The Signficance of Geospatial Information and the Role of Surveyors in Meeting the Challenges of Disaster Risk Reduction and Climate Change Adaptation

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Key words: Coastal Zone Management; Professional practice; Risk management; Spatial planning

SUMMARY

Spatial information plays a vital role in meeting the development goals of a country particularly in the areas of resource management, environmental monitoring and infrastructure development. However, the archipelagic nation of Philippines faces greater and more complex development challenges in the face of continuing struggle with ever-frequenting natural hazard events and the subtle ravages of climate change. Development processes therefore must incorporate risk reduction and adaptation strategies from disasters and climate change respectively. Possessing the ability to understand hazards and climate change phenomena can be achieved through better information especially those which are geospatial in character. The proposition put forward in this paper is that (1) the services and products by surveyors or geodetic engineers are critical in formulating the appropriate plans and actions to mitigate and reduce risks from disasters and climate change and that (2) in order to achieve a level of success in reducing risks from natural disasters and adapting to climate change, plans, programs and projects must take into consideration the geospatial aspects of safety, security and sustainability. Surveyors or geodetic engineers as main providers of spatially referenced data must assume a more aggressive role in meeting the geospatial data requirements of disaster risk reduction and climate change. A formidable challenge tin assuming this role is to bridge the knowledge gap between mere acquisition of spatial data to its downstream application among the students and practitioners of the surveying profession. Geodetic engineers must take a more proactive stance by reaching out to their counterparts in resource, environment and infrastructure application fields to identify and understand the required vis-à-vis appropriate spatial information for mitigating disasters and adapting to climate change.

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1. INTRODUCTION

Two of the most pressing environmental concerns facing the Philippines today are natural disasters and climate change. The Philippines is one of the world's most disaster-hit nations, topping the list of countries hit by disasters between 1990-2000. Damage caused by typhoons alone cost the country up to P15 billion annually, equivalent to an average of 0.5% of the country's Gross Domestic Product (GDP). The economy of the Philippines is dependent on natural resources, which makes it extremely vulnerable to climate change. The large and fast-growing population - a staggering 94 million in 2010 projected by National Statistics Office (2010) are at high risk and the most vulnerable. The large proportion of the country's population lives along coastlines where high concentration of human and economic activity are devoted to agriculture and fishery. A third of the population still live below the poverty line, with poor access to a health services and safe environment.

Although the root causes of disasters are environmental, economic, social and political in nature, the science and applications that technology-based professions such as surveying, or geodetic engineering as it is known in the country, address have important roles to play in addressing disasters. In an era of economic uncertainty and rapid environmental change it is imperative that concrete actions be taken to minimize risks from natural hazards and climate change. In this paper, we shall discuss the importance of reliable hazard information, appropriate tools and applications to forecast oceans and weather, and putting up early warning systems for various types hazards, and the contribution surveyors in utilizing natural resources at the same time protecting our environment in a safe, secure and sustainable manner.

2. NATURAL HAZARDS, CLIMATE CHANGE, DISASTERS AND RISKS

As part of Pacific Ring of Fire and Earthquake Belt (Figure 1), the geographic and geologic setting of the Philippines make it prone to various hazards, including those that are weather- and climate-related, volcano-related, earthquake-related and tsunami. Such conditions, enable 20 tropical cyclones to enter the Philippine Area of Responsibility (PAR) per year, about 9 cutting across the country bringing heavy rains and strong winds characteristic to many weather systems (e.g. typhoon, monsoon, cold front, etc.).

The Philippine's Country Report in the Intergovernmental Panel on Climate Change (IPCC) reveals that in most parts of the country, the intensity of rainfall is increasing with major cities like Baguio, Tacloban and Iloilo showing statistically significant increases (1951 – 2008). On the other hand, the frequency of extreme daily rainfall (from 1951–2008) in most parts of the country are generally increasing. Calapan, Laoag, Iloilo and Tacloban show statistically a significant increasing trend, while a significantly decreasing trend is found in Palawan. Generally, there are increases in total rainfall and number of raindays in the Visayas (trends not statistically significant). There are few significant decreases in hot days at coastal stations (Aparri, Virac, Puerto Princesa). There is no significant trend in the number of cyclones forming in or entering the Philippine Area of Responsibility (PAR) in the past 58 years (1948-2005). The trend in the five year running average of tropical cyclones greater than 150 kph is on the rise and found to be more frequent during El Nino events. There is a year to year variability in the number especially during El Niño and La Niña years. Few number of tropical cyclone were recorded in El Niño years (1972-73, 1997-98,1967-68).

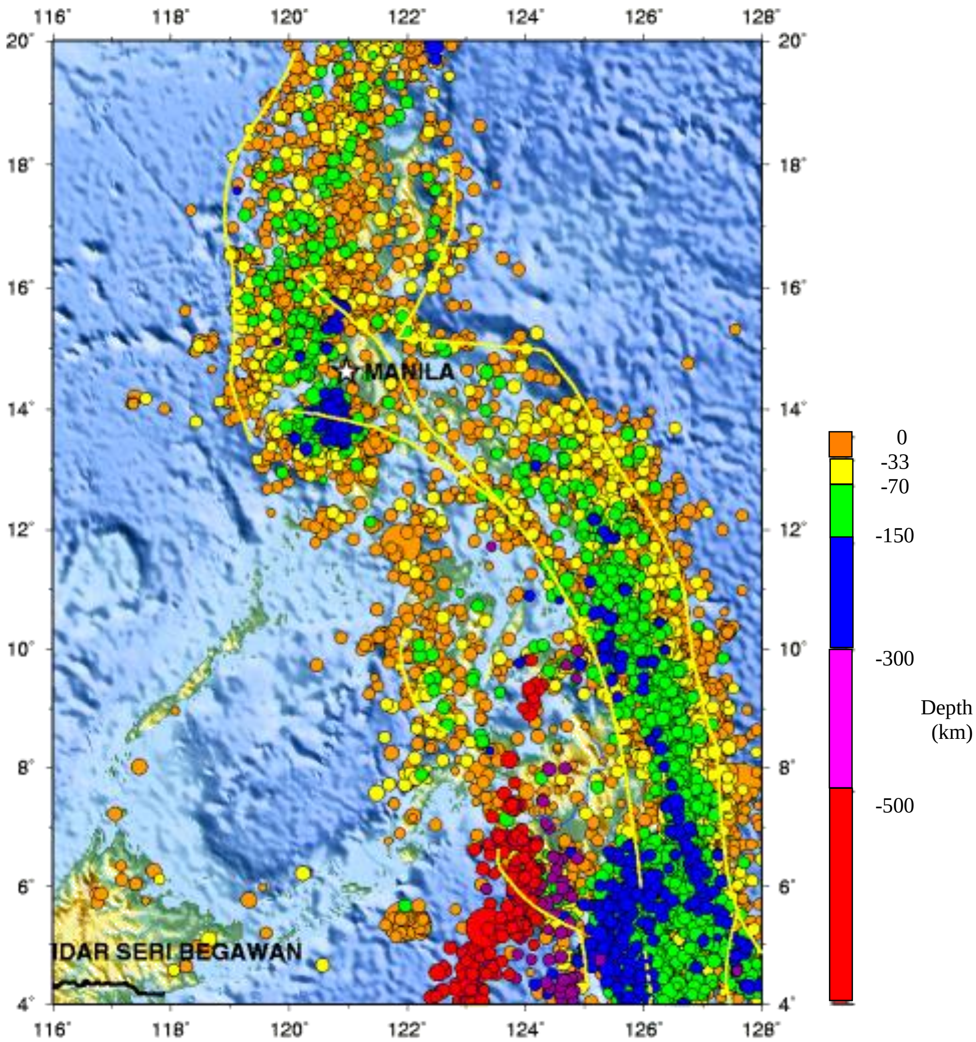


Figure 1. The seismicity map of the Philippines 1990 to 2006 (Source: USGS).

Climate change is not something new since the Earth does not have a relatively stable climate system. Throughout the earth's geologic history, global climate has undergone considerable natural variations: large cycles or even decadal to century scale variations. However, the present rate of climate change is said to be exacerbated due to emission of greenhouse gases that trap the radiated heat from the earth, causing global warming.

Figure 2. Locations of places in the Philippines mentioned in this article.

This warming effect causes ocean thermal expansion and melting of non-polar glaciers giving way to sea level rise. Globally, the rate of sea level rise for the last 20 years was 25% faster than in any other 20-year period. At the local front, more than 100 years of tide record in at Manila's South Harbour since 1902 indicate a rise of 1.3 millimetres per year - the global rate- until the early 1960s, when it increased to about 2.6 centimetres per year (Perez, et al. 1996).

Figure 3 shows sea level variations recorded at Manila, Cebu, Davao and Legaspi during the last 50 years from records (BCGS, CGSD-NAMRIA).

Inundation of coastal areas from sea level rise can be aggravated by ground subsidence which is caused by natural sediment compaction (Soria et al., 2006) or by over extraction of groundwater due to domestic use. In Metro Manila, the apparent rise in sea level correlates well with the increase groundwater use until 1995 (Rodolfo and Siringan, 2006). Earthquake-related movement may also cause uplift or subsidence of coastal areas.

Climate change is already present and will continue to happen as it is part of earth's history.

We need to address the risks posed by climate change together with other natural hazards. Natural hazards may be exacerbated by climate change or interact with intertwined effects of climate change and human activities. Hazards maps produced must be evaluated as to their applicability with climate change scenarios.

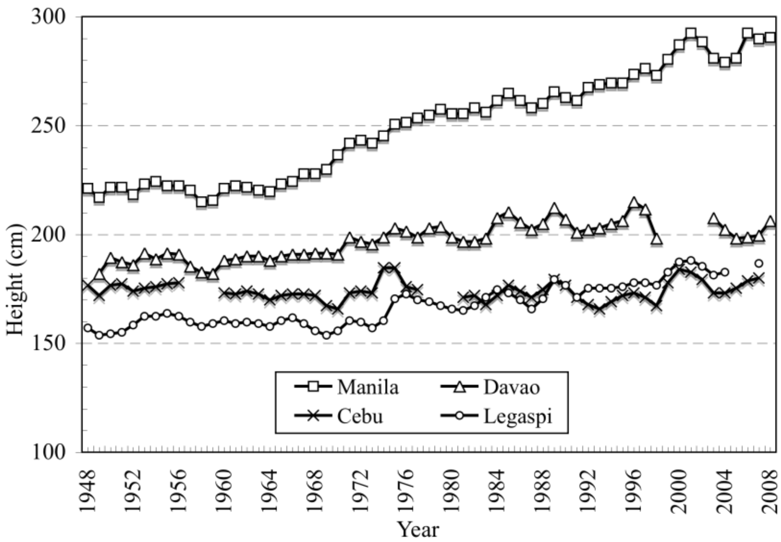


Figure 3. Sea level variations recorded at Manila, Cebu, Davao and Legaspi from 1947–2007 (Source: NAMRIA).

3. THE SOCIO-ECONOMIC MILIEU OF DISASTERS AND CLIMATE CHANGE

Our recent experience with the heavy rains brought by Ondoy (International name Ketsana) and Pepeng (International name: Parma), which caused swift flooding in Metro Manila and Northwestern Philippines and massive landslides in the mountainous region of Cordillera last year (September to October 2009), has brought to our raw consciousness the flaws in our land management system and leniency in our development practices. It cannot be denied that further casualties and damages could have been averted had areas with high susceptibility to flooding and landslide remain strictly closed to urban development. Pre- and post-disaster responses such as evacuation, rescue and relief would prove to be very futile and costly compared to mitigation measures such as relocation and differentiated land use zoning.

Meanwhile, the indigenous people of the hinterlands all the way to the urban slum dwellers, are still in quest of effective means to access land and remain largely unfamiliar with land tenure processes implemented by the government. The current land tenure system condones idle/absentee ownership. Large tracts of agricultural lands are controlled by a few rich people- a system rooted in our colonial past despite well-publicized land reform policies. The government, the largest and most powerful landlord likewise owns vast tracts of uninventoried and unutilized land all over the country.

City dwellers are not immune to the land problem. High prices of land in cities and urban centers force poor urban dwellers to the confines of what are supposedly considered uninhabitable spaces such as abandoned or unsecured land parcels, blighted urban pockets, ports and coastlines, railway curbs, riversides and esteros (urban streams). Low-income workers locate in nooks-and-crannies of the urban space to minimize costs for transportation to their workplace. Urban slum dwellers then fall prey to shanty "operators". Moreover, they do not enjoy the benefit and protection of rent control laws and therefore become more prone to abuse and even harassment. Enterprising "professional" squatters end up thriving as scrupulous leaders of tough urban slum communities.

Disasters do not occur only because of natural settings and natural events but they are also a product of the social, economic and political environment where people live in adverse socio-economic situations that lead them to inhabit high-risk areas and engage in risky livelihood activities. Informal settlers locate along inactive railways, abandoned if not condemned properties, river/creek banks, coastlines and even constructed floodways(!) – areas where they are less likely to be accosted for illegal occupation. It is not surprising that the very same marginalized segment of society become increasingly vulnerable to natural hazards because their places of abode are exposed to hazards.

Intensified land utilization for vast economic gains continue to compromise integrity of the environment and viability of land resources. Unsustainable practices in agriculture (slash and burn, use of toxic farm inputs, erosion) forest industry (illegal logging, loss of biodiversity, degradation) and urban development (massive industrialization, housing, establishment of large-scale commercial buildings) have taken its toll on the environment. Except those recently developed, many of large urban centers do not have segregated systems for treating wastewater and storm drainage, even for large commercial centers. Discharge of pollutants from industries remains unabated despite numerous environmental laws being passed routinely by Congress.

Again, environmental abuses also result in exacerbation of catastrophic events. The 1991 Ormoc flooding was largely a result of loss of forest cover in the upstream watershed (Mahmud, 2000). Residents of Infanta-Real-General Nakar who suffered from flooding triggered by heavy downpour in December 2004 attribute their tragic experience to rampant deforestation in the Agos watershed (Gaillard et al, 2007). Massive landslides in the slopes of highways to and from Baguio, whether induced by rainfall or earthquakes are aggravated by complete removal of topsoil cover along the sideslopes (Saldivar-Sali and Einstein, 2007).

4. GEOSPATIAL INFORMATION AND THE CHALLENGES OF DISASTERS RISKS (DR) AND CLIMATE CHANGE (CC)

No doubt, any response to the challenges of disasters and climate change requires concerted effort among stakeholders in different areas of expertise and from various sectors. One thing certain though is that these efforts primarily depend on the quality and reliability of information made available to them and to the community at large. Most of this information are geographically variable, location-specific and therefore should be spatially-referenced. There is urgent quest to derive more accurate, up-to-date geospatial information at finer scales.

In disaster risk assessment, one of the prime requirements is information on natural hazard. The precise location, measures of the relative level susceptibilities of the areas and their corresponding frequencies of occurrence of primal importance. Next the elements at risk or those exposed to the natural hazards must be identified, located and even valued. The elements at risk include the population living within hazard zones or properties that may be at risk of damage if and when disasters strike.

One of the fundamental requirements for conducting assessments of geo-hazard is elevation data. In the digital environment, a fine-scale digital elevation model (DEM) derived from a sufficiently dense elevation measurements is desirable. A DEM is a computer-based gridded surface representation of topography with a certain horizontal and vertical resolution. It is one of the main inputs in flood inundation modeling and simulation. Derivative product maps from a DEM, such as slope gradient and aspect, are also necessary factors for determining susceptibility to landslides and mass movements, whether they earthquake or rainfall-induced. From DEMs, flow direction and accumulation maps as well as watershed catchment boundaries can be delineated.

At the nearshore area, fine-scale, sub-centimeter level topographic information is needed to precisely assess hazards associated with low-lying environments. Among these are the susceptibility to coastal flooding, storm surges and tsunami hazards. Coastal areas in particular are investigated for potential liquefaction and ground subsidence. Together with very precise nearshore topographic information, time series data on sea level means to determine rate of ground subsidence vis-à-vis sea level rise.

Sea level rise (SLR) is one of the more closely observed phenomena of climate change. Coupled with nearshore bathymetry, coastal inland topography, rates of SLR can be used to project coastal flooding, analyze risk and understand vulnerability of coastal communities from inundation.

Land cover data too is essential information, especially for quantifying the impacts of slow-onset hazards such as drought and El Nino. Together with topographic data, land cover information can be used to understand inundation patterns through hydrological models that incorporate surface evapotranspiration, rainfall interception and soil infiltration characteristics -all these parameters have relationships with earth surface cover characteristics. In relation to climate change, land cover information is also needed for estimating greenhouse gas emissions. Increase in areas covered by tree plantation and upland farms can lead to carbon sequestration and arrest global warming.

Evaluation of the coastal planning problems requires some knowledge of nearshore environmental dynamics particularly wave, tidal and sedimentary processes. Over and above the ability to pinpoint unsafe zones though generation of hazard maps, it also important to determine the location, distribution and extent of elements at risk such as people, buildings, roads and other spatial features in both urban and rural regions, and to provide answers to relatively complex risk questions. To accomplish this, data depicting the different human functions and activities and other objects of value should also be collected. Maps showing the built zones and settlements, land use maps and their corresponding values should be generated. Proper land use and urban planning can help to mitigate disasters and reduce risks by avoiding construction of settlements and key facilities in hazard prone areas, control of population density and expansion.

5. THE ROLE OF GEODETIC ENGINEERS IN MEETING THE CHALLENGES OF DR AND CC

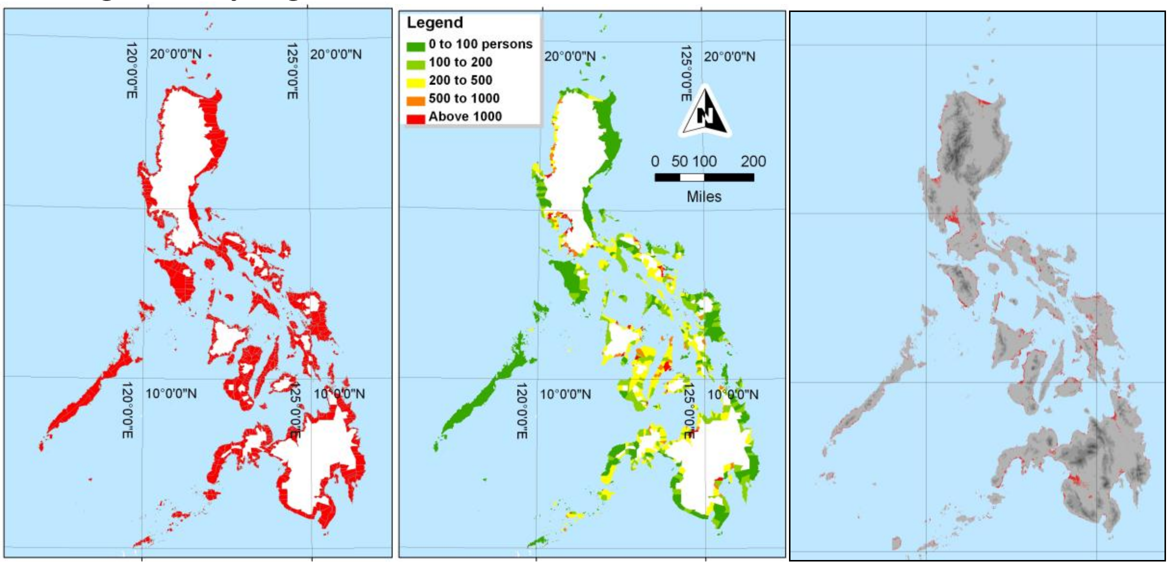
The Philippine law[1] defines geodetic engineering as professional and organized act of gathering physical data on the surface of the earth with the use of precision instruments. It is also the scientific and methodical processing of these data and presenting them on graphs, plans, maps, charts or documents. Thus, geodetic engineers are expected to provide services in high-precision, high-accuracy geodetic control and generate fine-scale topographic data from field surveys. Geodetic engineers are also anticipated to produce small- to large-scale topographic maps using photogrammetric and remote sensing techniques. Geodetic engineers are also trained to observe sea level, tide measurements and perform bathymetric surveys. It is apparent that most of phenomena related to climate change are well within the core competencies of the geodetic engineering profession.

There are many sources and techniques to acquire and generate elevation data. The more rapid method of Global Positioning Systems (GPS)-levelling for obtaining orthometric heights is not a new concept and is seen as an alternative to traditional method of spirit leveling. In fact, many studies have proven its usefulness to up to 3rd order accuracy. Hence, the question of whether GPS-levelling can provide a viable alternative to traditional techniques is no longer an issue. The more important question, however is the accuracy level that can be achieved using this approach relative to an application. Over the past decade, numerous advances have been made which have placed us in a position where we can begin to address the issue with more confidence. On the other hand, DEMs can be created from conventional on-site topographic surveys using precision instruments, stereo-photogrammetric compilation, aerial Light Intensity Detection and Ranging (LIDAR) and interferometric Synthetic Aperture Radar (InSAR) processing.

The calculation of the hourly sea level values for the other years is based on the tidal constituents obtained taking into consideration the tidal prediction. Then, hourly sea level values of 18 years tide gauge are quality controlled by comparing them with the predicted values by removing datum shifts and time errors as much as possible. A low-pass filter is applied to the hourly sea level values in the computation of daily values and the daily values are used to obtain monthly values with a simple average. Harmonic analysis is applied to the monthly sea level values of four tide gauges and mean sea levels (MSL) and relative changes of MSLs are calculated (IOC, 1994). Given the number of islands (more than 7100 vary

[1] Republic Act No. 8560 An Act Regulating the Practice of Geodetic Engineering in the Philippines.

according to tide) composing the archipelagic nation, it is inevitable that network of tide gauging stations must be thoroughly maintained. Geodetic engineers, armed with knowledge of hydrographic surveys and tide measurements can assume significant roles in maintaining, processing and analyzing tide data.



(a) (b) (c)

Figure 4. Coastal municipalities and cities (a, in red), the affected population therein (b) and portions possibly affected by 2m inundation (c, in red).

Although the country's total land area is small (<300,000km^2), the Philippine coastline is relatively long at 36,289km- the 5th longest in the world. About 854 out of 1634 local government units (LGUs)[2] in the Philippines have coastlines(Figure 4a). Eight (8) of these are in Metro Manila alone. These represent 54% of total land area (161,300 sq. km) of the country. 32% of population (30Million of 94 Million) live in cities/municipalities adjacent to the coast (Figure 4b). If inundations of up to 2m is projected based on estimates from finest digital elevation model available along these coastlines, 2,834km^2 will be affected (Figure 4c).

Subsidence can be monitored if a network of benchmarks is surveyed over a period long enough for the rates of subsidence to be significantly larger than the precision specifications. It has been established that the geoidal height, a parameter of datum between the two height systems, has significant influence on the reliability of subsidence estimated using the integrated models with combined data. The RMS (root mean square error) difference of up to 13 cm can be found between the annual subsidence rates estimated by using the so-called 'absolute' and 'relative' modes of integrated model. However, the 'relative' estimates of the subsidence, in which a differential mode of geoidal information between the two neighboring sites are used are consistent with those using two sets of GPS solutions by a RMS difference of around 5 cm.

[2] LGUs are either municipalities or cities

Earth observation satellites are used by geodetic engineers in providing data for a wide range of applications in disaster risk management cycle. Pre-disaster uses include risk analysis and mapping; disaster warning, such as typhoon tracking, drought monitoring. Satellite imageries can also be used to determine the extent of damage due to volcanic eruptions, oil spills, forest fires and the spread of land degradation; and disaster assessment, including flood monitoring and assessment, estimation of crop and forestry damages, and monitoring of land use/change in the aftermath of disasters. Land cover maps and statistics can be generated by processing remotely-sensed data set through digital image classification. At larger scales, it is possible to delineate different land uses from satellite- or airborne images. A series of remotely sensed observations also provide a historical records from which hazard maps can be compiled, indicating which areas are potentially vulnerable. Information from satellites is often combined with other relevant data in geographic information systems (GIS) in order to carry out risk analysis and assessment. GIS can be used to model various hazard and risk scenarios for the future planning and the development of an area.

While most of the data with socio-economic theme or content, the tools and technical assistance in using geospatial and social science data to develop visual renderings for specific end-users and communities to better understand the impacts of hazards and climate change can be best delivered by the mapping professional. Maps can be prepared depicting the location of the hazard.

Given the actual and prospective use of its products and services, geodetic engineers as main providers of spatially referenced data must assume a more aggressive role in meeting the geospatial data requirements of disaster risk reduction and climate change. A formidable challenge along this line is to bridge the knowledge gap between mere acquisition of spatial data to its downstream application among the students and practitioners of the profession. Geodetic engineers must take a more proactive stance by reaching out to their counterparts in resource, environment and infrastructure application fields to identify and understand the required vis-à-vis appropriate spatial information. Without proper guidance, a number of application specialists resort to poor, substandard and unreliable spatial data to generate the information needed by planners and decision makers. GEs can help level off expectations with respect to applicability of data to certain interpretations.

6. THE GOAL: A SAFE, SECURE AND SUSTAINABLE (3S) USE OF RESOURCES

Three goals can be pursued with respect to use of resources to mitigate effects of disasters and climate change: **s**afety, **s**ecurity and **s**ustainability.

Safety. Part of any planning practice is to identify not only productive but also safe areas for habitation and evacuation areas in time of disasters. Proposed development programs, projects and activities that do not impose further risk to life and property must be ensured. To accomplish this identification task, accurate topographic and hydrographic (in the case of floods, storm surges and landslides) data, and cultural (such as the cadastre) features would be necessary. Topographic information enable hazard specialists to precisely identify areas susceptible to hazard events. The elements at risk namely the population and properties can be accurately pinpointed and overlain on the hazard maps to estimate the degree of vulnerability that concerned communities face.

Security: That is, to empower people to equal access to land and land information for secure land tenure. Pro-poor policies and mechanisms to land ownership must be put in place. Strategic policies must be put in place that would discourage ownership of land if not productively utilized. This is only possible if land information is available for local governments. De Soto (2000) makes a convincing case that land tenure systems have a vital role to play in the efficient development of national economies. Presenting better opportunities and alternatives to own land or obtain right to property in safer locations also reduce vulnerabilities from disasters.

Sustainability. Sustainbility provides for means to develop today while ensuring the viability of future generations. Achieving sustainability goals is highly multidisciplinary in nature. There must be a concerted effort among resource and environment managers, planners and decision-makers. All of these efforts depend on reliable, accurate and timely information that is highly dependent on spatial positioning, location and navigation data. Particularly, sustainability is a critical consideration when dealing with climate change adaptation as climate change effects are seen to be aggravated when unsustainable ressource utilization practices remain uncurbed.

With its specialized skills, the geodetic engineers can substantially contribute to mitigation of disasters and to reduction risk. Requirements are not only engineering know-how but also the surveyors' variety of skills and knowledge in urban and rural planning, land management and development, building and land law, real estate and business administration, ecology, nature and landscape conservation as well as social competence. Among other things, the surveyor taking the hat of a land manager can:

1. formulate effective land use regulations such as zoning and conversion restrictions that veer urban and rural development to safe zones.
2. spearhead, coordinate and direct the complex procedures on land relocation, consolidation, land registration and land reallocation for owners who were displaced from properties ravaged by catastrophic events such as floods.
3. undertake equitable damage valuation of the destroyed or damage buildings and public facilities in the aftermath of a disaster for risk estimation and risk transfer.
4. establish sustainable infrastructural, economic and ecological conditions for developing urban and rural areas and resolving land use conflicts.
5. foster public-private partnerships in order to optimize ize economic, ecological and social land uses,

To meet the demand for disaster and climate risk information, there is a need to build capacity among students and professionals. A key strategy in implementing the capacity building measure is to stimulate the partnership between key players: the government, the industry and the academic institutions through research and development activities that are more sensitive to the aims of disaster resiliency in land administration systems and policies. There should be more opportunities for creating channels that allow dialogue and initiating relevant activities that address questions related to climate change and natural hazards. The other aspect of the capacity building measure is to aggressively campaign for graduate education for geodetic engineers. Geodetic engineers must be equipped not only with new measurement technologies, but skills to analyze datasets, not just measure them.

GEs must interact with hazard experts, local and regional planners, infrastructure engineers. GEs must not only be proficient in surveys and measurements but must also understand the downstream uses and applications of spatial data generated. In conclusion, GEs as providers of essential goods (information) and services (surveys), are in a very good position to make a difference. It is not the surveyor alone, who contributes to disaster risk management with special regard to land management. Land management and land use planning are interdisciplinary tasks that shift the responsibility for the described strategies and measures on various occupational groups.

7. CONCLUSION

Risks from disaster is more than a function of the strength, magnitude or intensity of a hazardous events; nor climate change risks just a function of the physical transformation of earth surface processes. Risk is also determined by the capacities of the affected community and the people's ability to withstand, shield itself and recover swiftly from their injurious or deleterious consequences. The long-term solutions lie in being able to build a more disaster-resistant, resilient, and adaptive society founded on a solid knowledge and thorough understanding of hazard events, climate change manifestations and human vulnerabilities. Practical steps towards this goal include enhancing the data and information support systems and services for decision-making and strengthening partnerships with civil society organizations.

The Earth is ever changing – it is part of its natural evolution. The Philippines itself undergoes a continuous process of very intense but nonetheless interesting change. Whether these changes are rooted on natural or anthropogenic causes, it drives the surveying profession to be a perpetual necessity for the humankind. So long as resources are utilized, environment looked out for, and developments pursued, there will always be a demand for measurement of earth and space in various levels of detail, frequency and scale. In this sense therefore, the surveying practice can never be obsolete. This promising scenario presents a bright prospect for geodetic engineers contrary to odd misconception that "everything" has already been surveyed.

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BIOGRAPHICAL NOTES

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