GPS Application in Disaster Management: A Review

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ABSTRACT—*The integration of Global Navigation Satellite System data, Geographic Information System, and Remote Sensing data have been and are still being used in wide range of applications. This paper discussed the utilization of these geomatic technologies in the areas of risk and disaster management by placing more emphasis on the use of GPS in monitoring, assessing and managing these disaster events. Furthermore, this study highlighted cases where GPS was used in three disaster periods namely; pre-disaster, during disaster and post-disaster events to predict potentially vulnerable areas, detect occurrences and identify the extent of damages done by disaster. Finally, the paper reveals that the integration of GPS, RS, and GIS in disaster management have not only helped in prediction, detection, and monitoring but also in mapping out the exact disaster extend and assessment of the damages.*

Keywords— GPS, GNSS, RTK, Disaster, GIS, RS

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1. INTRODUCTION

Disaster could be a natural or man-made hazard that has adverse effects and can cause significant damages to its occurring environment. These damages may not always be limited to its occurring environment alone, but could include the loss of lives and properties as well. Over the last few decades, both man-made and natural disaster have been increased worldwide, with Asia recording the highest number of occurrences, damages, and casualties. According to the 2013 World Disaster Reports, 6,699 natural disasters occurred between 2003 and 2012 worldwide, reportedly killing a total of 1,149,920 people and damaging properties worth $1,57,570 (2012 prices) [1]. Consequently, the effects of these natural disasters, if not monitored and managed properly, will continue to have adverse impacts on the biophysical characteristics of the environment, socio-economic activities and worst still destructions of lives and properties of host community [2].

Some natural disasters usually occurs abruptly thereby affecting large areas, thus, making it difficult to develop preventive measures. They include Earthquakes, Tsunamis, and Tornados etc. however, disasters such as Flood and Landslide can be predicted and mapped out more easily and the potentially affected people within the known vulnerable areas can be alerted in advance to avert more damages [3]. However, these naturally occurring disasters are not without mitigation measures. The utilization of geomatic technologies can have a significant contribution to disaster mitigation [4]. More so, Global Navigation Satellite System (GNSS) is one of the geomatic technologies that can monitor precisely through emitting of time signals allowing users on or above the earth surface to determine the positions with high accuracy. GNSS can also be used to precisely monitor deformation at scale in real time under any weather, at any time of the day [4]. With Global positioning system (GPS) module attached to a hardware platform, data on the point of observation at hazard site can be received in real-time. [5] Supported this notion of the importance of real-time or, at least, near-real-time imagery in emergency response stating natural and man-made disaster creates a need for rapid comprehensive and reliable information on the nature, extend and actual consequences of an event. The use of geospatial technology in disaster management is a natural fit because almost every aspect of a disaster is referenced by location [3]. Other geospatial technologies that can be integrated with GPS are Remote Sensing (RS) and GIS tool. The integration of GPS, RS data, and GIS mapping can help mitigate the effect of any natural disaster [6]. The GPS disaster management applications that are associated with preparedness and mitigation measures usually involves landslide and flood disaster prevention. Mitigation involves any activity that minimizes the impacts of disaster within potentially vulnerable areas while preparedness involves the activities that facilitates the preparation for response to disaster occurrence [7]. Response and Recovery efforts are associated with Post-disaster event. While response is always associated with immediate and short-term effects of disaster, the Recovery process deals with the restoration of affected areas back to normalcy (Pre-disaster period) normally through reconstructions [7]. However, this paper seeks to review the different applications of GPS in disaster management and how GPS has been used in managing some disasters of various kinds and their case studies.

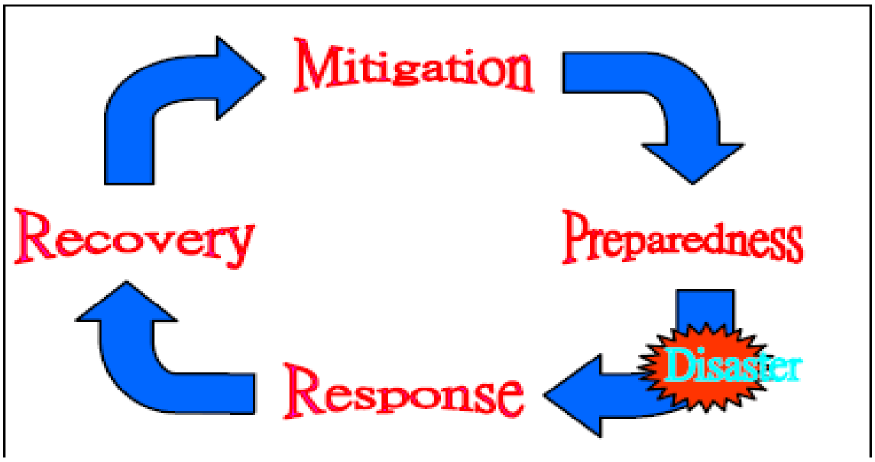

Figure 1: Disaster Management Cycle (Source: Chen et al. 2004)

2. GPS APPLICATION IN DISASTER EVENT

The importance of GPS application in monitoring and managing disaster events cannot be overemphasized [5]. This is because GPS is used in providing real-time information of location with high precision that can help in managing each of the processes of disaster event starting from pre-disaster, during disaster and post-disaster event.

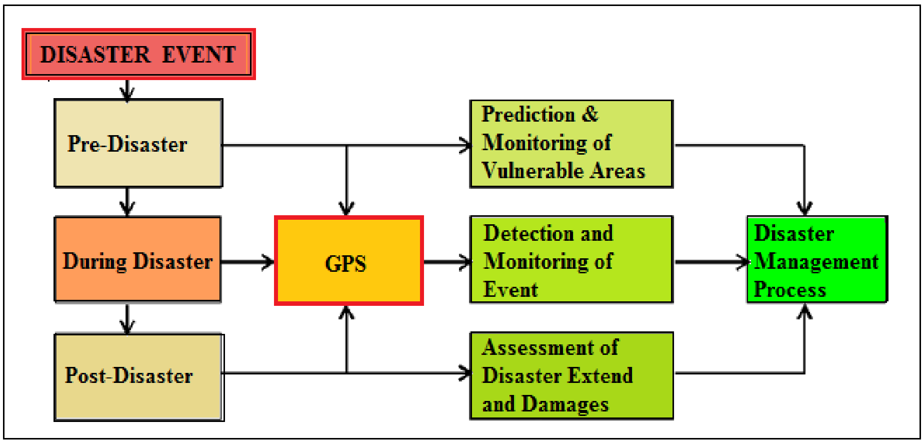

Figure 2: GPS Disaster management process

2.1 Landslide Study Using GPS Technologies

Land displacement monitoring in a certain landslide prone areas involves monitoring of gradual changes in distance, height difference and coordinates of station within the area under study [8] Since GPS is a passive, all-weather satellite-based navigation and positioning system, which is designed to provide precise three-dimensional position and velocity, as well as time information on a continuous worldwide basis [9]. Global positioning system can provide a relatively wide spectrum of positioning accuracy, from high accuracy level (mm level) to a normal level (a few meter levels). For the purpose of monitoring landslide phenomenon of little magnitude, the relative positioning accuracy required should be in mm level. And the best method that can achieve that is the GPS static survey based on phase data with stringent and cautious measurement and data processing [10].

2.2 GPS Application in Landslide Monitoring

The basic information required from the data of any earth observation satellite could be geological, morphological or land use driven which can help in assessing landslide effects and causes [11]. The static method of survey was used by [8] to study landslide displacement phenomenon. During the study GPS was used in providing the precise coordinates of the susceptible areas of displacement at certain intervals while studying the characteristics and rate of changes in the coordinate to derive the possible displacement. Dual-frequency receiver was used in obtaining the coordinates difference with precision at several mm levels. [12] Utilized GPS device and data in natural disaster monitoring and assessment of landslide in Koyulhisar City, Turkey. A network of 12 GPS stations were used, and the measurements were processed using rapid static and static methods from the network. The reference points were installed in the geographically stable ground away from the landslide area, and their location were determined by nearby international GNSS service station while the rovers were distributed across the vulnerable areas. GPS rapid static results were compared with static GPS solutions that were taken as the truth. The efficiency of the rapid static GPS survey method for slope monitoring was demonstrated. They recommended the method's suitability and suggested its application to regions with similar morphological characteristics, as well as in volcanic activity monitoring. [13] in their study, compared between inclinometer data and of GPS measurements in monitoring landslides. And opined that the GPS stations were vital in detecting the potential landslide areas.

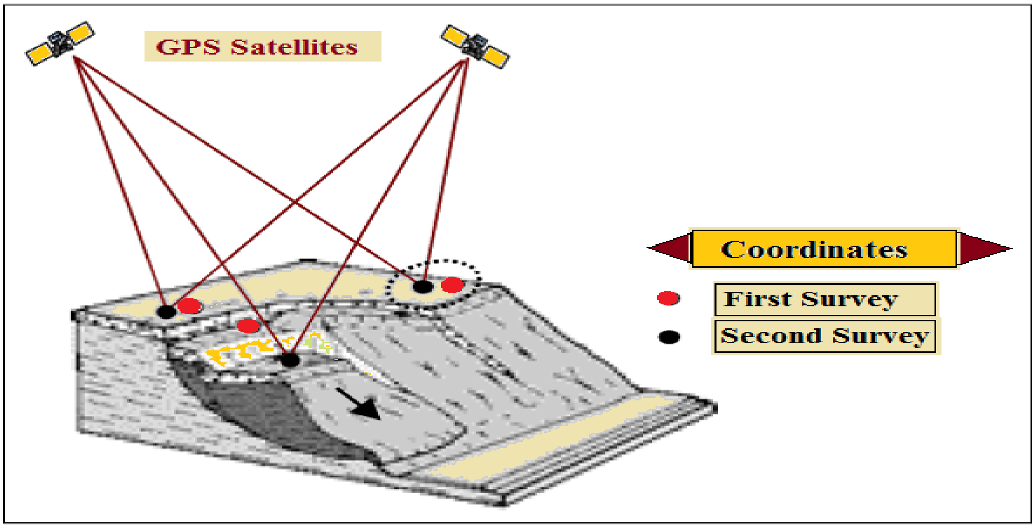

Figure 3: Landslide Monitoring Process. (Source: Abidin et al 2004)

2.3 GPS Application in Tsunami Management

In monitoring Tsunami, [13] compared between GPS ground photos of damage areas and post-event satellite data. The photos of each damaged building were synchronized with high precision kinematic GPS for positioning. Damage buildings were identified with their intensity of damages such as partially or completely damage, partially collapsed with roof intact, and slightly damaged. They then compared post-event satellite image with ground truth GIS data and finally compared pre and post-disaster satellite image of the area and generated a tsunami damage map. The comparison they said helped in differentiating between the totally and partially collapsed buildings. While the GPS was helpful in determining the exact coordinates of the damage buildings within the area. [15] Used GPS to survey the Indian Ocean tsunami where they used a variety of standard field survey techniques. The measurement includes the Tsunami run-off height and local flow depth based on watermark and eye witnessed accounts. Each watermark was located using handheld GPS device and photographed. During the survey, maximum runoff inundation was determined relative to the sea level at tsunami impact with laser range finder and digital inclinometer and compass.

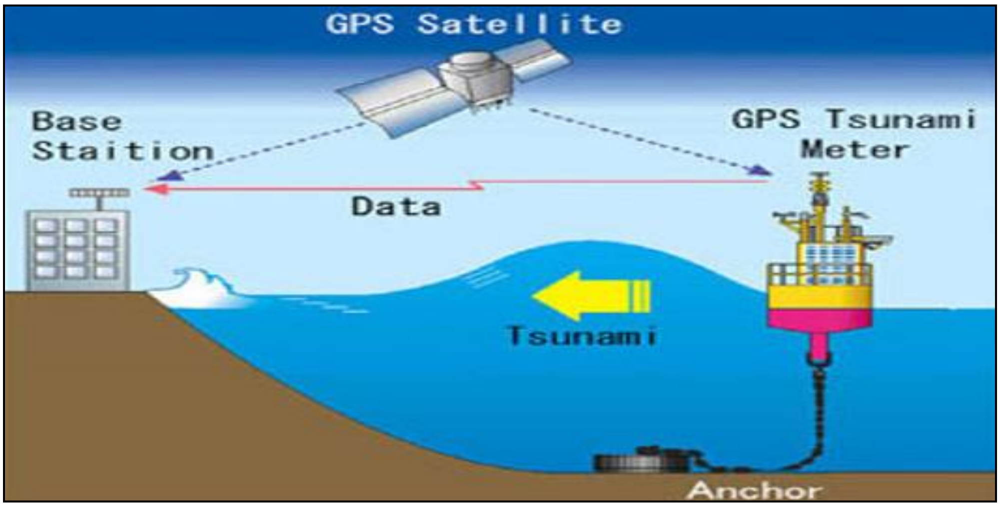

Figure 4: Tsunami Monitoring Process (source: Geogarage 2012)

2.4 Application of GPS in Earth Quake

Integrated ground measurements and satellite remote sensing can help meet these various requirements for baseline and time-series data. GPS, for example, used for navigation and positioning in civilian and military applications, provides the millimeter-level differential accuracy that is used by regional ground deformation networks to monitor inter-seismic ground deformation and co-seismic displacement [15]. Using monitoring data from GPS stations in Taiwan, Yang [17] in their study, used GPS geodetic data to quantify the three-dimensional surface displacement pattern associated with the Chi-Chi earthquake. They demonstrated the co-seismic displacement of the Chi-Chi earthquake (Japan). The measurements were taken at pre and post-phases of the event generating a complete dataset for displacement studies.

2.5 GPS Application in Forest fire management

A study carried out by [18] assessed the case of forest fire that gutted about 2,500 plus structures in the Oakland fire. Each of these structures was assessed with the aid of GPS and survey Questionnaire. The Global Positioning System was also invaluable in this phase for gathering locational information [19]. During the Oakland fire, GPS and GIS were used to map the fire perimeter and georeference the location and number of each damaged or destroyed structure. This information was then overlaid with census data and existing parcel maps to assess individual losses to help support the process of applying for rebuilding loans and grants. The overall application of GIS and GPS in the Oakland fire inspired a fire risk assessment study of other similar areas in California. An increase in adoption of geomantic technologies following disaster is a general trend. GPS has various ground based application in forest fire management ranging from preparedness to suppression processes [20].

2.6 Application of GPS in Flood Management

The utilization of Geomatic technologies i.e GPS, RS and GIS is being used increasingly for flood assessment, including the integration of inventory mapping, location of surface structures and roughness providing information on flow emplacement parameters (i.e. rate, velocity and rheology), and factors such as lithology, location of faults, slope, vegetation and land use [21]. In managing a flood disaster, [22] used GPS and Synthetic Aperture Radar (SAR) imageries to estimate flood water depth from SAR images. First of all, a land level map of Greater Dhaka was extracted from the DEM that consist four height classes. This land level map was used to collect representative ground truth data for each unit. Using a GPS, a total of 100 signatures (25 for each category) were collected and plotted on the land level map. Thus, a ground truth map was created and subsequently brought into GIS.

3. GPS COUPLING TECHNOLOGY

The usability of GPS to disaster management does not only stop at the handheld level, GPS are usually mounted onboard other platforms in managing disaster. [4] Utilized an Unmanned Aerial Vehicle (a digital imaging platform) for emergency response. The UAV has a collection of sensors (autopilots) that captures images coupled with GPS that provides the coordinates of different location as the UAV fly through the study site [24]. The photos of each building were synchronized with high precision kinematic GPS for position. After locating the position of satellite images, comparison between the damage level in the ground photographs and high-resolution satellite data was made.

4. ADVANTAGE OF GPS IN DISASTER MANAGEMENT

One of the greatest advantage of GPS in disaster management is its ability to be used at any time of the day under any weather condition.

Another advantage of GPS in disaster management is that GNSS has 100 per cent coverage of the planet GPS is free for all users, as such it can be used to manage disaster from anywhere in the world.

GPS is used at every stage of a disaster event, right from the pre-disaster, during disaster and post-disaster events.

The wide range of applications of GPS in every disaster situation cannot be unconnected to the fact that it allows for easy integration with other geospatial technologies that aid in disaster management.

5. GPS LIMITATION IN DISASTER MANAGEMENT

Like many other geomatic technologies, GPS also has certain limitations in its area of applications which disaster management is not an exception. Since GPS is mainly concerned with precise positioning, most of its limitation will not be unconnected to the degree of precision in finding locations. Consequently, these results to poor accuracy and low accuracies termed as “ERRORS” resulting from the satellite system, GPS receiver, atmospheric or environmental effects. Some of the GPS limitations include;

GPS satellite signals are weak (when compared to, say, cellular phone signals), so it does not work well in indoors, underwater, under bridge and trees, etc.

The highest accuracy requires line-of-sight from the receiver to the satellite; this is why GPS does not work very well in an urban environment or under thick canopies.

GPS accuracy is affected by certain sources of errors that could be from the satellite system, the atmosphere/environment or the satellite receiver itself.

6. CONCLUSION

In this paper, the various applications of GNSS-based methodologies for risk and natural disaster management were discussed. A brief review on the different types of disaster and how GPS was used to monitor, assess, detect or manage such disaster was presented in order to increase our knowledge of GNSS capabilities and to broaden our initiatives for the management and mitigation of disaster situations. However, the utilization of GPS technologies alone cannot be applicable in any disaster events needing comprehensive management except with the integration of other spatial technologies such as Remote Sensing data and GIS tools. The use of remote-sensing data with GIS offers high potential for vulnerability analysis of the interest region, although these techniques should be adapted according to the analyzed area. The easy accessibility of the available geomatic technologies will in no small way have a great application in not only disaster management but also help in solving a wide range of man’s problem and aid decision making. Today the use of orbital platforms is very efficient in preventing, monitoring and mitigating extreme disaster events.

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