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Review paper on Flood Water Analysis Using DEM & LiDAR

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ABSTRACT

It is a well-known fact, that the use of Geographic Information Systems (GIS) in Water Management is very necessary. New technologies of mapping sciences, which are used to collect ground profiles and elevation data for water management, are offering new workflows, quantitatively and qualitatively. Airborne Light Detection and Ranging -shortly called LiDAR - delivers Digital Surface Models (DSMs) with minimum 40 points per sqm, with an accuracy of 0.1m to 0.2m in height. Complementary to LiDAR, aerial photography collects digital images with up to 5cm Ground Sampling Distance (GSD). The resulting DSM will have an accuracy of about 0.2-0.5m GSD, but suffers from vegetation. Most recently, interferometric SAR – called InSAR – delivers DSMs as well, with height accuracies in a range of 0.2-0.5m. The TerraSAR mission is devoted to collect worldwide Digital Terrain Models (DTMs) with a ground sampling resolution of 12m, with height accuracies of 1m. The precise accurate information is one of the main pillars for flood water analysis. Moreover, hydrological GIS models for rainfall – runoff, continuous stream flow, flooding, and water quality are also presented. In combination with precise terrain information a thorough flood water analysis is feasible, allowing computing the directions of water flows and water drainage. The integration of data modeling together with advances in GIS using Universal Model Language (UML) programming is used as a toolbox for implementations. Finally, the GIS supported by a set of tools to manage terrain and hydrological data in combination, will be the most suitable software package to overcome the problem of flood water analysis. The necessary steps are therefore: Data collection, data management, data processing, data analysis and simulations. The outcome has to be presented and visualized in several categories, to address different clients and to propose the right decisions to protect people and infrastructures.

***Keywords:* - LiDAR, DEM, DTM, GSD, DSM**

I. INTRODUCTION

The competition over water around the world has increased due to urbanization and population increase. In addition to the use of water for agriculture, water is being increasingly used for municipal, industrial, re-creational and environmental fields. The economic value of land and water has increased dramatically. Earlier research results have shown huge potential for using high resolution airborne multispectral imagery to obtain the landscaped areas in urban sectors.

Flood is an inundation of the land that is usually dry. Floods are one of the most serious, common and expensive natural disasters that caused fatalities and considerable economic losses worldwide every year (Kovats et al. 2014). Flooding may happen in an area when large amounts of rain occur over a short period of time or from a single, heavy storm, tropical system, or hurricane. After these storms, we rely on manmade flood control systems to drain excess water from the low, flat lands. Flood control is achieved through an interconnected drainage system.

A GIS- based Flood Damage model has to be used to help the municipal Council and decision makers with the assessment of the economic benefits of intended flood mitigation options and secondly to assess proposed floodplain developments (Hatzopoulos J. N., 2002).

Recent research has shown that GIS tools, in combination with satellite and airborne data, have been used to estimate, monitor and manage groundwater levels in situ, and with hydrogeological database management systems may help to overcome the problems and challenges. Moreover, groundwater targeting, resource estimation, groundwater recharge estimation, evaluation of groundwater exploitation impact on environment (runoff, soil moisture, vegetation growth conditions etc.) are important factors and have to be integrated.

After that, simulations are carried out whose results are displayed and geo-referenced, allowing further analysis like Multi-criteria decision analysis to develop and evaluate alternative plans that may facilitate compromises among interested parties and display topological relationships between the model and other spatial features (Ouma Y. and Tateishi R., 2014). All these measures are required to achieve the necessary prevention such as to move people from dangerous places to somewhere safe ones and impose a state of emergency.

Remote sensing, covering a large geographical area at different spatial, spectral and temporal resolutions, provides a large amount of data that have been extensively used for flood management.

Optical satellite images are widely used for water body extraction and changes detection. Different image classification techniques can be used for water body delineation. For example, Verpoorter et al. (2012) used unsupervised classification for automatic water body delineation from Landsat 7 images, whilst Yang et al. (2017) used water indices for inland water body delineation and obtained an average Overall Accuracy (OA) of 97.2% and an average kappa coefficient of 0.73. Topaloglu et al. (2016)

used supervised Supported Vector Machine (OA 82% and Kappa coefficient 0.81) and Maximum Likelihood Classifier (OA 73%; kappa coefficient 0.69) from Sentinel 2 images, while Kaplan and Avdan (2017) proposed combination of water indices and object-based classification for river delineation from Sentinel 2 images, achieving perfect agreement between extracted water bodies and reference data.
However, there are some limitations, temporal resolution and revisit time depends on the satellite program, high-resolution images can be very expensive, and the area of interest may be covered by clouds and haze.
In this research, the researcher will try to improve the accuracy of the elevation data. For this purpose, airborne Light Detection and Ranging (LiDAR) data acquisition and processing will have to be employed.
Furthermore, the hydrological modeling has to be integrated with the processed LiDAR data within a 3D GIS application.

II. DATA COLLECTION

2-1- DSM and DTM

First of all, some definitions have to be given to differentiate between several terms important for Flood Water analysis. A Digital Surface Model (DSM) is the output of the point cloud generated directly from a LiDAR instrument when doing a 3D polar point positioning in surveying. The position of the LiDAR instrument in an airplane, helicopter or most recently octo-copter is given by Integrated Sensor Orientation (ISO) combining Differential GPS and Inertial Navigation Systems (INS) technologies to deliver directly georeferenced output. The DSM contains all vegetation information, and moreover, it captures all objects on the Earth's surface (buildings, cars, etc.). Extracting vegetation and man-made objects from the DSM finally leads to the Digital Terrain Model (DTM), which represents the plain terrain – necessary for the flood water analysis.
Most of the flood risk mapping is based on a conceptual risk approach where Digital Elevation Model (DEM) is used in order to estimate the flood hazard according to the projected water levels (van de Sande et al. 2012) and associated damages to properties and livelihoods. DEM is one of the most important input parameters. DEM resolution and accuracy highly influence the inundation extent, flow velocity, flow depth, and flow patterns (Wedajo 2017) hence, the accuracy and the reliability of the flood inundation maps (National Research Council of the National Academies 2009); Smeeckaert et al. 2013a; Brzank et al. 2008; Bodoque et al. 2016; Hofle et al. 2009) especially in lowland areas, where the offset of few decimeters in the elevation data has a significant impact, and urban areas are highly correlated with DEM.
The Shuttle Radar Topography Mission (SRTM) is the result of a collaborative effort by the National Aeronautics and Space Administration (NASA), the National Geospatial Intelligence Agency (NGA), the German Space Agency (DLR), and the Italian Space Agency (ASI) (Van Zyl, 2001; Rabus et al., 2003; Foni and Seal, 2004). The mission was launched on 11 February 2000 aboard the Space Shuttle Endeavour. Using radar interferometry, the SRTM DEM was produced for almost the entire globe. There are several resolution outputs available, including a 3 arc-second (version 4) and a 3 arc-second (version 2.1) product for the world. The absolute vertical and horizontal accuracy of the data collected was reported to be ±16m (Rabus et al., 2003; Kellndorfer et al., 2004; Miliaresis and Paraschou, 2005; Kaab, 2005). SRTM DEMs have been shown to suffer from a number of gross, systematic and random errors propagated from the Synthetic Aperture Radar (SAR) imaging system (Koch and Lohmann, 2000; Ozah and Kufoniyi, 2008). Such errors are due to baseline tilt angle, baseline length, platform position, phase and slant range. Although SRTM data produced a number of voids due to lack of contrast in the radar image, a methodology based on spatial filtering was developed to correct this phenomenon (Dowding et al., 2004; Jarvis et al., 2004). SRTM v4 with voids filled in is obtained from the website of the Consultative Group for International Agriculture Research-Consortium for Spatial Information (CGIAR-CSI), while SRTM30 v2.1 is obtained from the USGS Earth Resources Observation and Science Data Centre archive.

2-2- LiDAR Technologies

Airborne Light Detection And Ranging (LiDAR) remote sensing has become a widely-used method that provides high-resolution topographical datasets. LiDAR is an active remote sensing system which operates by emitting laser pulses of light at high frequencies towards the Earth's surface. Every emitted pulse propagates through the atmosphere before hitting a target, where parts of the pulse are reflected, absorbed, or transmitted, depending on the characteristics of the illuminated object. A receiver collects the photons which are reflected. The range is computed by the travel time between pulse and return of a signal. LiDAR system is generally mounted on an aircraft and integrated with Global Navigation Satellite System (GNSS) and Inertial Navigation System (INS) systems to determine the location and account for trajectory variability that occurs during the collection process (Turner et al. 2013). The LiDAR data are frequently used for flood modeling (Yan et al. 2015), flood risk mapping (Bodoque et al. 2016; Webster 2010) and surface water body extraction (Smeeckaert et al. 2013a; Brzank et al. 2008; Hofle et al. 2009) but all these processes are built around the generation of digital terrain models using raw LiDAR point clouds.

III. RELATED WORK

Urban environments have an artificial and natural barrier to the flow of water that complicates the calculation of volume estimates. It should be emphasized that this analysis is necessary for prevention of this type of natural disasters.

Some scientific papers published in this area were reviewed and discussed. The first paper discussed the use of satellite images from multiple sensors and data was analyzed to measure the extent of flooding caused by Hurricane Katrina in the New Orleans, La., area. The flood polygons were combined with a high-resolution digital elevation model to estimate water depths and volumes in designated areas. This analysis was based on the delineation of polygonal areas protected by levees, defined by the U.S. Army Corps of Engineers (USACE) as pumping cells, which were representing homogeneous areas with respect to water levels and drainage rates and each of the USACE cells defined a volume on the flood maps. The inundation depth for each pixel within the flood polygons was calculated by determining the difference between the elevation value (from the digital elevation model) and the maximum water level. Water volume for each pixel was then calculated by multiplying the depth by the pixel area. Pixel volumes were summed up within each USACE cell to obtain the total water volume within each of the four cells (Smith J. and Rowland J., 2006).

The results obtained by this study are very useful for reconstruction efforts, as well as for assessing the accuracy and effectiveness of emergency preparedness scenarios and response plans.

However, the researcher found also some limitations. As an example of these shortcomings, these results have not been verified or validated with ground-based information and are subject to revision. Moreover, it is important to note that this analysis was completed on four snapshots in time and it is likely that it may not have captured the maximum inundation volume caused by Katrina. Finally, the maximum volume derived from this analysis is less than the volume published by USACE. Identifying this difference between the two studies would require an analysis of methods and assumptions used by USACE to derive their estimates. Unfortunately, that information was not available at the time of this Analysis (Smith J. and RowlandJ., 2006).

The open issue of this study is the development of barrier-detection methods, which may be an area of future research to improve this type of emergency response.

Another paper presented a GIS urban surface water balance model, that has been built using ESRI GIS software model builder and uses the data of Keighley Town in West Yorkshire as case study to develop water balance model and explore redevelopment scenarios and pluvial flood risk management (J. Diaz-Nieto et al., 2008).

This model is made up of a series of sinks and their contributing areas are areas where surface water can be collected - thus forming a pond or an area of potential flooding and using a GIS database to create these sinks. Sink sewages are nested, with small catchments nested in larger catchments. Sinks fill up with excess surface water from their corresponding catchment and only once a sink is full; it is overflowed and will pass water further down the catchment. Now, LiDAR provides the right data for surface sink analysis Here the model analysis has been immediately highlighted by a screening process, followed by a comparison using Ordnance Survey Mastermap (OSMM) data or Google Earth images to determine whether indeed such a feature might exist or not. If so, a manual technique is used for cutting through and interpolating the surface heights below sinks that become full (or almost full) during small excess events . It is worth noting here, that there are some limitations such as the Urban DEM’s with corresponding features presents many false barriers to the surface water movement. In reality, water would move under the elevated structures. The second shortcoming is that values returned for water surfaces and shiny surfaces are unreliable (LiDAR does not penetrate water and shiny surface). Since this study is concerned with pluvial flooding rivers, watercourses or large open drains are boundaries. It was therefore necessary to identify and eliminate these features from the urban DEM. A further shortcoming is that, in some cases, sinks have more than one pour point; this occurs when there are exit points of equal height. Notable most conventional GIS based methods for flood risk mapping are based on ground surveys and aerial observations, but when the phenomenon is widespread, such methods are time consuming and expensive. Furthermore, timely aerial observations may be impossible due to prohibitive weather conditions. This study therefore proposes a multi-parametric approach for delineating flood vulnerability in a growing urban area through the integration of Analytical Hierarchical Process (AHP) as a multi-criteria decision making (MCDM) technique within a GIS mapping environment. Eldoret Municipality in Kenya has been taken as case study (Ouma Y., Tateishi R., 2014). Hence, the criteria considered in this study were chosen due to their significance in causing flood in the study area. The factors considered are: elevation and slope; soil types; annual rainfall distribution; drainage density and land-use/land-cover information. In this study, the slope map was prepared using the digital elevation model (DEM) and slope generation tools in ArcGIS software (Ouma Y., Tateishi R., 2014). The slope classes having lower values were assigned higher rank due to almost flat terrain while the classes having higher values were categorized as lower rank due to relatively high run-off.

For further studies, and to take further advantage of the versatility of AHP in urban flood studies, research efforts could be focused on how AHP can be combined with other techniques such as fuzzy logic. Additionally, studies on the impacts of longer rainfall/flood records and iteratively carrying out the judgment process on flood risk assessment using the AHP-GIS should be investigated.

The researcher found that GIS played an important role in manipulating, processing, integrating, modeling and visualizing the spatial data for the strategic flood risk assessment by taking Medway Estuary town as case study (Yan Evans et al., 2007). Moreover, the locations and the alignment of the primary and secondary flood risks were digitized by using a combination of unfiltered high level LiDAR data and unfiltered low level LiDAR data. These

digitized flood risks lines were used for the planning of the flight route of the helicopter survey.
The results from this survey explained that a greater point density was achieved than was specified. This is very beneficial and important to accurately define the height and location of flood risks, as illustrated in figure (1).

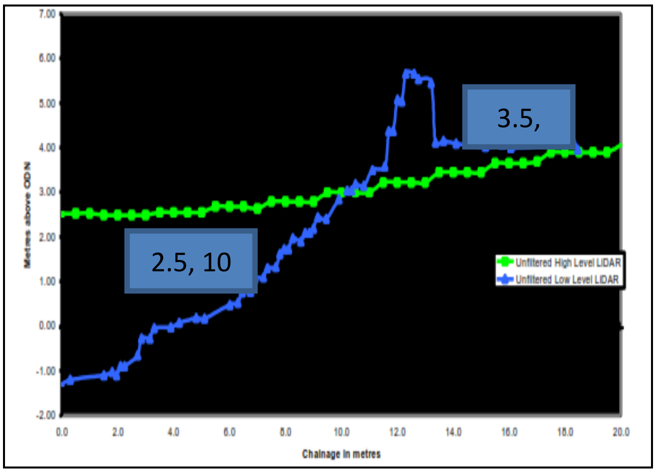

Figure (1): The height and location of flood risks

Once the low level LiDAR data was captured, the next key activity was to analyze and abstract flood risks data. Moreover, Strategic Flood Risk Assessment (SFRA) provides the necessary data to enhance the decision-making process and improve information management system for future development planning.
For further studies on this problem, the researcher investigated the use of Airborne LiDAR for hydrologic modeling, the accuracy of LiDAR data, its use as a tool for terrain change analysis and its effectiveness for basic flood extent modeling. LiDAR data captured in 2010 and 2012 covering the East Creek catchment in Toowoomba was obtained for this project. Hydrologic models were created and results were compared between the 2010 and 2012 LiDAR datasets. It was found that hydrologic flow lines and watershed boundaries varied on side streams. This variation was also found to be less in undeveloped areas than in developed areas. Many researchers have created and analyzed the quality of UAV-based DEM, DSM, and orthoimages for different applications. Unmanned Aerial Vehicle (UAV) photogrammetry was investigated for topography. More studies tried to solve this problem. The new flood prediction model, that computes accurately floodplain polygons directly from the results of hydrological modeling, allows emergency managers to assess the impact of the flood before it occurs and better prepare for evacuation and rescue of the population.
The method of simulating and predicting flood and its effects on utilities provides powerful visual representation for decision making on when buildings in the flood zone may be safe for people to occupy. Traditional paper maps and digital maps may not give us the possibility to do a 3D visualization of the detailed effect of a flood on utilities and infrastructure. The resulting 3D view does not only register a clear-to nature scenario, but also provides a more discerning outlook of the buildings and infrastructure during floods as illustrated in figure (2), (D.Mioc1 et al., 2016)

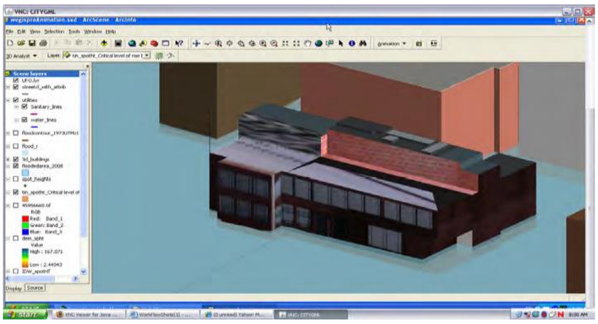

Figure (2): 3D Model compared with Photograph taken during the flood in 2008

Furthermore, this research investigated the DEM production of Unmanned Aerial Vehicle (UAV) data captured after Hurricane Mathew in 2016 from a flood-prone area, the town of Princeville. An accuracy analysis was performed by comparing UAV-derived DEM with an integrated LiDAR and USGS stream level elevations. There is general agreement (less than 30 cm difference) between the models. More work is required for UAV-based DEM creation for flood applications due to the extremely challenging application requirements (Leila Hashemi-Beni et al., 2018).
According to (Gizachew Kabite, 2017) study, it was found that Flood modeling, which is fully dependent on accurate and high-resolution DEM data, solves some of the limitations of Earth observation. As such, LiDAR system improved the performance of flood modeling via providing fine resolution DEM.
The opportunities that LiDAR technology provided for flood mapping includes provision of accurate and high-resolution DEM data, relatively cost- and time- effective data collection system, capability of penetrating dense vegetation, improved flood model accuracy and fine scale flood modeling, adequate representation of man-made and topographic features, and capability of determining flood depth. On the other hand, there are challenges to the use of LiDAR systems for flood modeling; The major challenges include LiDAR data filtering (classification), data availability and accessibility, data file size, high computational time, inability to characterize channels bathymetry, and insufficiency of representing complex urban features. More importantly, further researches have to be conducted to improve LiDAR data filtering algorithm, particularly that best fits urban areas. Furthermore, another study (José María Bodoque et al., 2016) aimed to characterize uncertainty in the first floor elevation of buildings prone to being affected by floods and located in communities where lowest floor elevations are at ground level. To this end, a 2D hydrodynamic model was used to obtain the 500-year flood zone in an urban environment. Next, a geostatistical

approach was put into practice to determine the spatial distribution of errors between the DSM derived from LiDAR and first floor control points in buildings. The Monte Carlo method was then used to describe errors with a probability density function (PDF).

Also, in another study (Alemseged Tamiru Hailea and T.H.M. Rientjesb, 2004) different ways were explored to hydraulically represent buildings (solid, partially solid and hollow objects) in a flood model approach by varying the surface roughness values. Simulation results were compared and it was shown that bulk flow characteristics do not change significantly. It is preliminarily concluded that building representation, through modification of the roughness coefficient only, is not sufficient to represent all hydrodynamic effects such buildings cause and generate in the real world. The overall conclusion of this study is that accurate simulation of topography has significant effect on flood simulation results. However, it was not clear from this study which generic aspects of the applied flood model approach cause significant differences.

Furthermore, the study of (Laurence Hawker et al., 2018) attempted to reinvigorate the idea of DEM simulation and highlight its value for flood studies. Despite repeated calls to produce a new high-accuracy open access global DEM (Schumann et al., 2014; Simpson et al., 2015), this unfortunately does not seem forthcoming, even increasing computing power has made global flood simulations possible (Sampson et al., 2015), while flood modelers also often run multiple models to explore model parameter sensitivities. However, the impact of DEM error has been largely overlooked in lieu of a lack of suitable stochastic DEM data. DEM simulation overcomes this restriction, making it possible for flood modelers to use a catalog of DEMs. Working in tandem with systematic DEM editing (e.g., MERIT), DEM simulation can fill the gap until a much-needed new high accuracy open access DEM is produced. Even when this long awaited DEM is eventually produced, DEM simulation will still be an invaluable approach for exploring the effect of DEM error in flood inundation estimates as long as good estimates of the spatial error structure can be made across a sufficient number of locations. Scientists are, therefore, encouraged to embrace geostatistics to simulate DEM ensembles and call for increased reporting of spatial dependence by DEM vendors and scientists alike.

As discussed in another study (K. McDougall a, P Temple-Watts a, 2012) approximately 20 images of flood damaged properties were utilized to identify the peak of the flood. Accurate position and height values were determined through the use of RTK GPS and conventional survey methods. This information was then utilized in conjunction with river gauge information to generate a digital flood surface. The LiDAR generated DEM was then intersected with the flood surface to reconstruct the area of inundation. The model-determined areas of inundation were then compared to the mapped flood extent from the high resolution digital imagery to assess the accuracy of the process. The paper concludes that accurate flood extent prediction or mapping is possible through this method, although its accuracy is dependent on the number and location of sampled points. The utilization of LiDAR generated DEMs and DSMs can also provide an excellent mechanism to estimate depths of inundation and hence flood damage.

Another study (J. R. Ternate et al., 2017) which can serve as a reference for water resources engineers and designers who decide to pursue construction of flood control facilities was reviewed. With the knowledge of return periods considered for individual water structures, engineers could utilize the rainfall-runoff model developed by the researchers to determine the design discharge. Furthermore, the use of river analysis software, HEC-RAS, is recommended in this study for identifying the areas that need flood control measures and facilities**.** Finally**,** the study conducted by (Mehebub Sahana et al., 2015) suggested that efforts should be made to remove the sediments for increasing the depth of river near the affected area of Malda district. Manikchak and Ratua blocks but these have been eroded. Therefore, measures such as construction of short spurs and bed bars for diverting flow should be adopted to save agricultural land, property and human lives**.**

IV. PROPOSED MATERIALS AND METHODS

4-1- Proposed research flowchart

In view of the literature reviewed by the researcher, it was decided to adopt the following flow chart to conduct the PHD. research under the title “Flood Water Analysis in Khartoum Using DEM & LiDAR”

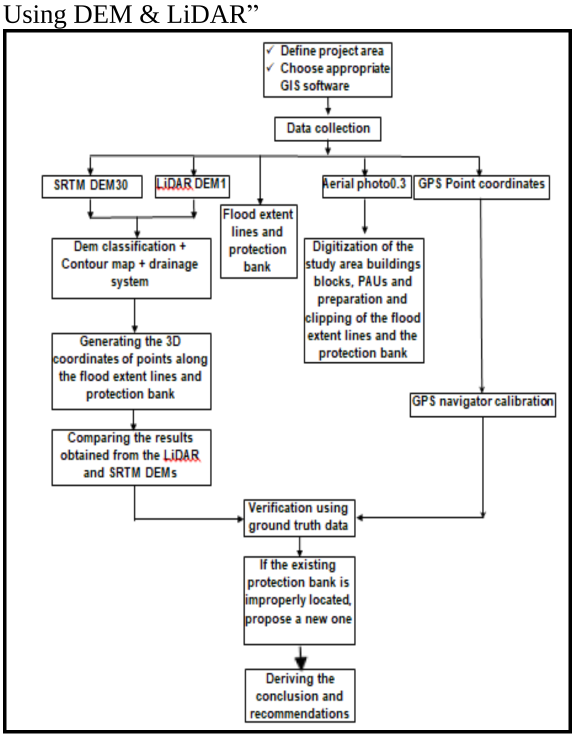

Figure (3): Proposed research flow chart

4-2- Study area

The study area is Azozab in Kharoum state, located between longitudes 32°28'30" - 32°28'45"E and latitudes 15°29′45″ - 15°31′45″ N as shown in figure (4). The total area is 4,247,568 m² and the Vegetation area is 166 acre (about 665,328 m²). Azozab is bounded in the north by Alazhari, the east by Railway, in the west by the while Nile, and in the south by Aldabasin.

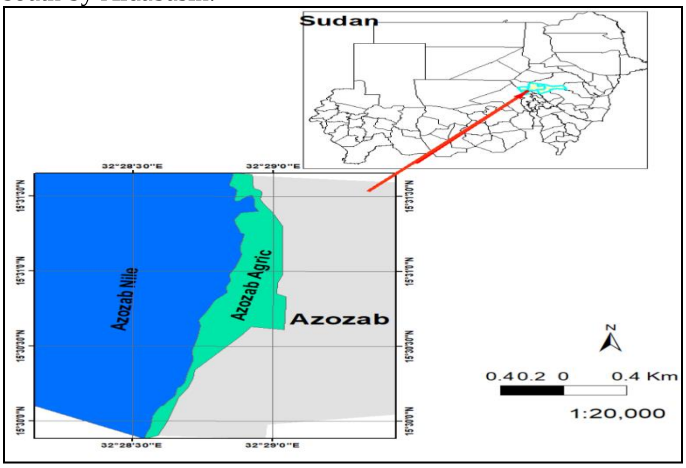

Figure (4): Location of study area (Azozab)

The area contains ten blocks (Wad Ajeeb, Aldabasin block 1&2, Azozab block 1, 2 &3, Faroug block 1,3&10, Gala block1). And inhabited by about 27,742 people as shown in table (1). There are eleven public administrative units in the study area as shown in figure (5).

Table (1): population age categories in study area

Age / Block	0-4 M	0-4 F	5-14 M	5-14 F	15-24 M	15-24 F	25-44 M	25-44 F	45+ M	45+ F	Total
Azozab 2,3	396	358	797	718	800	800	1384	1342	779	622	7,596
Azozab 1	101	122	220	200	265	270	340	414	238	206	2,376
Wadajeeb	184	168	300	304	444	336	567	510	310	245	3,368
Dabasin West	107	130	239	194	248	215	408	382	219	195	2,337
Dabasin East	126	141	272	238	353	315	487	489	287	249	2,957
Faroug b 3&10	218	198	369	396	549	467	649	629	377	323	4,175
Faroug b 1	45	43	91	105	366	88	258	129	80	63	1,268
Gala b 1	151	118	338	303	390	372	450	509	336	298	3,265
Total	**1,328**	**1,278**	**2,626**	**2,458**	**3,415**	**2,863**	**4,543**	**4,404**	**2,626**	**2,201**	**27,742**

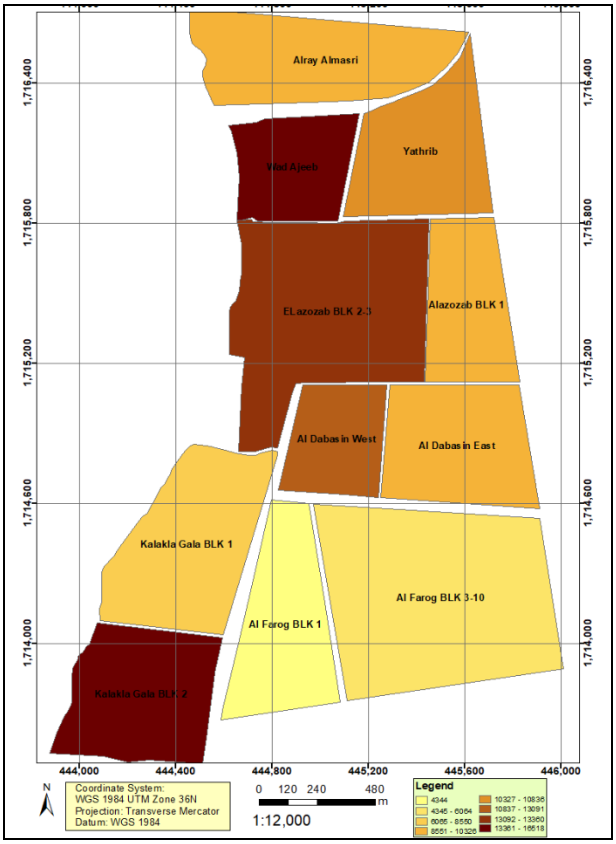

Figure (5): blocks of study area

During 1946 and 1989, the highest floods occurred in Khartoum state. For this research, only data from Azozab area will be used, as it is the area which has been frequently exposed to the flood.

4.3. Data collection

Floods are one of the most serious, common and expensive natural disasters that cause fatalities and considerable economic losses worldwide every year. Climate change has dramatically increased the frequency and the severity of the flood events (Gordana Jakovljevi´c and Miro Govedarica, 2018).

In this research, based on the literature review, the researcher has made efforts to improve the accuracy of the elevation data, and used new satellite (world view) to get two high accuracy images (50 cm). In addition, the researcher is collecting the DEM (1m) of this area as shown in figure (6). Furthermore; the hydrological modeling was integrated with processed data within a 3D application.

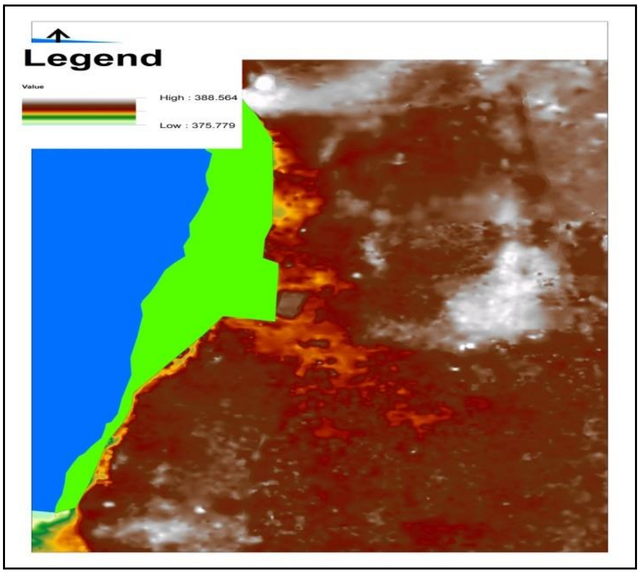

Figure (6): LiDAR DEM (1 m) of study area

Light Detection and Ranging (LiDAR) is a data collection technique that uses a beam of light to make range-resolved remote measurement of features within the path of a reflected beam of light. The researcher downloaded three world view high accuracy satellite images i.e. about 50 cm (2016, 2017, and 2018) which are shown in figures (7).

LiDAR is an active remote sensing that produces highly accurate and dense elevation data which are suitable for flood modeling (Brzank A. et al, 2008). LiDAR system uses a laser scanner mounted on ground, aircraft or satellite. The system releases discrete pulses of laser, records the time required for the pulses to travel from the scanner to ground targets and calculates the distance between the scanner and the targets. An airborne LiDAR system is typically composed of three main components: a laser scanner unit, a Global Positioning System (GPS) receiver, and an Inertial Measurement Unit (IMU). The instantaneous position and orientation of the laser with respect to the ground can be determined using the Global Positioning System (GPS) and Inertia Navigation System (INS) on board the platform. Additional information on the scan angle and GPS base station are required to construct the 3D position of the ground feature (Bater CW, Coops Nc, 2009).

4.4. Data Processing:

Inverse Distance Weighted (IDW) Interpolation Method:

(Geomatics, 2019) Many definitions have been formulated with regard to the concept of interpolation (e.g. Burrough 1986; McCullagh 1988; Robinson 1994). According to Burrough (1986): interpolation is the procedure of estimating the value of properties at unsampled sites within the area covered by existing point observations / data.

There is a great range of methods, models and techniques available for data interpolation, based on parameters that affect the quality of the result. Many of these methods and techniques are well established and are commonly used because they provide acceptable results. At the same time, research continues with the aim to evaluate their effectiveness and improve the quality of the results (Oswald & Raetzsch 1984; Gold 1989). The accuracy of a DEM that is produced with an interpolation procedure is related to the density and the distribution of the reference altitudes, as well as the interpolation procedure used (Schut 1976). Even the simplest interpolation method may be useful if the density of the reference altitudes is high and their distribution is ideal.

The Inverse Distance Weighted (IDW) method is widely recognized as the basic method in most systems that create and manage DEMs (Burrough 1986; Schut 1976). The main characteristic of this method is that all the points on the earth's surface are considered to be interdependent, on the basis of distance. Therefore, the calculation of altitudes in an area depends on the altitudes of the data points in the vicinity.

The basic IDW interpolation formula is shown in equation (1). Where x* is unknown value at a location (P), w_i is the weight, and x_i is a known point value, d_i is the distances of the points from point P; n is the number of points used in the interpolation procedure for estimating the elevation of point P. The weight is inverse distance of the point (P) to each known point value (w_i) that is used in the calculation. Simply the weight can be calculated using equation (2).

$$x^* = \frac{w_1 x_1 + w_2 x_2 + w_3 x_3 + \ldots + w_n x_n}{w_1 + w_2 + w_3 + \ldots + w_n} \quad \text{---Eq.(1)}$$

$$w_i = \frac{1}{d_{ix^*}^{P}} \quad \text{--------------------------Equation (2)}$$

The points are the vertices of the digitized lines. Interpolation is effected on this basis. Sometimes, it is possible to select a subset of these points, when for example there are more points than the minimum required to define the geometry of the contour. This involves a process of contour generalization.

Figure (7) shows several intersection points between the flood lines (produced from the LiDAR DEM and the SRTMDEM "in light blue color") and the protection line 'in red color". Only two intersection points are shown where the elevations of each point are equal. Thus, each intersection point represents a risk-generating point as a point where the flood water will start draining (discharging) towards the study area "Azozab"

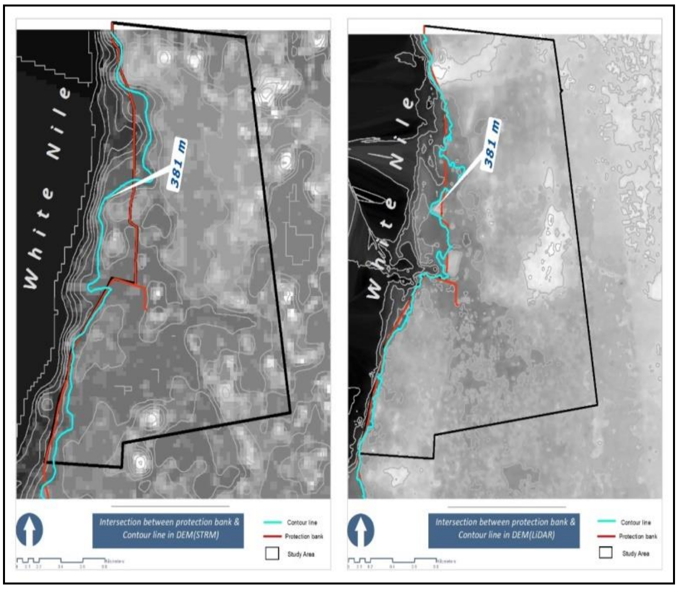

Figure (7): intersection between protection bank & contour line (381m) in DEM left (SRTM) and DEM right (LiDAR)

V. RESULTS AND DISCUSSION

As a result of this literature review, the candidate researcher has got the opportunity to show that she has understood the body of the academic work that has already been done in relation to the flood analysis topic and has surveyed scholarly articles, books, data, research papers, and other sources relevant to her particular area of research. Conducting the literature review has established familiarity with and understanding of current research in this particular field for the student before carrying out her investigation, and enabled her to find out what research has already been done and identify what has not been unknown within her topic. The literature review has given a theoretical base for the research and helped the PhD. student (the researcher) determine the nature of her research.

VI. CONCLUSION

The new flood prediction model that computes accurately floodplain polygons directly from the results of hydrological modeling allows emergency managers to assess the impact of the flood before it occurs and better prepare for evacuation of the population and flood rescue. The method of simulating and predicting flood and its effects on utilities provides powerful visual representation for decision making on when buildings in the flood zone may be safe for people to occupy. Traditional paper maps and digital maps may not give us the possibility to do a 3D visualization of the detailed effect of a flood on utilities and infrastructure.. LiDAR data provides a cheaper, faster and denser coverage of features for 3D mapping. LiDAR data will be processed to generate 3D maps. Floodplain delineation will be computed by intersecting the Digital Terrain Model with the simulated water levels. The DTM and the 3D models of the government buildings, infrastructure and utilities will be overlaid and presented as a 3D animation. The resulting 3D view will not only register a clear-to nature scenario, but also will provide a more discerning outlook of the buildings and infrastructure during floods. Finally, based on the literature reviewed, the researcher has found out that GIS and LiDAR technologies combined with hydrological modeling can significantly improve the decision making and visualization of flood impact needed for early emergency planning. The candidate researcher will explore the application of 3D modeling using LiDAR data to provide an analysis of the risk of floods on government buildings and utilities in Azozab locality.

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