack maps of the areas they are working in, rescue efforts will be compromised and the provision of emergency aid made difficult. Many emerging and developing economies lack the critical land and geospatial infrastructure needed to plan for disaster events and to enable them to improve their resilience to disaster events, including up to date registry information, maps and cadastres that reflect reality on the ground, and town planning and building control processes that are able to cope with the pressures of urban growth and for informal development.

This paper presents the results of research undertaken for a World Bank report on improving resilience and the resilience impact of land administration and geospatial information. The methodology employed included country case studies, interactive workshops with countries seeking to improve their land administration and geospatial information planning for and responding to disaster events, and comparative studies of the roles of land administration and geospatial information in disaster events and recovery and disaster planning and risk mitigation.

2. THE IMPORTANCE OF LAND AND GEOSPATIAL INFORMATION FOR RESILIENCE

Some parts of the world are regularly subjected to cyclones, hurricanes, or tornados, and others periodically experience blizzards or prolonged drought. Places where disasters tend to strike often have features that make them attractive places to live, such as fertile soil, natural resources or accessibility to employment, resulting in substantial populations being put at risk. Urbanization has increased the risks to populations. Urban areas are densely populated, and their residents highly dependent on infrastructure that can be damaged by natural disasters. This makes them disaster risk hotspots (World Bank, 2012). Many of the world's largest cities are particularly vulnerable, as they are located in low-lying coastal areas. Not all disasters result from natural events. Some are man-made such as those produced by fires, explosions, pollution, biological hazards, collapsing buildings and infrastructure, like dams or power supplies, economic or political collapse, or resulting from wars and conflicts. Some disasters come upon human populations very suddenly with little advance warning, such as tsunamis or earthquakes. Others are more slow-moving and gradual in their impact, such as local impacts from climate change, or environmental degradation.

Many of the causes of disaster events are beyond the ability of human beings to control. Disasters, such as earthquakes, floods, droughts, landslides and hurricanes, are increasing in frequency and severity around the world (Thomas and Lopez 2015). This is often a direct result of land-related human activities, including unplanned urbanization, unsuitable land-use, deforestation, unsustainable agricultural production, population growth, and the over- exploitation of natural resources, the impacts of which are all exacerbated by climate change. In 2016 and 2017 alone, over 18.8 million people were displaced as a result of disaster events. Although absolute economic losses are concentrated in high income counties, the human costs of disasters fall disproportionately on low and lower income countries. People exposed to natural hazards in the poorest countries were more than seven times more likely to die than equivalent populations in the richest countries and six times more likely to be injured, lose their homes, be displaced or evacuated, or require emergency assistance (Wallemacq and House, 2018).

Human populations are not passive, destined to accept whatever fate throws at them. Rather, they can work to make their settlements and societies more resilient to hazards. Governments can develop preventative processes and plans to mitigate, or at least resist, some of the impacts of disasters. These can include evacuation plans for the population, back-ups for essential services, constructing or retrofitting buildings so that they are more resilient to events like earthquakes or floods, and inoculating a population ahead of an epidemic or pandemic. They involve planning and developing systems to enable rebuilding and recovery to take place more quickly once disaster strikes so that the resulting disruption is minimized and taking steps to mitigate impacts ahead of a disaster event.

Several key initiatives aiming to build resilience to disasters have emerged in recent years, in particular, the 2030 Agenda for Sustainable Development (United Nations, 2015), the Hyogo Framework for Action (UNISDR, 2005), and the Sendai Framework for Disaster Risk Reduction (GFDRR, 2012). These seek to reduce the risk of disaster and losses through the implementation of strategic goals and integrated and inclusive measures to prevent and reduce hazard exposure and vulnerability to disaster and to increase preparedness for response and recovery. They outline key points for improving resilience to disasters, as well as highlighting the positive effects that national land administration and geospatial information systems can have. In addition, the Integrated Geospatial Information Framework (United Nations and World Bank 2018) builds on many of these ideas with a focus on geospatial information and how it can be improved to support global development.

The more secure, formal and reconcilable property rights and systems are, the less vulnerable land users are to eviction or loss of livelihoods following a disaster. In the aftermath of disaster, lack of clarity over titles and land claims can significantly delay reconstruction and lead to conflict (GFDRR, 2010). Comprehensive and secure land records offer critical protection of rights when a population is displaced by a disaster. Investment in tenure security is therefore a direct investment in disaster recovery and resilience. One question that can arise following a disaster event is whether settlements should be rebuild where they previously stood, or be moved to a less vulnerable location. Sometimes there is no real choice - for instance, where an earthquake results in liquefaction of the soil as a result of shocks and vibration, so that the subsurface is too unstable for reconstruction. This raises issues about compensation for those who are not permitted to return to their homes or businesses, as well as for the owners of the land that may be requisitioned for new construction. Secure tenure and comprehensive land administration systems provide guarantees that those undertaking the investment will get the benefits from it, incentivizing them to increase investment in dwellings. This in turn reduces risks and improves resilience through better siting and construction.

Security of tenure contributes to rapid disaster recovery and to the resilience of vulnerable households. Conversely, if nothing is recorded, it is very difficult to reconstruct the property rights – whether individual or collective – that used to exist before a disaster swept away physical features on the ground and may also have killed those whose memories the society relied upon. The most vulnerable households are those that rely on access to land with temporary and insecure tenure. Minorities, women, children, the elderly, and those with disabilities may be vulnerable due to past discrimination in securing tenure. Culture and customary rights can be destroyed by a collective loss of memory through the deaths of their custodians through disease or disaster. The argument for using land administration information in the process of disaster risk management is simple: the combination of hazard information with relevant information on land tenure, land value, and land use enables the necessary risk prevention and mitigation measures to be identified and assessed in relation to legal, economic, physical and social consequences (Enemark 2009). Land administration and geospatial information can reveal vulnerabilities and exposure to hazards. Data regarding topography, for example, is particularly useful in its ability to reveal tsunami, storm tide, tropical cyclone, bushfire, and landslide risk (Middelmann 2007). The better the knowledge base of information that is available for assessment of the risks, the more informed disaster risk management assessment is likely to be (Schneider et al 2009).

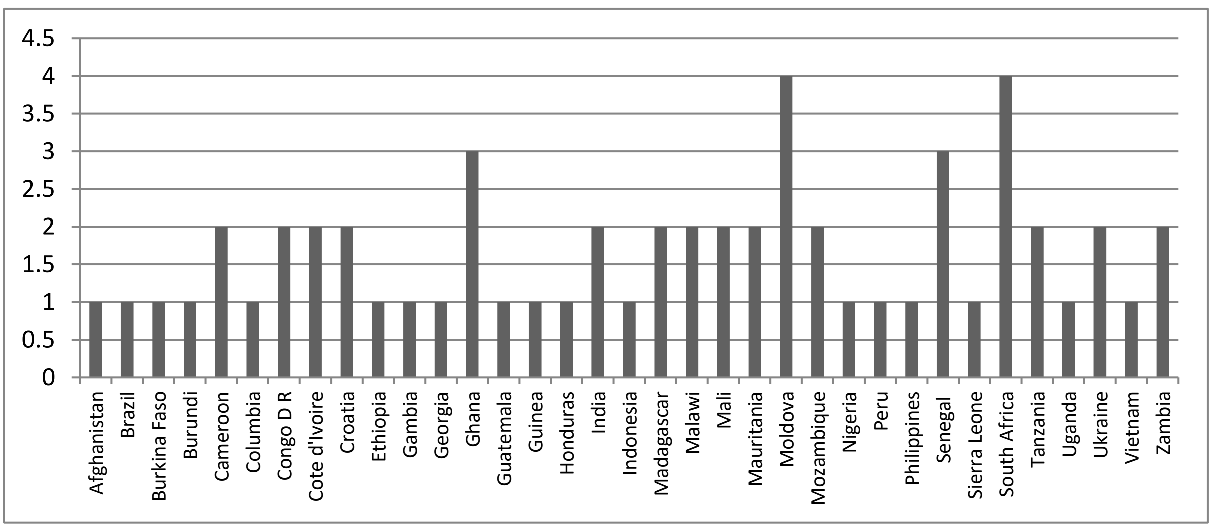
Although the reasons why some communities are more resilient than others are complex, a key factor is land resilience. Land resilience means the ability of land and people-to-land relationships to recover after hazard events so that land tenure, value, use, livelihoods, and development activities can resume. This requires reliable administration systems and authoritative geospatial information. Land administration systems (LAS) comprise a number of systems and process concerned with land rights, land use regulation, land valuation and taxation, and land development to provide security of tenure, control inappropriate land uses, ensure safe construction of buildings and infrastructure, and undertake land valuation for finance, taxation and compensation. An authoritative geospatial information system comprises series of fundamental databases including addresses, buildings, settlements, elevation and depth, functional areas, geographical names, geology and soils, land cover and land use, land parcels, orthoimagery, physical infrastructure, population distribution, transport and utility networks, water, and a geodetic reference framework. An effective LAS that provides current, reliable and complete land tenure information, coupled with comprehensive and authoritative geospatial information can secure the quick recovery of economic activities. A mature and resilient land and geospatial information system plays a key role at the forefront in all Disaster Risk Management phases by providing land use, building, value, and zoning data for disaster risk modelling, monitoring, planning, mitigation, as well as a platform to implement decisive actions before, during and after disasters.

Land and geospatial systems can only perform if they are themselves resilient. No matter how good the system, it will fail if it is not capable of delivering accurate information in real time during a disaster event. Paper-based land records and maps are vulnerable to deterioration, for example through insect infestation, or exposure to light, heat, water damage, and dust. In a disaster they can be destroyed by flood or fire or lost in the collapse of buildings. For instance, on 26 December 2004 a 9.1 to 9.3 M_w earthquake off the west coast of northern Sumatra triggered huge tsunamis across the Pacific Ocean leaving more than 230,000 people dead or missing and 700,000 homeless in Aceh and Northern Sumatra. Widespread destruction resulted in significant insecurity in land and property rights, including exposure to land grabbing, particularly for the vulnerable and least able to protect their rights, such as widows and orphans. Some 300,000 land parcels were affected by the tsunami, of which only 60,000 were secured by title certificates. Marks on the ground that defined property rights were wiped out, and deaths robbed communities of the memories of the location of these boundaries. The clean-up operation also destroyed physical evidence of land ownership,. All of the records were paper-based and stored on ground floors. Approximately 10 per cent of land books were lost and many of the remainder were damaged by sea water and mud, requiring conservation and restoration. Records in the hands of landowners were largely destroyed, and records of mortgages were also lost. In Banda Aceh the land office lost 41 people - approximately one third of its staff. Beyond the loss of documents and staff, computers, cameras, printers, and other equipment needed to support the recovery of property rights were destroyed. Recovery required the recreation of land records and of the administrative systems for recording and registering land rights. This meant the reconstruction of land records damaged by the tsunami; surveying and mapping land parcels so that rights could be registered and title certificates issued; community-driven adjudication; and regulations to support a stream-lined process. Land records and maps needed to be digitized and computerized with secure back-up and safe off-site storage to ensure that the loss of information would never recur (World Bank, 2005a; World Bank 2005b; World Bank, 2010; World Bank, 2011).

Remote storage of electronic data offers greater protection, though this may also be vulnerable to degradation or destruction through hacking, ransomware, or damage to equipment or buildings unless suitable back-up systems are put in place. For instance, in May 2019, the City of Baltimore, USA, was subjected to a ransomware attack that took down voice mail, e-mails, a parking fine database, and the system used to pay water bills and property taxes. The attackers demanded 13 Bitcoins (about US$100,000) to release the systems (*New York Times*, 22 May 2019). The City did not pay the ransom but is reported to have spent $18 million on its systems as a result, and five weeks after the event a number of the systems were not fully functioning, with bills remaining unsent (CBS Baltimore, 12 June 2019). Protocols are also needed to prevent employees, particularly corrupt employees or those with a grievance against their employer, from obtaining unauthorized access, making alterations, or maliciously destroying records. Employees also need to be trained against letting hackers into the system through carelessness, such as opening e-mails containing malware or using easily guessed passwords.

The gap between what is needed in LAS and geospatial information and what actually exists can be illustrated from the responses to the World Bank's Land Governance Assessment Framework (LGAF), which has to date been undertaken by nearly 40 countries. One of the questions posed in the LGAF is whether land registry information is up-to-date and reflects reality on the ground. Figure 1 shows that for most of the countries studied the information in registry information is seriously incomplete, with 18 out of 35 countries for which there is data reporting that less than 50 per cent of the information was up-to-date.

Figure 1 Whether registry information is up-to-date and reflects the reality on the ground



A score of A is given if more than 90 per cent of the information they contain is up-to-date; B if between 70 and 90 per cent is; C if between 50 and 70 per cent is; and D if less than 50 per cent of the information in the registry cadastre is up-to-date. A = 4, B = 3, C = 2, and D = 1.

Source: The World Bank Land Governance Assessment Framework, http://www.worldbank.org/en/programs/land-governance-assessment-framework

Byamugisha (2013) found that 80 per cent of Sub-Saharan and South Asian countries still have paper-based systems that are in various states of deterioration, even though 61 per cent of the rest of the world has electronic databases for encumbrances. A 2019 survey by Geospatial Media Communication of the geospatial readiness of 75 countries based upon their data infrastructure, policy framework, institutional capacity, user adoption, and industry framework awarded just 11 countries (all with the exception of China, developed economies) scores of 40 out of 100 or better, and 44 countries (all emerging or transitional economies) scores of less than 25[1].

Spatial planning and building regulation are vital in ensuring that urban development does not take place in vulnerable areas, and that development proposals incorporate designs and specifications that are appropriate for the risks encountered locally. The magnitude of the impact of disaster events is often amplified by development having taken place in unsuitable locations, by being informally constructed, and without an appropriate degree of resilience. Inappropriate land uses can also increase the risk and the consequences of a disaster event. For instance, encroachment on forests and water channels and the removal of vegetation on slopes increases runoff rates and the risk of flooding and landslides, while building on firebreaks and evacuation routes is likely to increase the casualties resulting from wildfires. For instance, the population of Freetown, Sierra Leone, grew rapidly, as a result of people fleeing the civil war in the 1990s and the boom in iron ore exports. The resulting housing shortage caused the expansion of urbanization into vulnerable areas and the stripping of vegetation from the lower slopes of Sugar Loaf Mountain for fuel, destabilizing the soil and speeding up the rate of water run-off. On 14 August 2017 Freetown was struck by powerful rainstorms that caused water to cascade down Sugar Loaf Mountain, creating major landslides that engulfed houses and buildings, entombing those inside and sweeping others away. The World Bank subsequently estimated the death toll at 1,141, with approximately 3,000 people losing their homes. The economic loss was put at $32 million, and the recovery costs at $82 million (IBRD/IDA, 2017; Trenchard, 2018). In a situation in which there is a chronic housing shortage and no effective means of enforcing town planning and building control policies, commercial opportunities exist for anyone able to exercise control over land, no matter how unsuitable it is for development. An efficient LAS can prevent such developments.

[1] https://issuu.com/geospatialworld/docs/20190329-geobuiz-report-2019-freeve

Combined land and hazard information has been identified as a critical element in the mitigation of new disaster risk management developments (Emergency Management Australia 2008). Hazard information using land administration information as a foundation can assist in making decision-makers more aware of potential risks, and more motivated to implement appropriate disaster risk management strategies (The World Bank 2010). The ubiquitous nature of maps and other land and geospatial information today makes for straightforward interpretation of visual information for the majority of stakeholders (Tate et al. 2010). The value in land administration data is that it enables the nature and extent of hazards to be visualized, allowing their impacts to be easily understood, and informing disaster risk management strategies (National Emergency Management Committee 2011; Tate et al. 2011). Land administration information can reveal vulnerabilities and exposure to certain hazards. For instance data regarding topography is particularly useful in its ability to reveal tsunami, storm tide, tropical cyclone, bushfire, and landslide risk (Middelmann 2007). The better the knowledge base of information that is available for assessment of the risks, the more informed the disaster risk management assessment is likely to be (Schneider et al 2009).

3. **HOW A RELIABLE LAND ADMINISTRATION SYSTEM AND AUTDHORITATIVE GEOSPATIAL INFORMATION CONTRIBUTE TO RESILIENCE**

Land administration systems and geospatial data infrastructure are fundamental to disaster risk management. They play a major role in developing plans for the mitigation of disasters, and in facilitating recovery and reconstruction. Disasters have devastating impacts on the populations affected, and on the economies of the areas and countries concerned. Land is the core social safety net; once access to land is lost, resuming livelihoods becomes challenging or even impossible, and this increases vulnerability. When disasters displace people, land records and cadastral data are key to protecting their property rights and building resilience. They also play a key role in rebuilding - the absence of clear property rights and challenges by those claiming rights over land needed for reconstruction or for the improvement of infrastructure can hold up reconstruction, or cause projects to be abandoned.

Land administration is the process of determining, recording, and disseminating information about the tenure, value, and use of land when implementing land management policies (UNECE, 1996; Williamson et. al., 2010). Land administration comprises a range of systems and processes including:

- **Land rights** – the recognition or allocation of rights and obligations; the delimitation of boundaries of parcels for which the rights are recognized or allocated; the transfer from one party to another of land rights through sale, lease, loan, gift or inheritance; and the adjudication of doubts and disputes regarding rights and obligations and parcel boundaries;

- **Land-use regulation** – land-use planning and enforcement and the adjudication of land use conflicts;
- **Land valuation and taxation** – the gathering of revenues through forms of land valuation, value capture, and taxation; the adjudication of land valuation and taxation disputes (FAO, 2002); and the determination of compensation for losses or when property is expropriated;
- **Land development** – implementing utilities, infrastructure, and construction planning; and the enforcement of construction standards and building codes.

Land information includes authoritative detail about parcels, ownership, property rights, restrictions, responsibilities and obligations, and valuation. It covers topographical and environmental data, land use information, utilities and infrastructure, and land development plans. Cadastre information is at the core of any land administration system. It provides information about geographical objects and their attributes, including, critically, their locations, assets and asset values, which is vital support for implementing land policies, land management strategies, land markets, effective land use management, and effective disaster risk management practices (Williamson 2002; Nasruddin and Rahman 2006). In attempting to achieve an effective LAS that supports resilience to disasters, a number of issues can arise. For example, if the land registration system is inefficient or ineffective key data about what happens where, where production is located, and who lives where, will not be available. This can be compounded by an inoperative land information system, an incomplete and/or outdated cadastre, a lack of trained surveyors to conduct high-quality land surveying, and the absence of geospatial data sharing protocols. Situations like this undermine disaster risk management and mitigation activities, contribute to difficulties in tax collection, distort land markets, and result in poor urban and land use planning, which can compound the losses from disaster events. A compromised geospatial base has negative direct implications, for example for tsunami, flood and landslide modelling, and to the national capability to put in place disaster response and early warning systems.

This information must be accessible to all the agencies that need it: agencies should not maintain their own databases just because they cannot access the information they require because it is the property of another agency. Instead specialists should be responsible for compiling and maintaining databases, the contents of which should be shared with those who need access to them. There should not be duplicate – and even conflicting – databases purporting to contain the same information, maintained by different bodies for their own exclusive use. Rather, those with specific responsibility and specialist skills and equipment should produce high quality data on which all other bodies can rely. Thus, for example, land use planners can access data about topography, hydrography or vegetation cover, and valuers can access the location of buildings and parcel land rights. This is possible when there is a high degree of cooperation between organizations, rather than unproductive competition and rivalry. It also implies that the data should be readily accessible on demand. This can only be achieved if the data is available electronically and compiled using common standards. Sharing information with disaster risk management agencies and enabling them to harness this valuable data in their planning and operations enhances the overall process and supports government-wide agendas. For instance, since 1996 the Netherlands has developed a series of base registers which all public bodies are obliged to use. One body is responsible for the production and maintenance of the dataset. Key registers include those for persons, the cadastre, addresses, buildings, businesses, topography, subsurface, vehicles, and property values. Not all datasets are geospatially referenced, but they contain a wide range of accurate and reliable social, commercial and economic data as well as geospatial information (Kuijper and Kathmann, 2016). However, in many contexts, there is disconnect between various key players or departments and the systems they use.

To be able to use data effectively, a National Spatial Data Infrastructure (NSDI) needs to be in place, with coordination across technologies, policies, standards, and human resources to acquire, process, store, distribute, and use geospatial data. This system provides a common location platform and, in the context of resilience, is essential for identifying the impact areas and damage, directing the responses, reconstituting the pre-disaster land use, identifying areas for temporary shelter, and facilitating longer term planning and reconstruction and recovery of production systems (UN-HABITAT 2010). For instance Norway provides a good example of a functioning NSDI. The government established a portal to provide geospatial data to support public services and private investment. Data delivery organizations deliver data to the National Geoportal, where Geospatial Information specialists convert it into ready-made maps for end users. Some 50 organizations and 400 municipalities contribute to the system, and 600 have an agreement on the joint platform, standards, and cost-sharing, with the Norwegian Mapping Authority as the coordinator. Data capture is funded by partners, with 34 percent of the costs met by local authorities, 24 percent by the national mapping agencies, and 14 percent from the road administration. Cross-sectoral themes include topography, population, pollution, agriculture, geology, cultural heritage, fisheries, energy, biodiversity, climate and weather, cadastral information, and crisis management. The databases include orthophotos and terrain models, LiDAR data, bathymetry, urban zoning plans, hydropower, cultural monuments, wildlife, land slide susceptibility, aquaculture, soil pollution and contamination, noise, and borehole stability data. User groups define their needs and drive developments, and the system is orientated towards the needs of large users, such as the police, emergency services, coastal rescue, the military, local government, and national crisis management. The legal basis for the development is derived from the European Union's INSPIRE Directive, which was translated into Norwegian law in 2010, with a revision in 2017 (Lillethun, 2017)

The reality is that many countries which are vulnerable to disaster events lack NSDI systems or may not have a culture of data sharing. Interoperability is a particular challenge with most of the countries that were investigated in this study[2] reporting that agencies worked without sharing land information, or recording it to a single standard. Central to the interoperability of systems is whether the country has a national geospatial information management policy or strategy. If the policy or strategy exists, its status needs to be known, particularly whether it has been endorsed by the government and by law, and whether there are clear objectives and a roadmap to achieve these. The policy or strategy needs to be aligned with other government policies which impact on it, particularly e-government and open data policies. The e-government policy is likely to determine the policies for the migration of data and the supply of public services on-line. The data policies will determine the extent to which datasets can be made public, what licensing arrangements are required in accessing datasets, and the re-use and redistribution rules. It will need address institutional arrangements and governance, communications, standards and infrastructure management, and how the policy or strategy is to be financed.

Interoperability problems mean that a NSDI policy cannot be implemented, as data produced by one organization cannot readily be accessed by others. The impediments to interoperability fall into four main categories (UN/WB IGIF 2018).

- **Technical.** These include the absence of data standards and data models, or the failure to adopt them universally. A key issue is how data is geo-referenced, and whether there is consistency in how locational data is stored. Use should be made of international data standards. At the start of the development of an NSDI system, it is likely that some key datasets will be in paper form, so a policy will be needed for scanning these and transferring them into an electronic format.
- **Capacity**. Those who need to access data may lack the equipment or software with which to do so or the people with the technical competence to enable access or understand the importance of interoperability.
- **Legal**. There needs to be a legal framework for the sharing of data. This includes who has access to what data, who has the right to change it, and who has obligations to convey to the data owner any errors that have been identified through use. Licensing agreements, covering intellectual property

[2] As part of this study nine case studies were as conducted by independent consultants. The country level case studies are the key component of this overall project, being the primary source of investigation, information gathering and data collection. The case studies focus on land administration, specifically, the land and geospatial information and systems they can offer disaster risk management practices.

rights, need to be in place to enable users to access relevant data. Policies need to be in place as to which data is to be regarded as open, and which data the owners can charge an access fee to. This is linked to the question as to how various data providers are to be financed. Since the sharing of data is electronic, the framework for interoperability will be influenced by e-government policies, such as portal and database specifications, and by plans for migrating public services from paper-based delivery through offices to electronic services accessed through the internet.

- **Cultural**. A culture of data sharing needs to be developed so that it can be accessed by those who need it for risk mitigation and recovery planning. There is a risk of silo mentalities, where those who own data see it as being their private domain rather than regarding themselves as a service provider to others.

Effective disaster risk management still eludes many regions and communities, even within developed countries. Despite a wide range of available information and resources related to the implementation of risk management practices, significant problems are faced during disaster events. Even countries with strong economies, well-established social systems, and good governance, can struggle to respond to climate change and natural disasters and fail in attempts to implement effective strategies to address these issues. Those countries have within their reach resources, such as established land administration systems, that are known to be effective in disaster risk management but how to harness them effectively, optimizing these institutions and the information they generate is not always clear. A holistic approach to disaster risk management is required to enhance resilience and reduce the vulnerability of stakeholders to disasters (FIG 2006).

Good governance in land administration and geospatial systems is one of the central requirements for achieving effective planning to mitigate the impact of natural hazards, and for reconstruction and recovery when disaster events strike. Governance problems on land are widespread globally and have a negative impact on resilience. If land administration and geospatial systems are compromised by corruption or office capture, they will be poorly positioned either to enable the planning of mitigation measures for potential disaster events, or to respond to these events when they occur. Weak governance may mean that land is not used appropriately to create wealth for the benefit of society, and that unsuitable development, which makes a society vulnerable to natural hazards, is not constrained. Planning to mitigate the impact of natural hazards either does not take place or is ineffective. Failings in governance make the impact of disasters far worse; at best, weak governance may cause the process of recovery and reconstruction to be delayed unnecessarily.

Many emerging and developing economies lack the critical land and geospatial infrastructure needed to plan for disaster events and to enable them to improve their resilience to these eventualities. Such events though may act as a spur to bring about improvements. In such circumstances the reconstruction of what has been damaged or destroyed is not enough. There is no point in rebuilding poorly constructed informal buildings that have not withstood a disaster event, or allowing ongoing deforestation or encroachment on waterways, fire breaks, or evacuation routes, which had contributed to the impact of a previous disaster.

"If restored to pre-disaster standards disaster-affected communities would face the same difficulties if exposed to another disaster event in the future" (Mannakkara and Wilkinson, 2014).

Rather, in line with the Sendai Framework, the opportunity must be taken to strengthen disaster risk management by adopting a policy of "building back better". As President Clinton (2006) argued, "Good recovery must leave communities safer by reducing risks and building resilience."

Building back better is not just a matter of rebuilding buildings and infrastructure to higher construction standards so that they are more resilient, but must also involve tackling the factors that undermine the security of livelihoods, such as insecure property rights. It also means enhancing the community resources needed to improve resilience, such as networks to pass on warnings and to facilitate emergency drills. Governance will also have to be enhanced so that central, regional and local governments are more responsive to community needs, more willing to work together, to share information and resources, and to monitor recovery and reconstruction programs more closely.

The costs of improving resilience are illustrated in Table 1, which shows that the mark-ups involved are relatively modest. The "building back better premium" is made up of the cost of quality improvements plus technological modernization plus relocation to safer areas if needed, plus disaster risk reduction standards and multiannual information.

Table 1 Building Back Better Factor

Sector	**Building Back Better Premium**
Housing	1.10-1.35
Schools	1.10-1.50
Hospitals	1.10-1.50
Agriculture/ Livestock and Fisheries Infrastructure	1.10-1.40
Industrial Facilities	1.10-1.40
Commerce and Trade	1.10-1.35

Source: World Bank (2013), GFDRR (2010)

Is building back better cost effective? The answer is that the lack of resilience is expensive. A study of power, water and sanitation, transport, and telecommunications infrastructure found that natural disasters caused damage estimated at $18 billion per year to low- and middle-income countries, but that more resilient designs would cost only 3 per cent compared with overall investment needs. On average, there is $4 in benefit for each $1 invested (Hallegatte, Rentschler, and Rozenberg, 2019). In the case of infrastructure, the costs of not building back better are particularly high. Natural shocks are among the leading causes of infrastructure disruptions. The consequences of failure to invest in resilience go far beyond immediate economic losses arising from destruction of infrastructure and property and the loss of productive capability, and include long-lasting impacts, such as on healthcare and morbidity and mortality and loss of educational opportunities if children and youths cannot attend schools and training.

The benefits of building back better are illustrated by the programme adopted by Kerala in India after the 2018 floods. Between 1 June and 19 August 2018, the State of Kerala in India experienced its worst floods since 1924, following rainfall that was 42 percent above normal. There were 498 casualties, 5.4 million people (one-sixth of the State's population) lost assets and property, and 1.4 million were displaced and forced to move temporarily into relief camps. Although Kerala coped with the aftermath of the disaster, it was realized that weaknesses in its land administration and poor land management controls had contributed to the scale of flooding, and that recovery was hampered by weaknesses in these systems. The impact of the heavy rainfall in 2018 was aggravated by a number of factors, including changes in land use and cover; the poor condition of waterways and reservoirs, leading to shrinkage of their carrying capacity; encroachment of settlements onto flood plains; poor agricultural practices impacting downstream; encroachment into bodies of water; sand mining from rivers, water channels and canals; and poorly controlled urban development. Weaknesses in Kerala's land administration and geospatial information systems exacerbated the impact of natural events, including a fragmented system of land records and out of date records that were vulnerable to destruction. The State recognized there was a need to go beyond traditional approaches to recovery and reconstruction, in order to prepare better for future disasters and adopted the *Rebuild Kerala Initiative*, to produce a "more resilient, green, inclusive and vibrant" vision for the future. This involves tackling the root causes of the factors that undermine resilience. Flooding in urban areas exposed the lack of risk-informed urban planning and approved master plans, failure to comply with design standards, and uncontrolled encroachment onto water channels and floodplains. Resilience could be improved even further by prioritizing the resurvey and updating of records for villages in the areas most vulnerable to disasters.

Early warning systems of hazard events are notably cost effective, typically yielding benefits that are 4 to 36 times initial costs (World Bank, 2013). For instance, in October 1999 a Category 5 cyclone devastated the eastern coastline of India and left 10,000 people dead and 1.7 million homeless with losses estimated at US$4.5 billion. In October 2013 a Category 4 cyclone hit the same area causing fewer than 40 deaths and losses estimated at US$700 million. Between those two events there had been investment in early warning systems, cyclone shelters, evacuation routes and coastal embankments, improved weather forecasting, and preparedness simulations, such as storm drills, involving community and volunteer organizations, and making use of greater ownership of mobile phones (World Bank, 2013).

The Pacific Catastrophe Risk Financing and Insurance Initiative (PCRAFI) is an innovative program that builds on the principle of regional coordination to provide state-of-the-art disaster risk information and tools for enhanced disaster risk management and improved financial resilience against natural hazards and climate change. It established the Pacific Risk Information System (PacRIS), which contains detailed, country-specific information on assets, population, hazards, and risks. The exposure database makes use of remote sensing analyses, field visits, and country-specific datasets to characterize buildings (residential, commercial, and industrial), major infrastructure (such as roads, bridges, airports, ports, and utility assets), major crops, and population. More than 500,000 buildings, representing 15 per cent of the estimated number of buildings, have been digitized from very-high-resolution satellite images. About 80,000 buildings and major infrastructure assets were physically inspected to calibrate satellite-based data, and about 3 million buildings and other assets, mostly in rural areas, were inferred from satellite imagery. PacRIS includes a comprehensive regional historical hazard catalogue of 115,000 earthquake and 2,500 tropical cyclone event, and an historical loss database for major disasters. It has state-of-the art country-specific hazard maps for earthquakes and tropical cyclones, risk maps showing the geographic distribution of potential losses for each country, and other visualizations of the risk assessments. These can be accessed through an open-source web-based platform (The World Bank, 2013).

CONCLUSIONS

The main conclusions to emerge from the study include the following.

- Land administration and geospatial information play an important baseline and development platform role at the forefront in all disaster risk management phases: disaster prediction, prevention, preparedness and mitigation, emergency response, evacuation planning, search and rescue, shelter operations, and the post-disaster restoration and monitoring. Comprehensive and resilient land and geospatial systems can secure the quick recovery of economic activities through accessible and instant data on the impact, help to minimize the value of losses and disruptions, and provide appropriate levels compensation and required investment to restore activities.
- Assessing the likely impact of disaster events requires detailed inventory of real estate assets, buildings, housing, crops, and infrastructure.
- Secure tenure is the key to reducing vulnerability and risks. The more secure, formal and

reconcilable the rights and systems are, the less vulnerable land users are to eviction or loss of livelihoods in the case of a disaster, and the more likely they are to receive compensation for losses sustained. Secure tenure increase investments to dwellings, which reduces risks and improves resilience through better siting and construction of buildings.

- Land and geospatial information needs to be accurate, reflect reality on the ground, and be up to date if it is to contribute to disaster preparedness and risk mitigation and responses to disaster events. In many countries this is not the case making them vulnerable to disaster events.
- Sharing land and geospatial information with disaster risk management agencies and enabling them to harness this valuable data in their planning and operations enhances the overall process and supports government-wide agendas but often there is disconnect between a number of these key elements and a lack of interoperability. National Spatial Data Information systems are essential to overcoming these. Improving interoperability means overcoming technical, capacity, legal, and cultural impediments.
- Land administration and geospatial information systems can only perform their roles if they are themselves resilient. The systems will fail if they are not able to deliver accurate information in real time during a disaster event. Yet often records are paper-based and are vulnerable to destruction. Remote storage of electronic data offers greater protection providing such data is properly secured. The organizations responsible for land and geospatial systems need to have business recovery plans which are regularly tested and in whose operation their staff have been trained.
- Governance issues play in important role in the effectiveness of land and geospatial systems. Corrupt or ineffective town planning, land management, or building control systems enhance the risks from disaster events and impede recovery and reconstruction. Stakeholder involvement in needed so that all parties know the part they must play in the event of a disaster event. Those responsible for disaster planning and mitigation and for reconstruction and recovery should be accountable to the population and respect human rights.
- After a disaster event, it is not sufficient just for reconstruction to take place, but construction and land administration and geospatial information should be enhanced through building back better so that there is greater resilience to future disaster events. Disaster events often reoccur so that just undertaking recovery work is an inadequate response as it is likely to be destroyed by the next disaster event. Only by building back better can communities be protected in the future. Investment in doing so produces substantial returns on the capital employed.
- Rebuilding after disaster events requires high levels of accuracy in geospatial data to enable engineering and construction works to be undertaken, something that crowd-sourced mapping from

satellite images cannot achieve.

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