ISSN 2229-5518

Geospatial Response with Remote Sensing, GIS, OpenStreetMap and Ushahidi:The Haiti earthquake of 12th January, 2010

Unabor, H.

Abstract— Geospatial response technologies which incorporates fields of Remote sensing, GIS, Crowdsourcing and Crisis mapping have withnessed improvements in recent years due to their real-time interactive commitments in acquiring, processing, analysing, and disseminating spatially referenced information towards response phase of natural disasters. This post disaster research in its full course evaluate geospatial response with Remote Sensing, GIS, OpenStreetMap and Ushahidi to the unprecedented January 12th, 2010 Haiti Earthquake. Critical appraisals provided here involves evaluation from case studies, air and space borne deployments, pre and post disaster imagery analysis for damage detection, damage priortization, analysis of post disaster road network conditions, geospatial criteria for base camp establishment for internally displaced persons and finally OpenStreetMap's crowdsourcing and Ushahidi Crisis Mapping initiatives. As effectively evaluated through presenting major roles including geovisualizations and photo fecilitations, a true picture of result emerge. Techniques adopted from case studies employed here unifies itself to fill needed knowledge gap. In conclusion, main ideas justified prooves beyond doubt, that a cutting-edge in seismic disaster response provided by geospatial responders and their techniques employed have been reached due to abilities to make important verdicts central to geospatial science.

Index Terms— OpenStreetMap, Crowdsourcing , Ushahidi, Crisis mapping, Post disaster, GIS, Remote Sensing.

1 Introduction

The geospatial industry has a current world-wide market of about $5 billion and a growth rate of 10% to 13% per year which is expected to continue for the rest of this decade [12]. Its applications to emergency responses whether large or small scale disasters have withnessed wide appreciation mostly due to its capacity to efectively determine magnitude of damages, post disaster road network analysis and geospatial support for communication and transportation systems through collaborative means [18]. Collaborative means mentioned illustrate an almagamation of geospatial disciplines (GIS, photogrammetry, remote sensing, cartography and geodetic surveying). As [1] puts it, such almagamation provides a form of spatial interaction among various categories of responders, the public, victims and also provide room for spatial information creation, dissemination and validation during emergencies notably earthquakes.

Mother nature unleashed an unprecedented wake up call to Haitians on the 12th January, 2010 inform of a disastrous 7.0 Mw earthquake. [4] reported that on the 12th January, 2010 at 21:53:10 GMT (16:53:10 local time), a massive earthquake of 7.0 Mw struck the heart of the Caribbean nation of Haiti at approximately 15km (10 miles), South-West of the nation's capital (Port-au-Prince) which was then quickly followed by several aftershocks which ranged between magnitude 5.0 Mw - 6 Mw. [29] statistics reported 230,000 deaths and damages estimated to be around US$8 billion or 120 percent of GDP. Also reported, the earthquake affected 2.8 million people of which 300,572 were injured, 97,000 houses destroyed and 188,000 damaged [15]. To sum it, the Haiti earthquake of January, 2010 joins the 283 recorded earthquakes between 2001 to 2010 which claimed 680,145 lives, that is 55.6% of natural disaster deaths between 2001-2010 [29]. As this research probes into emergency response to Haiti through geospatial technologies (Remote sensing, GIS, crowdsourcing with OSM and crisis mapping with Ushahidi), logical path which emanates through writing process provide answers to concise research questions like; 'What roles did these geospatial technologies played during post disaster response?', How does January earthquakes of 2010 differ when compared to recorded earthquakes in Haiti within the decade years (2001-2009)?' and 'What main concerns did crowdsourcing and crisis mapping present during the earthquake's aftermath?'. Clear-cut answers to these inquiries are been fitted into this research.

2 General Overview of Study Area

Haiti is a Caribbean country situated at the heart of Western world countries. Located at the Western part of the Hispaniola Island of the Dominican Republic, the country has a total land area of 27,750 sq km, and capital situated at Port-au-Prince. Depite been the first black state and first independent Caribbean nation which overthrew French colonial dorminance and slavery in the 19th Century [5], an impoverish state of the country have always been in existance. A population of over 10.1 million reveal a density of over 500 persons per sqkm living in its capital city 'Port-au-Prince' which was most affected by the earthquake of 12th January, 2010 [23]. GDP growth after the earthquake stood at -5.4% [28] which stands out as an indication that about 56% of it population live in multidimensional poverty and deprivation in health and living standard make up 53% of its population [22]. Uneven distribution of industries exist for the country as visualized. Similar to sub-saharan Africa, Haiti enjoys a tropical climate of

- *Unabor, H., (MSc. Geographical Information Systems)* University of South Wales, Pontypridd, Cardiff, UK. *(BSc. Geography and Regional Planning)* Delta State University, Abraka, Nigeria.

ISSN 2229-5518

warm and himid nature. Although, times of periodic drought and hurricane season from June to November occurs [16].

Tectonic influence from the Caribbean where Haiti sits on comes more often from the Caribbean plate unlike the North American plate boundary. Seismic history in the region owes it dorminance to the Enriquilo-Plantain Garden fault which had a role in the January, 2010 earthquake. As [3] stated, no evidence of damaging earthquake activities have been recorded in Haiti for over 240 years besides the earthquake of January 12th, 2010.

Fig. 1 Study Area

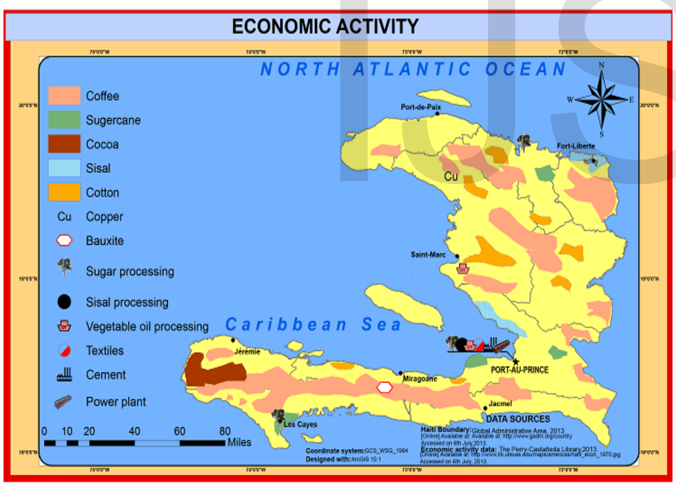

Fig. 2 Economic Activities

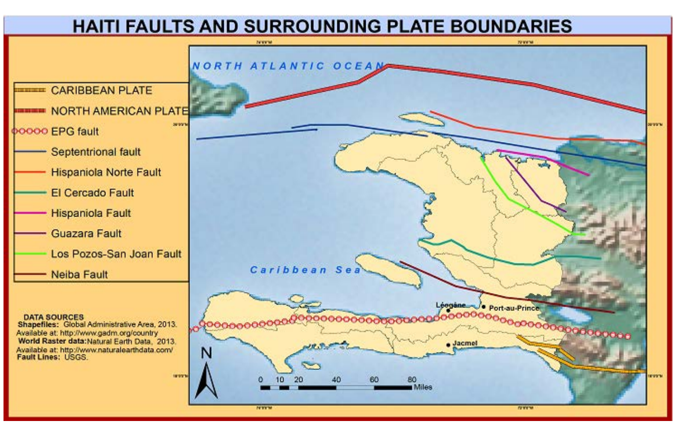

Fig. 3 Haiti Fault lines and surrounding plate boundaries

3 Methods

3.1 Research Methods and Approach

An inductive route to scientific explanation is been adopted in this research. An appraisal of geospatial response techniques adopts both qualitative and quantative research approach normally used in geospatial sciences whose goal aims to generate information, themes, evaluate patterns but not to prove any theory [20]. The route to this qualitative research flow through the following; First, developed intrest from information gathered from case studies, secondly, recognition of salient geospatial response techniques, third, identifying consistensy in geospatial techniques, and finally, integrating linkages with examples and presenting results which in this case represent the role of Remote sensing, GIS, OpenStreetMap (crowdsourcing) and Ushahidi (crisis mapping) at the aftermath of the earthquake.

3.2 Data collection method and sources

For this research, both qualitative and quantitative data was adopted. Case studies reviewed involves journals, conference papers, oranizational statistics, articles and book from published printed and electronic sources.

Geospatial data sources utilized used in ArcGIS to produce maps were from the following sources;

USGS Earthquake hazard programme: Real-time censored data concerning the January 12th 2010 earthquakes including aftershocks was acquired from this primary source. They were converted into GIS format and fed into ArcGIS.

Global Administrative Area database: This spatial database holds the political boundary of all countries in the World in GIS format. Map of Haiti in shapefile format was acquired here.

Natural Earth database: Maintained by North American Cartographic Information Society, this database provided cross shaded relief raster data of the earth utilized in this research.

4 Result and Discussion

4.1 Visualizing significant differences between Haiti Earthquake of January 12th 2010 and recorded earthquakes between (2001-2009)

In other to fulfil the research main theme, it was deemed fit to provide a justification to one of the research question stated earlier through geospatial visualization of relationships between the Haiti earthquake of January 12th 2010 as compared to other earthquakes (2001-2009) within the decade. it is worthy to note that in the next figure which represents output from GIS analysis, large effort is been paid to distinguishing the maximum magnitude of earthquakes received between this two periods (2010) and (2001-2009). Moreso dates of maximum magnitude received, total earthquakes as obtained primarily from the USGS earthquake hazard programme and it been analysed with ArcGIS. Result further reveals characteristics about its main shock, spontaneous aftershocks, number of spontaneous aftershocks and date of maximum aftershocks. Besides facts produced from primary sources, symbolizing earthquake's magnitude for these times and visualizing Haiti numerous fault lines indeed makes the map to tell a story.

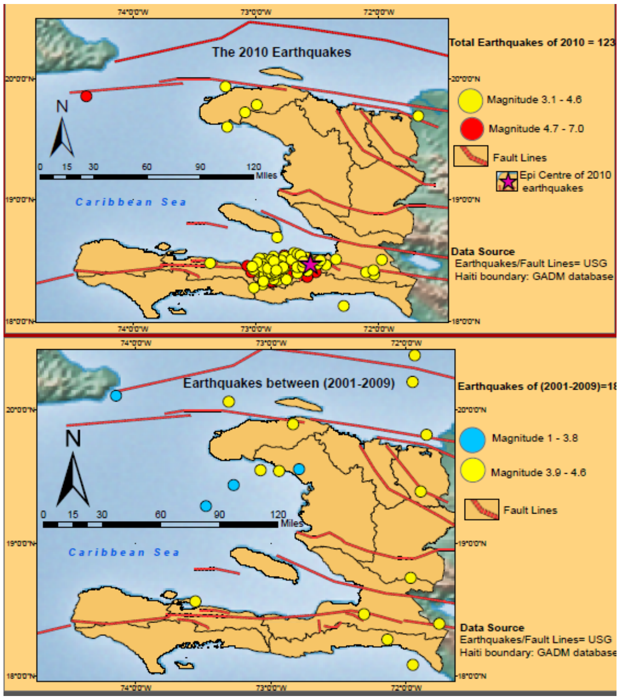

Fig. 4 Visualization of the January 2010 earthquakes and Earthquakes between 2001-2009

Earthquakes (2010)	Earthquakes (2001-2009)
Total earthquakes =123	Total earthquakes =18
Maximum magnitude = 7.0 Mw	Maximum magnitude = 4.6 Mw
Date of Maximum magnitude 12th January, 2010.	Date of Maximum magnitude 1st May, 2008.

Table-1 highlight of major characteristics visualized

Observations(Mainshock and Aftershocks characteristics)
Mainshock (7.0 Mw), Date; 12/01/2010, Time; 21:53:10 GMT
Spontaneous Aftershocks (4 - 6 Mw), Date 12th-30th January, 2010
Total Number of aftershocks =92
Date of Maximum aftershock; 12th/01/2010,
Time; 22:00 GMT ; 7 Minutes after Mainshock (7.0 Mw)

Table-2 Facts observed

4.2 Remote Sensing role to Geospatial response

Remote Sensing in geospatial emergency response, deemed a pre-requisite in response phase of disaster management aided in gaining quick time accurate information through diverse multispectral view of earthquake affected areas. Presence of wide spread physical restrictions and need to provide accurate visualization of current event as they unfolded on ground saw the need for remotely sensed deployments through international and regional responders.

The aftermath of the event witnessed its first consultation by ImageCat, World Bank and RIT which saw its first deployment to the disaster area, LIDAR systems concurrently with WASP airborne sensors coupled to an Applanix POS AV310 inertial navigation system (INS) at 760m altitude for accurate monitoring, damage detection, and georeferencing of imagery [25]. Primarily executed after remotely sensed data acquisition was immediate damage intensity evaluation and assessment. These resulted to aerial images been geometrically orthorectified followed by further image processing techniques like layer stacking, subsetting to damaged areas and pre and post imagery change detection.

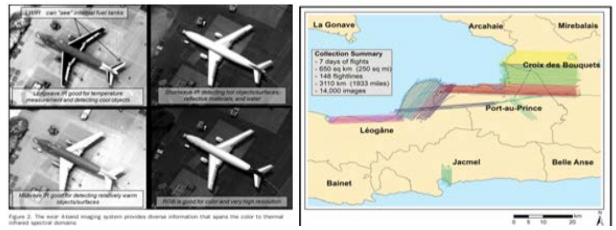

Fig. 5 Flight and path covered (LIDAR and WASP sensor deployment) [25]

Besides air-borne operations, space borne deployments to Haiti at its earthquake's aftermath was also felt, thanks to American commercal satellite organization 'GeoEye' which is in merger with Digital Globe. The first optical high-resolution (0.5m) imagery over Port-au-Prince was acquired by the EST GeoEye-1 satellite which collected almost 3,000 square km of imagery on January 13 at 10:27am within a few hours, courtesy to absence of cloud cover at the timing [**cccheck**].

Fig.6 GEOEYE IMAGERY (Before and After) EST GeoEye-1 Satellite [2]

In addition to remote sensing role, efforts from DigitalGlobe made possible QuickBird, Wordview-1 (Wv-1), and Worldview-2 (WV-2) multispectral images of 2-m spatial resolution and 8 spectral bands; Coastal Blue, Blue, Green, Yellow, Red, Red-edge, and two Near-infrared wavelengths [9]. Prioritizing coverage areas was deemed relevant due to large extent of damages and urgencies for quick-time acquisition of imageries by awaiting geospatial relief groups. DigiGlobe deployed its World-view 1 from 14-31st January, 2010, World -view2 from the 15th January and QuickBird from 17th to 30th January, 2010.

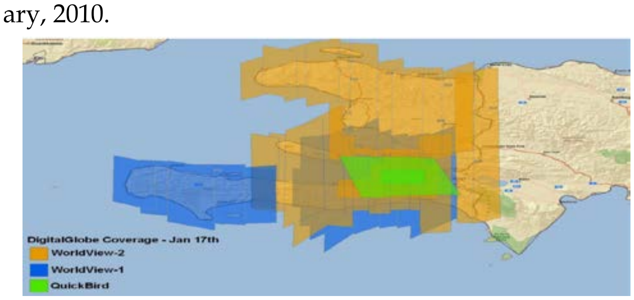

Fig. 7 DigiGlobe Satellite Coverage [2]

ISSN 2229-5518

Fig 8. Before and After Imagery (Port-au-Prince Cathedral by DigiGlobe [2].

Further needs to detect damages during the Haiti earthquake presented obvious concerns immediately after the disaster in a bid to adopt more suitable satellite systems with a wider application capability in analysing and estimating building damages. This was brought to light, courtesy of International efforts by one of the World leading Japan based geospatial group 'PASCO Cooperation' who utilized the synthetic aperture radar satellite "TerraSAR-X'' and optimal images in scrutinizing damaged buildings for immediate damage inspection. Its coverage delineates areas of its main shock and aftershocks with more focus on its capital city Port-au-Prince where extensive building occurred. The accuracy of damage detection from the pre- and post-event SAR images was evaluated by overlying the extracted results on different urban settings, an approach that utilized differences and correlation coefficient in a bid to reveal threshold values, then further superimposed with pre-event optical NDVI imagery for accuracy evaluation of damaged areas [24].

The likes of remote sensing raster graphic application (Erdas Imagin) utilized for most of these operations contributed to successful extraction of remotely sensed information. Thus, the prioritization of critically damaged areas based on urban density classifications became a criteria for mapping the disaster refion. It was known that efficient accuracy estimation made to all damaged areas took into cognisance vital strategies on damage differentiation. This indeed made extinsively damaged areas of Port-au-Prince which houses the Prisidential palace, Ministry of education, finance, public works, communication, culture, the national assembly to be among top priotities where humanitarian efforts should be geared towards. Further analysis of imageries yeilded insights into regional perspective of land cover and land use, distribution of population centres, topography and geology as they were compared with pre-event data [14].

Literally, remote sensing deployments to the January 2010 Haiti earthquake exist in diverse forms by international and regional humanitarian responders.

4.3 GIS Role to Emergency Response

Air and space borne deployment during the January 2010 earthquake provided bulk of data which was highly utilized in Geographical Information Systems and applications by diverse geospatial disaster response team. The potential of GIS was felt through diverse ways of achieving several goals which culminated various aspect of visualizating, modelling, analysing, interpreting, understanding spatial patterns/dimensions, trends and relationships of existing wide range post disaster situations. Enthusiasms developed from imageries and the willingness to offer volunteered humanitarian assistance presented driving force for the utilization of GIS by notable organizations.

Following the aftermath of the event, the United Nations Institute for Training and Research (UNITAR) utilized data obtained from its operational satellite (UNOSAT) in symbolizing building damage levels which aided optimum deployment of search and rescue efforts. Beside damage intensity been analysed in raster format which indeed provided first hand information, an obvious need for georeferencing critical damage areas (vector and raster format) with respect to locating, symbolizing and prioritizing damages found the importance of GIS. Their deployment of GIS personnel aided in identifying and prioritizing 110 sites within critical damaged areas which constituted schools, government -related buildings and hospitals for decision making as regards emergency response [11].

Fig 9. Analysing and Prioritizing damaged areas [9],[11].

Again with GIS, was the analysis of accessibility levels following the disaster. Accessibility conditions also posed a major area of concern fue to heavy amount of blockages and damages on road networks. The Likes of ESRI ArcGIS showcased its geospatial strength in dealing with structural damages and urban accessibility issues. Deploying the network analyst algorithm of ESRI's ArcGIS for immediate analysis, delineation of functioning and non functioning road network was found to be a major resort by by disaster team responders. As [8] stated, the network-based systems involved rigorous processes which saw distruption points snapped into nearest road lines, debris buffer been created along road segments/intersection, cummulative cost analysis determined for road conditions and road network delineating good and bad accessibility conditions properly visualized. Here, GeoEye's imagery found its full utilization as been used for backdrop mapping.

In essennce, GIS have potrayed the immense ability to utilize topologocal properties of road network exsting in points, polygon and polylines (shapefiles) to make effective decisions with respect to defining best level of accessibility. Through GIS network analyst, improved transferability conditions brought about by successful deployment of networked based GIS resources aided in detecting the best possible flow route for humanitarian aid among critically damaged areas. Thus,

ISSN 2229-5518

GIS network-based output was found to provide the best solution which addressed urban accessibility issues following the disaster.

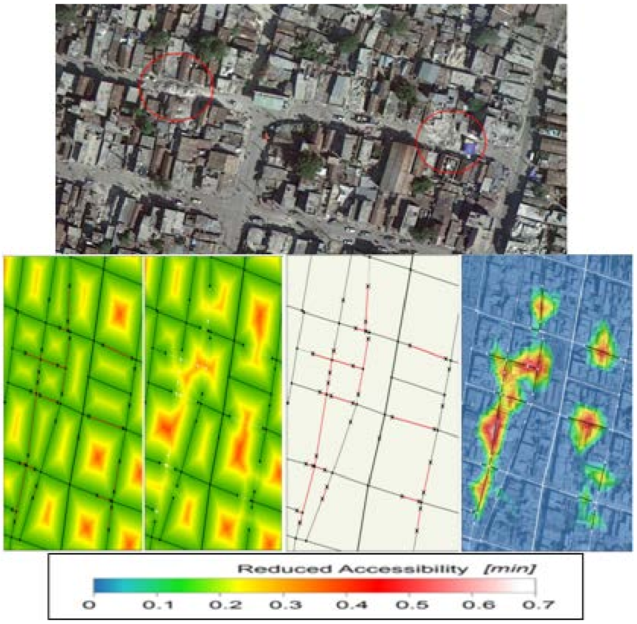

Fig. 10: Road Network Analysis with GIS [8].

In addition to dealing with accessibility issues, GIS usage at the aftermath of the disaster was also found useful in defining suitable location for aid points where relief efforts were to be directed towards. As [8] emphasized, inputs for locating aid distribution points was dependent on spatial data (accessible road network, levels of destructions) derived from authoritative datasets (Remotely sensed imageries) and social data (Population distribution & post disaster conditions) obtained from census data and agency reports. Through effective decision amking with GIS, aid points provided adequate help and support which bolstered relief to earthquake victims. Similar methodology adopted by GIS for aid point location also goes in line with its approach to locating base camps for internal displaced persons. This procedure involved more advanced querying options involving geographic variables. Rational decision making involving querying georaphic variables for locating relief base camps for internal displaced persons are thus summarized;

Positive Correlations involving GIS selection process
(Locating relief base camps for internal displaced persons IDP)

- At certain distance tonearest aid points (Centres for health, food, water , shelter and military protection)
- Presence of accessibility and large open space (Obtained from NDVI)
- Close to international airports and fresh water bodies.

Negative Correlations involving GIS selection process
(Locating relief base camps for internal displaced persons IDP)

- At certain distances away from areas and vulnerable places for earthquake aftershocks (A total of 92 aftershocks was recorded bythe USGS earthquake hazard programme).
- At distances away from areas affected by landslides
- At distances away from steep slopes vulnerable to debris fall
- At distance away from areas which delineate the Enriquillo Plantain- Garden Fault line.

[9].

Fig. 11: Base camp establishment with GIS [2] [25]

4.4 How volunteered mapping initiative started

The earthquake which struck Haiti in January 12th, 2010 raised concerns to every part of the world of which diversed number of individuals thought of several ways of devising posible ways to offer humanitarian aids. Despite the large financial will posed by many regional and international geospatial responsers, there was also in existance, a large global population having great will to contribute geospatially, but however lacked the financial will or capability to deploy remote sensing and GIS infrastructures. Thus, a suitable way to offer humanitarian aid by these geospatial communities made up of professionals and a considerable high numbers of amatures were to utilize their knowledge of the Hatian geography and other forms of intuitive reasoning for diverse geographic contributions through crowdsourcing and crisis mapping platforms. Seen as a focal figure for geospatial emergency response, these systems were solely based on open data principles and thus presented a turning point in showcasing the cartographic strength of seveal local, regional and international voluntary contributors.

4.4.1 Crowdsourcing with OpenStreetMap

Following the disastrous earthquake, huge revelations about the poor geography of Haiti became widely known and thus presented large concerns interms of mapping the affected region by humanitarian responsers. A call for help led to the quest for collective knowledge which was largely emphasized thorugh diverse interactive mapping activities with OpenStreetMap Platform. A medium of universal openness which called for universal participation was thus been left for the world to show how they can make sensitive geodicisions which could help improve response process.

As emphasized by [6], OpenStreetMap immediately after the earthquake became the defacto source of Haiti map data created by volunteers who started digitizing road conditions, collapse buildings, road network conditions, spontaneous relief camps, aid points, loaction of internal displaced persons and other features where needed. Instantaneous contributions by global volunteered mapping communities utilized editors containing diverse symbologies in vector formats. As requested due to cryouts of several relief groups who had difficulties in obtaining maps to understand the geography of the area, heaby influx of edited logged in sessions were thus made in realtime at various post earthquake intervals. Before the earthquake, approximately 20 logged in sessions existed for Haiti while just 24 hours after the earthquake, the OpenStreetMap website produced over 400 edited logged-in sessions [19],[6]. Within three weeks, an amazing total of 640 online voluntary mappers have provived over 1.4 million logged-in sessions [26]. Mapping logged-in sessions by volunteers were made in most cases through tracing satellite imagery data from google, Yahoo, GeoEye, DigitalGlobe and other map sources. Volunteers with good knowledge of the Haitian local geography also utilized their intellect in producing logged-in sessions. Due to high motivation by volunteered mappers, great enthusiasm was created to map the entire nation and not only areas affected by the disaster.

Fig. 12: OpenStreetMap Visualization [6]
(1) Before the Earthquake (2)Immediately after the earthquake
(3) 1 week after (4) Four Week after

Concerns with OpenStreetMap

Although crowdsourcing with OpenStreetMap have been given much credit despite its outright usage by large numbers of inrained volunteers who were less experienced in producing logged in sessions. Basically, as viewed by researchers, OpenStreetMap presented a time-conscious ability to map real-time event as they unfolded during very early hours (critical stages) after the earthquake. However, it was worthwhile to note that its utilization at the aftermath of the earthquake was also associated with several issues due to large unprofessional logged-in map sessions.

First, verifying certain geocoded logged-in sessions generated issues which ideally, were conflicting and tehrefore was subjected to high degrees of uncertainty.

Literally, the platform's limitation which emanates from its participatory oppeness to non experts in the field of mapping or who use informal knowledge to map geographic features of both pre and post-earthquake conditions.

Logged-in sessions produced lacked standard. procedure neither do they contain any policy act.

Despite these conditions, certain crowdsourced information with OpenStreetMap followed good standard procedures similar to those in paid cartographic employment. Crowd maps from participatory GIS created by OpenStreetMap in the early hours of the earthquake's aftermath was critical in aiding humanitarian agencies in making geospatially based decisions.

4.2.2 Crisis Mapping with Ushahidi

Ushahidi, a mobile and web enabled crisis mapping technology of African descent which denotes 'testimony' in Swahili has its origin and gained popularity from Kenya due to its ability to geocode incident of post election violence by Kenyan citizens at the aftermath of the 2007 elections. Ushahidi's successful response to Haiti was largely dependent on its open source mobile enabled crisis mapping services which a large number of Haiti citizens had on their mobile phones. Unlike OpenStreetMap where the focus was mapping pre and post earthquake conditions and facilities of affected areas, Ushahidi's main thrust after the earthquake was to direct response efforts through geocoding and visualizing locations of victims in need of assistance, reporting post earthquake conflict/crisis situations and locating internal displaced persons through reports sent from the public. Crisis reports were of different sources which when processed porvided the best form of aid for directing response groups to the location of trapped victims, correspoding area where crisis had developed due to insufficient medical aids, food distribution and other relief provisions.

According to deployment information as confirmed by [17], Ushahidi was deployed in the first twohours following the January 12th 2010 earthquake by Ushahidi, Inc.'s director of crisis mapping and strategic partnerships 'Patrick Meier' who went live in mapping crisis situation with the Ushahidi-Haiti map through technical support from staffs and volunteers at the Fletcher School of Law and diplomacy (Tufts University Boston, US). The main source of information which served as a per requisite to mapping came directly from thousands of social media reports (facebook and twitter) thanks to a seemingly large population of Hatians who had their internet enabled mobile phones still active after the earthquake. Moreso, suitable thanks goes to response teams who quickly revamped destroyed mobile communication infrastructures which in turn propelled an outright usage of mobile phones by Hatians in reporting crisis situation with respect to their locations. Tracking and geocoding these information using google maps, OSM, and then visualizing it on Ushahidi was the main thrust of volunteered mappers who desseminated it to save lives. Ushahidi's ability to receive crisis report came through diverse mediums. Due to large publicity of Ushahidi's deployment which generated much local, regional and international report from facebook, blogs, twitter and SMS messages were produced of which were utilized outrightly by geospatial response groups.

Ushahidi presented a magnificent support which went beyond borders of humanitarian response through generated media reports. It stood, a primary source for information for management of crisis situations mostly as regards areas of voilence and conflict perpetuated by despirate locals

and conflicts by despitrate locals who felt neglected interms of food and relief distribution. Literally, its success at the aftermath of the 2010 Haiti earthquake depicts the potential and collaborative strength of social media, short messages services and crisis mapping at unpresidented levels.

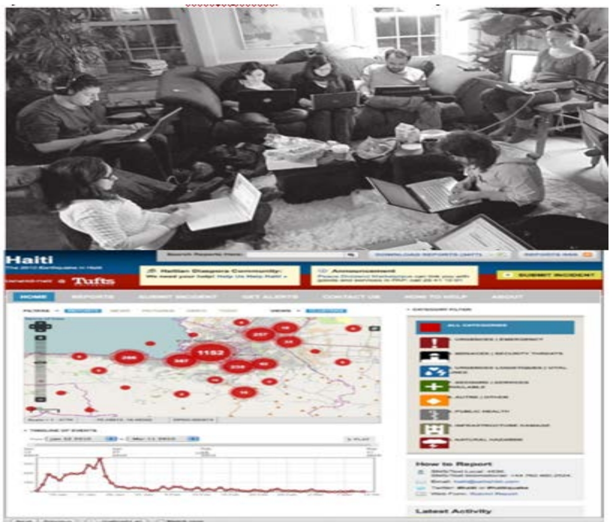

Fig. 13: Ushahidi Crisis Mapping Initiative [17], [6].

Concerns with Ushahidi

Ushahidi's response to Haiti have paved ways to innovations which denotes participatory empowerment with respect to crisis mapping. Despite outright response in realtime following the earthquake, a seemingly number of challenges were inherent. Social media and SMS reports in most cases were presented in inaccurate forms by locals as regards location of displaced persons, trapped victims under duress and conflict warnings as a result of post earthquake resource aid distribution.

In most cases, reports proved difficult to authenticate and geocode due to informal presentation.

Crisis mappers lacked standard operating procedures in differentiating and prioritizing between accurate and inaccurate crisis reports with Ushahidi.

Condidentiality and confiding in the authenticity of certain reports also presented concerns. There existed difficulties in checkmating the authenticity of reports often often related to post earthquake violence and conflict.

5 Conclusion

Starting more explictly, its is worthwhile to affirm that a research filfilment has been meet with respect to geospatial emergency response through roles of remote sensing, GIS, OpenStreetMap and Ushahidi after the Haiti earthquake of January 12th, 2010. A journey to this end point have been affirmed through deductions from major proponents incourse of writing. With respect to geospatial emergency response to the event, an evaluated remote sensing role, GIS role, crowdsourcing role with OpenStreetMap and crisis mapping with Ushahidi, a logical conclusion is been propounded that a breakthrough and turning point to these collaborative technologies have indeed been meet through their efforts in solving post disaster issues which rely solely on geography.

As revealed, geospatial visualization produced for the event have illustrated vital information which confirms that both main shock and aftershocks (4-5Mw) of the event have greater cummulative strength interms of numebers, total magnitude and depth than a combined earthquake between 2000-2009. Ideally, natural disasters of last decade not only put the Haiti earthquake of January 12th 2010 at the forefront due to massive damages, sufferings and deaths but rather, puts it as one which withnessed the hightest form of deployments in geospatial infrastructures. Just like all forms of geospatal emergency response techniques to large scale disasters notably earthquakes, the Haiti experience of 2010 have expressed its uniqueness due to massive delivery of geospatial response techniques from diverse responders (local, regional and international).

Presently (four years after the earthquake), collaboration and mergers of major geospatial responders have been made in a bid for them to make advances improvements in post disaster response. For instance, as proclaimed by [21], partnership between ESRI and Ushahidi made just 9 months after the earthquake was set to improve crisis mapping services through an outright enhancement of analytical tools and extensive GIS data provisions for the Ushahidi web platform. Mors so, a complete merger as observed during early 2013 have involved that between two pf the world's most powerful commercial satellite organizations and role players in Haiti (GeoEye and DigiGlobe) in a bid to provide more sophisticated services. Thus a stronger collaboration and merger have emphasized a plan to deal in future, more decisions central to geography in the area of better response standards, timeliness to geospatial resources and effective maganegent of post-earthquake activities.

References

[1] Aman, H., Irani, P., and Liang, H. (2012) 'A review of Information Communication Technology Applied on Common Tasks during Times of Emergency', *Proceedings of the 9th International ISCRAM Conference,* Vancouver, Canada, April 2012. [Online]. Available at: http://www.iscramlive.org/ISCRAM2012/proceedings/210.pdf (Accessed: 23rd November, 2013).

[2] Atcheson, C. (2010) 'DigitalGlobe response to Earthquake Disaster in Haiti', *MDA Geospatial Services,* Richmond, BC, Canada. Available at: http://www.un-spider.org/sites/default/files/ATCHESON_4th_ws-bonn_12_10_10.pdf (Accessed: 15th October, 2013)

[3] Bakun, W.H., Flores, C.H., and Brink, U.S. (2012) 'Significant Earthquakes on the Enriquillo Fault System, Hispaniola, 1500-2010: Implication for Seismic Hazards' *Bulletin for the Seismological Society of America,*102(1), pp. 18-30. [Online]. Available at: http://www.bssaonline.org/cgi/doi/10.1785/0120110077 (Accessed: 30th October, 2013).

[4] BBC (2010) *Haiti devastated by massive earthquake,* BBC Report, 13th January 2010. [Online]. Available at: http://news.bbc.co.uk/1/hi/8455629.stm (Accessed: 1st June, 2013).

[5] BBC (2012) *Haiti country profile,* BBC Report, 17th October 2012. [Online]. Available at: http://news.bbc.co.uk/1/hi/world/americas/country_profiles/1202772.stm ,(Accessed: 12th January, 2014).

[6] Boccardo, P. and Pasquali, P. (2012) 'Web Mapping Services in a Crowdsource Environment for Disaster Management: State-of-the-art

and further development', *Journal of the International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 39(9), pp.543-548. [Online]. Available at: http://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XXXIX (Accessed: 23 January, 2014).

[7] Boccardo, P. and Tolono, G. (2012) 'Haiti Earthquake damage assessment; Review of Remote Sensing role', *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 39(9) , pp.529-532. [Online]. Available at: http://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XXXIX (Accessed: 21st May, 2013).

[8] Bono, F. and Gutiérrez, E. (2011) 'A network based analysis of the impact of structural damage on urban accessibility following a disaster: the case of seismically damaged Port-au-Prince and Carrefour road networks', *Journal of Transport Geography*, 19(6), pp. 1443-1445. *Elsevier Journal* [Online]. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0966692311001372 (Accessed: 4th January, 2014).

[9] Bramante, J.F. and Raju, D.K. (2013) 'Predicting the distribution of informal camps established by the displaced after a catastrophic disaster, Port-au-Prince, Haiti', *Journal of Applied Geography*, 40, pp.30—39. *Elsevier* [Online]. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0143622813000398 (Accessed: 14th January, 2014).

[10] Crooks, A.T. and Wise, S. (2013) 'GIS and agent-based models for humanitarian response', *Journal of Computers, Environment and Urban Systems*, 41 pp.100-111. *Elsevier* [Online]. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0198971513000550 (Accessed: 15th May, 2013).

[11] Chen, L. and Miller-Hooks, E (2012) 'Optimal team deployment in urban search and rescue', *Journal of Transportation Research Part B*, 46(8), pp. 984-999. *Elsevier* [Online]. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0191261512000409 (Accessed: 1st May, 2013).

[12] Dibaise, D. et al. (2010) 'The new Geospatial Technology Competency Model: Bringing Workforce Needs to Focus', *Urban and Regional Information Systems Association (USIRA) Journal, 22 (2) , pp. 55-72.* [Online]. Available at: http://www.elmhurst.edu/~richs/EC/GISMaterials/ToBeLinkedonGEODeptWebsite/URISA%20Journal%20Vol.22%20Issue%202.pdf#page=58 (Accessed: 1st May, 2013).

[13] Dong, Y. et al. (2011) 'Extracting damages caused by the 2008 Ms.8.0 Wenchuan earthquake from SAR remote sensing data', *Journal of Asian Earth Science*, 40(4), pp. 907-914. *Elsevier* [Online]. Available from: http://linkinghub.elsevier.com/retrieve/pii/S1367912010002282 (Accessed: 15th July, 2013).

[14] Duda, K.A. and Jones, B.K. (2011) 'USGS Remote Sensing Coordination for the 2010 Haiti Earthquake', *Journal of Engineering and Remote Sensing*, 1(5), pp.1-27. [Online]. Available at:ftp://ftp.ecn.purdue.edu/jshan/000000_special_issue/09Duda/text/Duda_USGS%20Haiti%20Coordination_v10Mar2011-1808-forPDF.pdf (Accessed: 17th May, 2013).

[15] Échevin, D. (2011) 'Vulnerability and Livelihoods before the Haiti Earthquake', *World Bank Policy Research for Latin America and Caribbean Region* October, 2011. [Online]. Available at: http://wwwwds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2011/10/21/000158349_20111021085837/Rendered/PDF/WPS5850.pdf (Accessed: 20th June, 2013).

[16] Gorum, T. et al. (2013) 'Complex Rupture Mechanism and topography control symmetry of mast wasting pattern, 2010 Haiti Earthquake', *Journal of Geomorphology,* 184,pp. 127-138. *Elsevier Journal* [Online].Available at:http://linkinghub.elsevier.com/retrieve/pii/S0169555X12005478(Accessed: 20th June, 2013).

[17] Heinzelman, J. and Waters, C. (2010) 'Crowdsourcing Crisis Information in Disaster-affected Haiti', *United State Institute of Peace (USIP) Special Report*, [Online].Available at: http://www.usip.org/files/resources/SR252%20%20Crowdsourcing%20Crisis%20Information%20in%20Disaster-Affected%20Haiti.pdf (Accessed: 23rd May, 2013).

[18] Manfré L.A. et al. (2012) 'An analysis of Geospatial Technologies for Risk and Natural disaster Management', *ISPRS International Journal of Geo-Information,* 1(3), pp. 166-165. *Open Access Journal* [Online]. Available at: http://www.mdpi.com/2220-9964/1/2/166/ (Accessed: 15th January, 2014).

[19] Maron, M. (2010) *Building Digital Technology for our Planet; Haiti OpenStreetMap Response.* Available at: http://brainoff.com/weblog/2010/01/14/1518 (Accessed: 1st May, 2013).

[20] Steinberg, S.J. and Steinberg, S.L. (2006) *Geographical Information Systems for the Social Science:* 1st Edn, London: Sage Publication, p. 77-82.

[21] Theodore, J. (2010) *Ushahidi and ESRI team to improve Crisis Mapping Services.* [Online]. Available at: http://www.esri.com/news/releases/10_4qtr/ushahidi.html (Accessed: 10th January, 2014).

[22] UNDP (2012) *Haiti Human Development Indicators.* [Online]. Available at http://hdrstats.undp.org/en/countries/profiles/HTI.html (Accessed 4th January, 2014).

[23] United Nations (2011*) Statistic divisions for Haiti*. [Online]. Available at: http://data.un.org/countryProfile.aspx?crName=Haiti (Accessed: 4th December, 2013).

[24] Uprety, P. and Yamazaki, F. (2012) 'Building Damage Detection using SAR images', *15 WCEE Report*, Lisboa. Available at:http://ares.tu.chiba-u.jp/~papers/paper/2012/2012WCEE_0850_Uprety.pdf (Accessed:1st, December, 2013).

[25] vanAardt, J.A.N. et al. (2011) 'Geospatial Disaster Response during the Haiti earthquake; A case study of spanning airborne deployment, data collection, transfer, Processing and dissemination', *Journal of Photogrammetric Engineering and Remote Sensing,* 77(9), pp. 943-952. [Online]. Available at: http://ipler.cis.rit.edu/ipler_files/van_Aardt_et_al_Haiti_Geosptial_Disaster_Response_PERS_2011.pdf (Accessed: 4th December, 2013).

[26] Walker, M. (2012) 'Disaster Response Efforts Highlight Value of Relationships',NonTraditionalPartners' *National Geospatial Intelligence Agency Magazine*, 10(4), pp.1-24.[Online].Available at:https://www1.nga.mil/MediaRoom/Publications/Documents/Pathfinder%20Magazines/2012(Accessed: 20th December, 2013).

[27] World Bank(2011) *Focus on Hunger and Malnutrition* [Online]. Available at: http://www.ifrc.org/PageFiles/89755/Photos/307000-WDR-2011-FINAL-email-1.pdf (Accessed: 5th May, 2013).

[28] World Bank(2012) *Haiti Earthquake Overview* (Country at a Glance) [Online].. [Online]. Available at: http://www.worldbank.org/en/country/haiti/overview (Accessed: 4th November, 2013).

[29] World Disaster Report(2011) *Focus on Hunger and Malnutrition* [Online]. Available at: http://www.ifrc.org/PageFiles/89755/Photos/307000-WDR-2011-FINAL-email-1.pdf (Accessed: 5th December, 2013).