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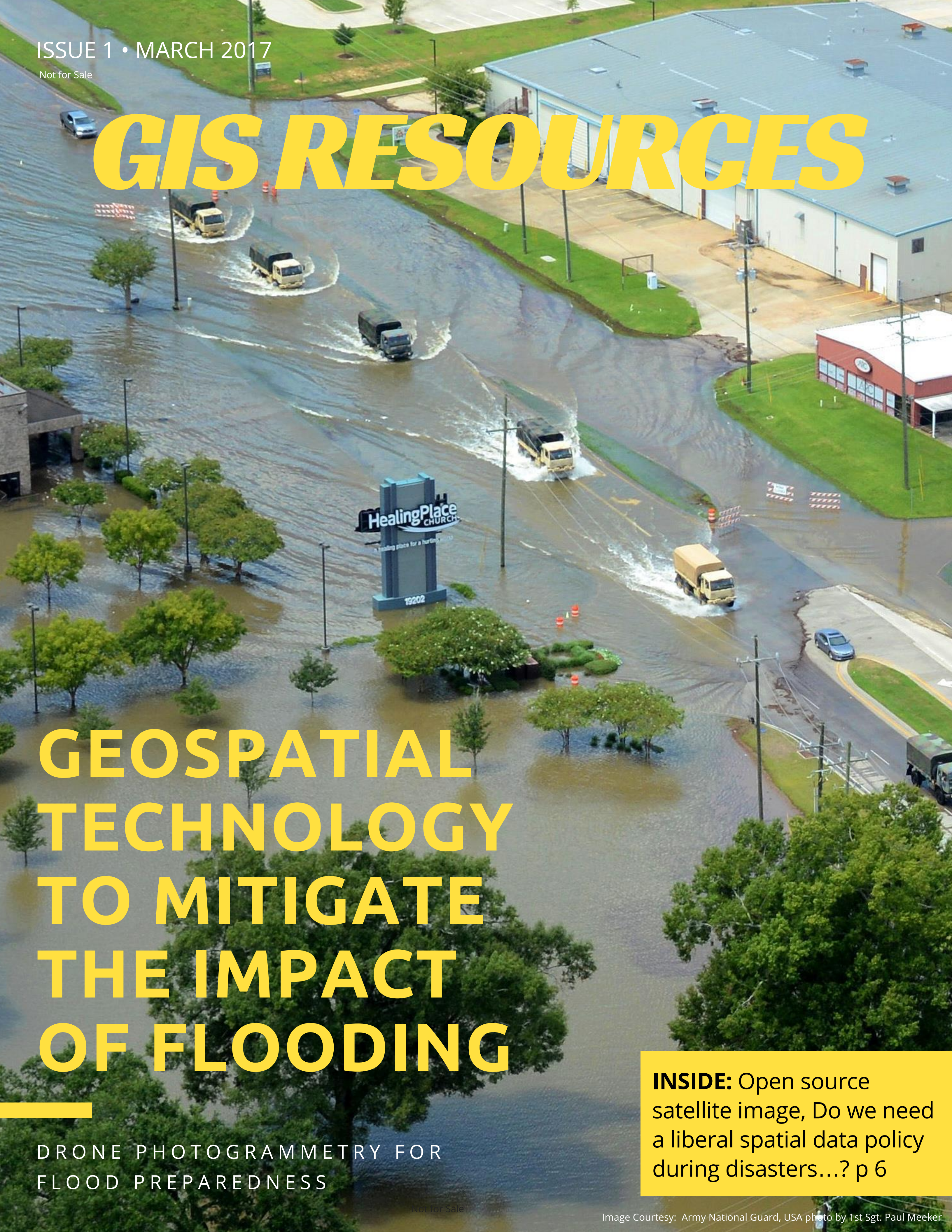

GEOSPATIAL TECHNOLOGY TO MITIGATE THE IMPACT OF FLOODING

DRONE PHOTOGRAMMETRY FOR FLOOD PREPAREDNESS

INSIDE: Open source satellite image, Do we need a liberal spatial data policy during disasters…? p 6

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Image Courtesy: Army National Guard, USA photo by 1st Sgt. Paul Meeker

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Ashok Prim
Editor

GIS & Decision Support Scenarios to Mitigate the Impact of Urban Flooding

A short spell of rain is enough to create chaos on roads in most urban areas in cities. Assurances by local authorities about preparedness to meet exigencies arising out of short bursts of heavy rain and during monsoons are proven inadequate time and again.

Every year it is the same. Urban roads turn into rivers and drains soon overflow. Public & private road transport is thrown out of gear causing great inconvenience to commuters. The worst affected are those seeking to reach hospitals, airports, railway stations etc.

As is often said, preparedness is the best way to reduce the debilitating impact of urban flooding. GIS is a tool that can be used to prepare for various scenarios that the phenomenon of urban flooding can lead to. Inputs such terrain, drainage pattern, rainfall pattern, urban infrastructure, population density etc can be used to create models to assess the possible impact of rainfall over time in urban areas.

Current mobile platforms are sophisticated enough to enable applications to be built to create to create 'Decision Support Scenarios' so that a user has the capability to decide what to do it such situations.

Government departments, municipalities, Survey of India, State Remote Sensing Agencies and other such organisations must come forward to build 'Decision Support Scenario' applications or put them up on their websites for stakeholders to use. Technology can help cities to create smart infrastructure for citizens to help mitigate their problems when faced with the phenomenon of urban flooding.

Open Source Satellite Images in Flood Monitoring. Do We Need a Liberal Spatial Data Policy During Disasters...?

Image Courtesy: NASA

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The predictions of the meteorological department regarding the onset of natural disasters and the actual incidences of natural calamities were failed to converge in most of the situations in India during the last three decades. The Utharakhand cloud burst occurred in June, 2013 was the most recent example to cite the failure of such predictions. The abrupt changes in the local climate phenomenon together with global climate change triggered the frequency of occurrence of natural disasters in the form of floods, droughts, landslides and uneven rainfall events. Though the recent developments in communication technology and modern mitigation strategies have brought down the severity of natural calamities, the population in disaster prone areas are under threat due to uncertainty. According to CRED (Center for Research on the Epidemiology of Disasters) 2.3 billion people were affected by flood globally during 1995-2015 .

The record of worldwide affected population of 115 million per year, alarm the researchers and decision makers to identify the reliable solutions to overcome and resist the natural calamities of varying intensities. For a quick response during these calamities decision makers need reliable information with greater accuracy and quality for a very large area. Satellite remote sensing provides a synoptic view of the area with repeated updates through images.

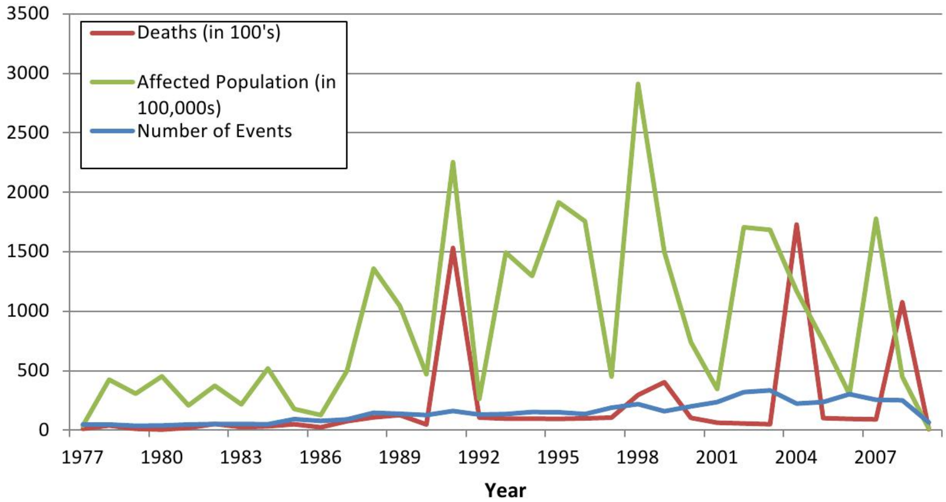
It is the only solution which gives a large amount of information in different scales and perspective with greater accuracy and frequency to the disaster managers and earth science research community. Many satellites have launched by different countries to look at the changing earth and its atmosphere. The volume of data collected by ground stations from these satellites is huge, so that a small government agency cannot handle it easily. According to NASA's Earth Observing System Data and Information System (EOSDIS) metrics of 2014, it managed more than 9 petabytes (PB) of data. It is equivalent to 9000 terabytes. There are many remote sensing agencies currently collecting data in the same level as the NASA does and the data produced are huge in terms of petabytes.

Who really uses it...? Whether this data is underutilized?

Here comes the importance of open data policy. At least during the time of disasters, the barriers of data access have to be taken out, so that the common people with scientific aptitude can process it to help the people in agony. There will be a time in the near future when each panchayath in the country start making their own maps of natural resources and disaster management. This article focus on the use of open source datasets and tools in disaster management and how the participatory approach in data processing can encourage the use of remote sensing.

Land and water resource utilization without any vision and rapid urbanization during the last 3-4 decades made the environment a card castle, where any small change can create a butterfly effect on the environmental balance. Every year droughts and floods are occurring cyclically in the Indian subcontinent. Around one eighth of the total geographical area is flood prone in India. News on loss of life and wealth due to natural calamities are considered as 'usual'. Between July and August in every year, flooding affects more than a million people in North Eastern states of India. For people in Assam, it is, an annually expected phenomenon and the death toll and agony is often less noticed by the rest of the world.

Meteorological information related to flood and rainfall are not available in many parts of the country. If available, the instrumentation at many meteorological stations are not maintained or calibrated properly. This is one of the many reasons that made the satellite-based tools more useful to evaluate the flood and related ground conditions. Since independence, there have been many worst flood events in India. Bihar flood in 1987 killed 1399 people and Maharashtra flood in 2005 killed 1094 people. Gujarat flood in 2005 created a financial loss of 8000 crore rupees for the nation. In 2012 Assam flood displaced around 5 million people from flood inundated areas. The instances of flood disasters in India since independence are still many, and the loss of life and wealth created by these disasters are poorly accounted and the victims are often ignored. Mitigation strategies are often failed, killing hundreds of poor people and making millions homeless. In most of the cases, human being and his technology stay defeated in front of natural disasters, leading to the collapse of his financial well-being. Natural calamities often destroy the habitats and healthy environment around him. The death toll due to sudden disasters followed by epidemic diseases often worsen the situation beyond our control.



Flood events affecting human populations by year

Courtesy: The Human Impact of Floods: a Historical Review of Events 1980-2009 and Systematic Literature Review by Shannon Doocy et. al.

Geo-spatial data and flood management strategies

Scientific and effective disaster management strategies can speed up the resilience. Flood disaster management has mainly three different cycles, which are preparedness stage for flood, flood occurrence stage, and mitigation stage. The scientific and management group has been already reached the consensus of selecting the spatial data sets, as the most effective inputs for achieving the targets for all the three stages.

The major challenges during flood preparedness stage are to identify the most affected geographic regions during the past flood events and planning for evacuation. The second stage, the most critical stage of disaster management, targets to identify the spatial extent of flooding, flood progression, and the recession. The output of this stage is most important for immediate action and rescue operations. The mitigation stage focuses the identification of changes in river courses, flood control works, erosions of river banks, drainage congestion, flood hazard and risk vulnerability assessment. The recent constellation of Earth Observation satellites of different spectral and spatial configurations is sufficient enough to provide reliable inputs for these different stages of management.

Legacy of Earth observation satellites

The occurrence of flood is associated with various reasons. In most of the cases, floods due to heavy rainfall are predominant. At rainy conditions, overcast can limit the use of optical imagery. Thanks to Lansdat program and NASA's Aqua Terra satellites for providing the images for flood monitoring to a greater extent during the last decade.

The synoptic and temporal coverage of satellite images facilitate the flood mapping related studies at inundated areas of different conditions in climate, morphology and land use. Satellite images captured by optical sensors were mainly used for flood related studies before 10 years. Riverine flooding due to glacier melt and coastal flood due to tidal surges can be studied effectively by optical images. The inability of optical sensors to procure clear images during cloudy weather conditions, limits its application potential during flood events accompanied by clouds. The onset of microwave remote sensing satellites paved the way towards all weather condition images. Data acquired from several SAR (Synthetic Aperture Radar) instruments like ERS-2, ENVISAT/ ASAR, RADARSAT1/2, ALOS PALSAR, RISAT, TandemX etc. used in various flood events worldwide. Sentinel 1A and 1B, launched as a part of ESA's Copernicus program is the latest among SAR satellites which have an open data policy.

The space era of Earth Observation satellite began with the launch of Landsat series of satellites in 1972 and today the Landsat mission is the longest acquisition program for satellite images of Earth with its latest in the series, Landsat 8. Landsat mission is the favorite mission for the user community, because of its 30m spatial resolution and 16 days temporal resolution. Free data availability and spectral bands at Visible, Near-infrared Middle infrared and thermal infrared regions make this mission a unique one.

The Indian Remote Sensing Satellites (IRS) series from 1A to today's Resourcesat 2A are another promising series of optical satellite datasets which are useful for flood management studies. A participatory approach in flood mapping is not possible at the current scenario, because the process of ordering data, payment, data processing and its delivery, were the concerned time constraints that delay the retrieval of output for a quick response and action. Since the IRS data availability to the user community is delayed due to policy issues, flood monitoring studies are carried out by government agencies themselves. Liberalizing the data availability to the public during disasters and disseminating them through the internet to the scientific community can boost data processing and disaster management activities.

The requirement of high-resolution image at daily basis is again a hurdle in flood monitoring. MODIS (Moderate Resolution Imaging Spectrometer) images are the only option available today. MODIS on-board Terra and Aqua satellites revisit every nook and corner of the Earth on a daily basis. Since the spatial resolution is 250m, flood maps with moderate resolution can be made using these datasets. This is the only sensor that can provide images in daily basis with reasonably good spatial resolution. Red and Near infrared bands in MODIS has 250m spatial resolution and these bands are used for generating flood maps. NASA's Global Flood Mapping system uses these MOIDIS bands for generating daily flood maps for the entire globe.

Urban flood studies still demand very high-resolution images and getting high-resolution images on a daily basis is a costly exercise. No satellite currently provides high resolution images on a daily basis and the only possible option is to gather data is from a constellation of different satellites that are taken together. Due to this, government agencies mostly depend upon aerial surveys for high resolution images.

Another promising mission is Sentinel 2, which is also an optical remote sensing satellite launched as a part of ESA's Copernicus program. The twin satellites 2A and 2B together has a revisit period of 5 days with a spatial resolution of 10m. The data is free for the user community.

Open data policy in remote sensing has the prospects of connecting communities of different domain together to build a robust solution for quick actions towards disasters. Also the participatory approach can reduce the workload on the government agencies that will help to reduce the gap between the action and reaction. Nowadays, when an earthquake or flood happens, the user community is open to the current data and we expect people to come up with solutions to help the people. The CLOUD to beat the cloud burst is a promising platform for flood disaster management.

Chennai Floods in 2015

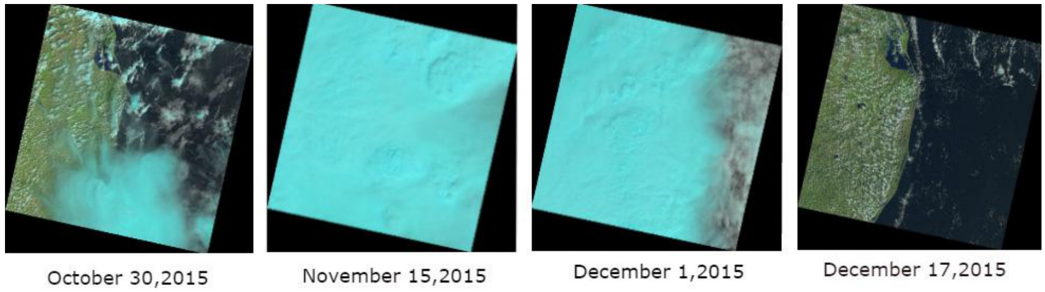
The period of northeast monsoon during October-December 2015 drew a red line in the history of Chennai city by witnessing the flood events of uncontrolled magnitudes and their impacts on human life. Chennai recorded a rainfall of 1218 mm in the month of November as per the Skymet data which was three times more than its normal rainfall and it was the highest received since 1918. The crisis of flood in Chennai opened up the facts related to the management of Cooum river, Adayar river and Buckingham canal which are the major water drains of the city towards the sea. Beyond the magnitude of rainfall, poor management of the drainage system was mainly attributed to the severe crisis of flooding. The illegal encroachment of city's drainage channels through unsustainable development was the sole cause of not keeping the city alive for days after the heavy rainfall. The garbage dumps and solid wastes on storm water drains alarmed the city's population to dig a way out of this situation through proper planning and sustainable management of its resources. The hand-in-hand, of technological advancement and infrastructure development may be a better platform towards an intelligent solution for mitigation of such kind of unprecedented flood events. .

The south Indian flood during 2015 November was due to heavy rainfall and as a result, the overcast conditions for almost 2 months starting from November to December. It was very difficult to get any images of the flood inundated area through optical remote sensing. Figures (1,2) show images from MODIS and ALI (Landsat 8) during this period , which are completely obscured by clouds.

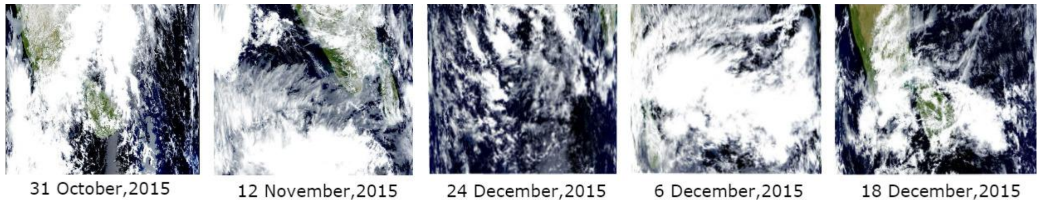
The SAR images to penetrate through the cloud made the technology more appropriate for this type of condition. Another major issue with flooded water bodies is that the water contains high amount of suspended sediments which are carried from channel beds and shores. These reflectances can mis-classify water body as land while using optical remote sensing. SAR images can easily distinguish land and water bodies, even though they carry heavy loads of sediments.

SAR images from sentinel 1A launched by ESA in 2013 gave a clear picture of the flood occurred in and around Chennai region. The Ground Range Detected images collected on 31st October, 12th November,24th November, 6th December and 18th December 2015 gave a clear picture of flooding in this region. SAR backscatter coefficient (sigma nought) is used for distinguishing flooded and non flooded areas.

Image threshold is one of the most common technique for flooded and non-flooded areas. It is generally performed by acquiring two imageries taken before and after the flood. The histogram of VV sigma nought images of flooded area can give a clear difference between the pixels of flooded and non-flooded areas. The advantage of selecting VV polarization is that it has the potential to identify partially submerged features also. The idea behind using SAR images is that the back-scatter from the water surface is very low compared to land and vegetation. As a result flooded areas appear as darker in sigma nought images. Extracting the pixels with low back-scatter values by applying an



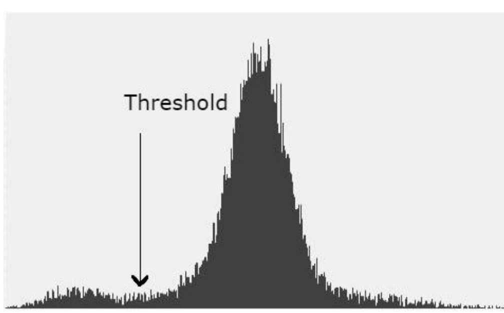
Figure(1). Landsat 8 images obscured by clouds during different dates during south Indian floods in 2015



Figure(2). MODIS images obscured by clouds during different dates during south Indian floods in 2015

optimum threshold value can generate a flooded area map with greater accuracy. Selection of optimum threshold value can be done by analyzing the histogram of the sigma nought image.

Histogram of 6th December is shown in the Figure (3) with optimal threshold value. Peaks in the histogram shows pixels containing flooded and non flooded areas.The back-scatter coefficient value midway between these peaks is taken as threshold value. Optimization of threshold values to be done in certain situations where the back-scatter values from different polarization channels are analyzed and a threshold value is determined.



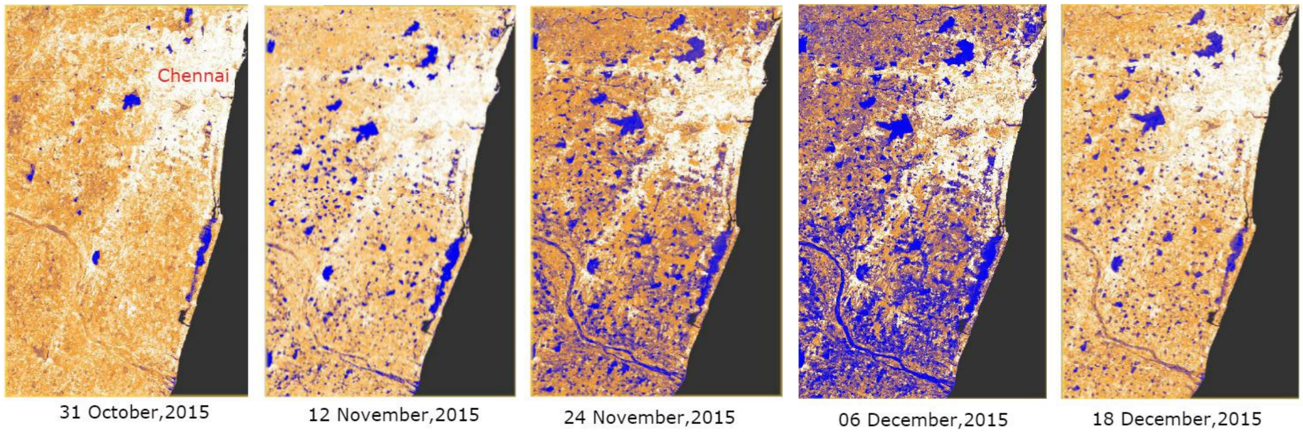
Figure(3). Histogram of sigma nought Sentinel 1A image dated 06 December 2015

Figure (4) shows the sigma nought images of 5 different dates in and around Chennai region. It is clearly observed that during 24th November and 6th December flood inundated a very large area in the region. It was reported that the maximum rainfall happened during 22-24 November and 1-2 December 2015. On 24th December at Nungampakkam and Meenumpakkam areas reported rainfall of 50mm in an hour and within 8.30 PM many areas was engulfed by knee level flood water. According to NASA's GPM data, during November 29th to December 2nd, over 400mm rainfall occurred in the southern part of Chennai. Figure (5) shows the thresholded map of the Chennai and surrounding areas in which white pixels show the water bodies and submerged areas.

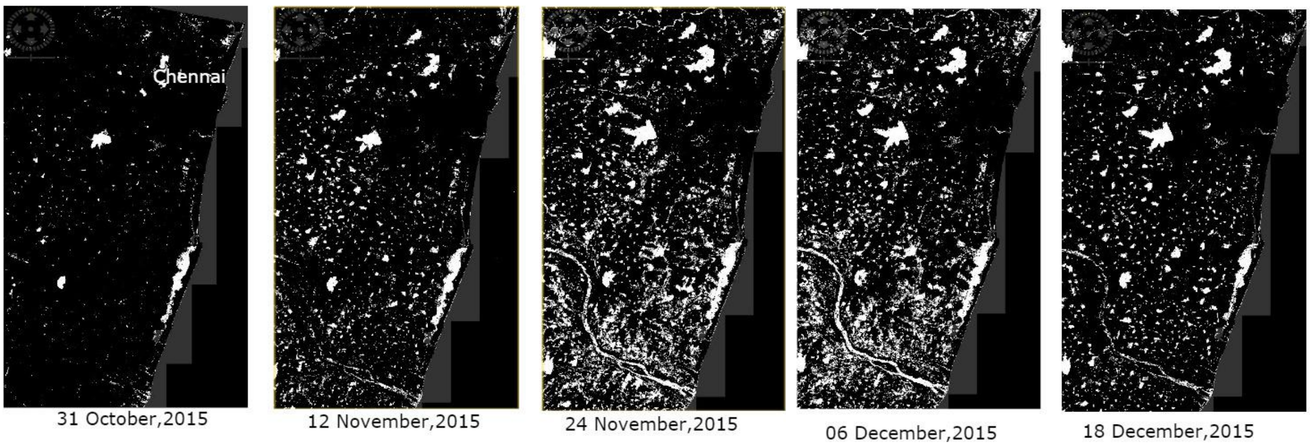
Figure (6) shows interesting developments on the Palar river and the great salt lake back waters. The river was almost dry with stagnant pools of water in October 2015, flooded to a dangerous extend submerging small land masses in its estuary on 24th November. The great salt lake was also encroached nearby areas by increased flood levels.

Tail End

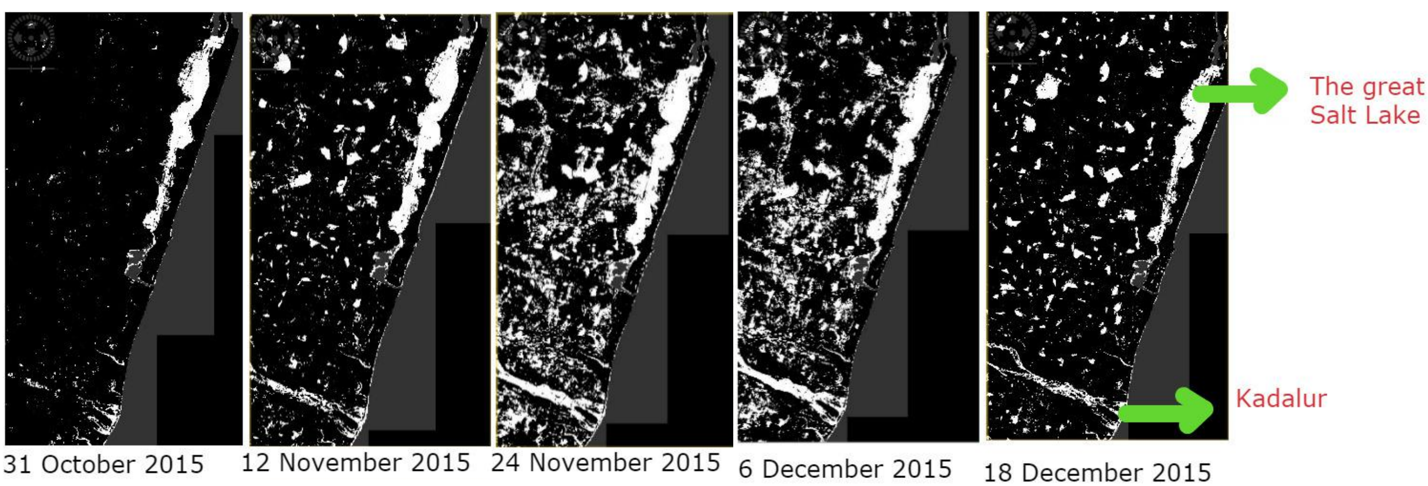
In India, getting data from government agencies is the most difficult task. Especially geospatial data is mostly denied due to security reasons.



Figure(4). Sigma Nought images from Sentinel 1A SAR Images showing Chennai and surrounding areas during floods in 2015.



Figure(5). Thresholded images from Sentinel 1A SAR Images showing Chennai and surrounding areas during floods in 2015. White pixels are water bodies..



Figure(6). Thresholded images from Sentinel 1A SAR Images showing Palar River and great salt lake

Scientific community and the common man always understand the spirit of such restrictions. Still a huge amount of data is collected at the cost of common man's money in spatial and non spatial category and laid to rest in the files of government agencies. Let the data be in the cloud, which are not sensitive to any security issues. Era has gone when people look at satellite images as a rare thing that they have never seen before. Now people are capable of mapping the land surface with their own drones with loaded cameras.

Acknowledgement

We acknowledge U.S geological survey for Landsat 8 (ALI) data for the Chennai Region during October-December 2015. We acknowledge ESA's Copernicus program, for their Sentinel -1A images of Chennai region. We also acknowledge Processes Distributed Active Archive Center (LP DAAC) for their MODIS images of the same area.

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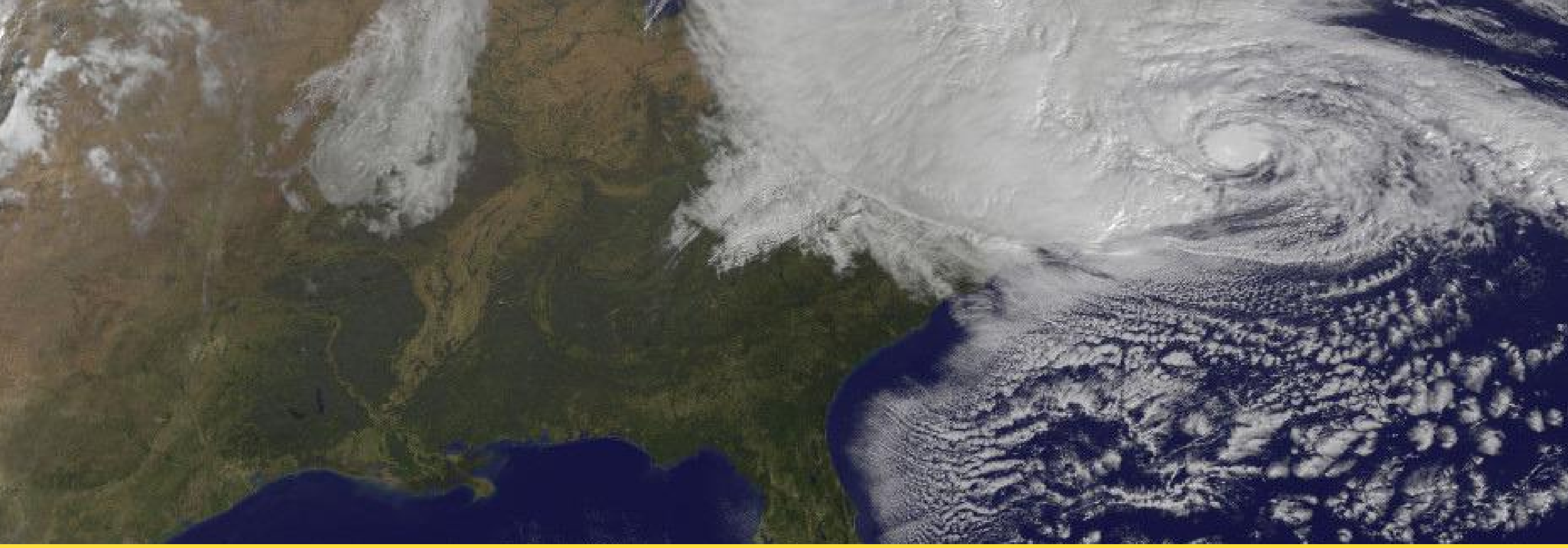

Storm Water Modeling and Flood Disaster Management Using Open Source Software

Image Courtesy: NASA

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Geo-spatial data serves as an input in hydraulic simulation softwares and thereby the simulated results can further transferred back to GIS system for real world graphical representation of the potential flood vulnerability zones. Reliable, large scale and good quality data is very important in management of flood disasters. The present scale of geo-spatial data available in urban local bodies is not sufficient for detailed and accurate assessment of flood vulnerability. In addition to climate and meteorological data, a detailed level of critical infrastructure and its related information is also vital and shall be integrated in GIS platform.

Introduction

Majority of Indian population lives in urban areas which are often prone to floods. These floods affect large number of people, properties and their lives. Assessing the behavior of urban flooding has to be given top priority since flooding takes place very quickly due to the dense urbanization. High intense rainfall due to rapid change in climate poses a great threat to engineers and urban planners throughout the world and resulting urban areas being inundated from hours to days. Rapid urbanization results with encroachment of natural lakes and drainage channels causing serious flooding. It is further aggravated due to the absence of proper and inefficient sewerage system. Due to this the impact is widespread, including disruption of communication network, damage to civic amenities, relocation of public, deterioration of water quality and risk of epidemics. The recent floods in Mumbai and Chennai turned out to be an eye-opener for the public and government.

This paper highlights the key inputs required for simulation and assessment of behavior of micro level urban storm water catchments. It is important to generate large scale database in GIS platform to find out flood vulnerable areas with respect to various storm events. One of the main objective of the study is to utilize the open source softwares in the domains of GIS, Remote Sensing and Hydraulics for generation of vital geo spatial data sets like urban catchments, Digital Elevation Models at different levels, soil, landuse, storm water network and its associated components, rainfall and runoff etc.

Study Area

The catchments from Zone1 of Greater Visakhapatnam Municipal Corporation (GVMC) is selected for the proposed study. GVMC has a jurisdictional area of 515 sq. km. The geographical area of Zone1 is 117 SqKm. The city is strategically located midway, between Calcutta and Chennai. The city is the first-largest urban agglomeration in the state of Andhra Pradesh in terms of population. As the city is a coastal city, it experiences heavy rains, particularly between August and December every year. Due to the nature of the terrain and topographical conditions, the rainwater collected from the hills and catchments flow at much higher velocity and gush through the un-trained major drains, before reaching the sea. GVMC receives an average annual rainfall of 1,100 mm.

Geo Spatial Database for Flood Modeling:

The recent advancements in geospatial technologies and tools in conjunction with very high resolution Remote Sensing satellite images, Terrestrial and ground based survey methods like Photogrammetry, LIDAR and DGPS helps in capturing, integrating, modeling large scale very high precision datasets representing all the key inputs. There are many open source softwares are available to process and analyze the data, collected from different tools and different platforms.

The list of open source softwares using for the study start from creating the datasets to till simulation and modeling is given below.

SAGA: SAGA (System for Automated Geoscientific Analyses) is open-source digital image processing software capable of processing satellite images and producing thematic maps in different formats. This software is also capable of generating Digital Elevation Models from contour and other topographical survey data. It supports with several tools for catchment and watershed analysis to determine hydrological characteristics. SAGA also provide tool to calculate overland flow distances to a river or channel network based on raster DEM data sets and channel network information

QGIS: Quantum GIS is an Open Source GIS software supports its functionality for number of raster and vector data formats. This software facilitates importing data captured from Electronic Total Stations, Differential Global Positioning System (DGPS) and Light Detection and Ranging (LIDAR) surveys. It also offers topographic analysis, creation of DEMs, slope, aspect and viewshed maps. It helps to create, visualize, query and analyze all the said four stages of geo spatial data. It also offers georeferencing, overlay analysis, neighborhood operations, geo-processing, and database management tools.

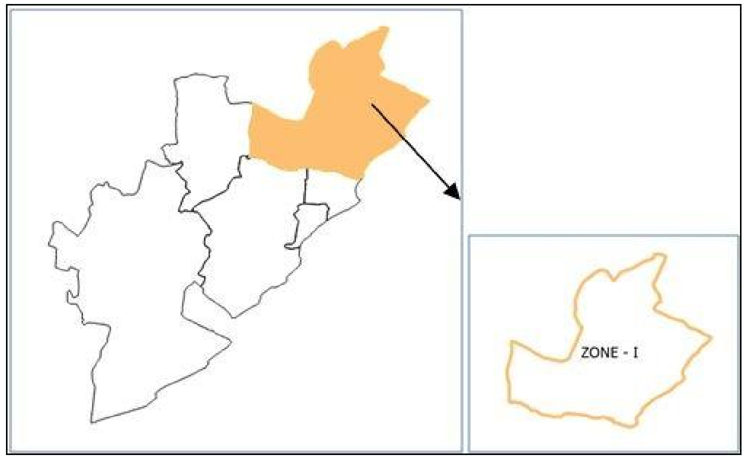

Figure (1): Study area (Zone 1 of GVMC)

EPA SWMM: EPA SWMM is an open source Storm Water Management Model (SWMM) has been widely used and effective in analyzing urban storm water catchments and its components. This model performs simulation of single and continuous rainfall events. Statistical analysis can be performed on long-term precipitation data and on output from continuous simulation. SWMM can be used for assessment of urban runoff problem or proposed abatement options. It also supports dynamic flow routing equations for accurate simulation of backwater, looped connections, surcharging, and pressure flow. The simulated results in the form of database can be linked back to GIS map features to visualize the flood scenarios with reference to geo spatial database

Before, during and after the floods, there are four stages of geo spatial database creation in meeting the objectives of the study for assessment, mitigation and management. These are:

- Geo Spatial database creation for simulation of storm water network
- Geo Spatial database creation for safe and opportunity mapping
- Geo Spatial database creation for social and resource mapping
- Geo Spatial database for Risk and vulnerability mapping

Table 1 shows the essential inputs and the software to process:

SNo	Data	Thematic Layer/map	Layer Type	Softwares can be used
1	Topography, Slope And Aspect	Contour, DEM, Physiography, Slope Aspect, Viewshed	Line, Raster/TIN, Polygon	QGIS, SAGA
2	Climate And Meteorological Data	Rainfall, Rainguage	Polygon, Point	QGIS, SAGA
3	Geology, Soil And Landuse	Geomorphology, Geology, Soil, And Landuse/Landcover	Polygon	QGIS, SAGA
4	Catchments And Sub Catchments At Micro Level	Catchment	Polygon	QGIS, SAGA
5	Storm And Sewerage Network Database	Storm Drain(Natural And Manmade), Sewer Drain, Drain Invert Level, Road Edge, Drain Top, Culverts, Bridges, Lakes And Reservoirs	Line,Point	QGIS, EPA SWMM
6	Buildings And Critical Infrastructure	Buildings, Landmarks(Hospitals, Police Stations, Fire Stations, Primary Health Centres,	Polygon, Point	QGIS
7	Transportation, Utility And Communication Network	Road, Rail, Canal, Electrical Lines, Electrical Sub Stations, Telecom Lines, Telecom Towers,	Line, Point, Polygon	QGIS
8	Inundation Areas	Flood Plain Zoning Map	Polygon	QGIS
9	Administrative Boundaries	Municipal, Village, Ward And Zone	Polygon	QGIS

Table (1): GIS layers and open source software

Work Flow

Figure (2) shows the process flow for creation of Geo Spatial database which consists of Satellite Data processing with DGPS control points, digitization and database generation of base and other important layers for flood modeling and simulation. Figure (3) shows the process flow for importing, simulation, modeling and mapping of flood risk areas for various return periods. Various tasks involved in all the stages of analyzing the flood behavior can be seen in Figure (4) and Figure (5).

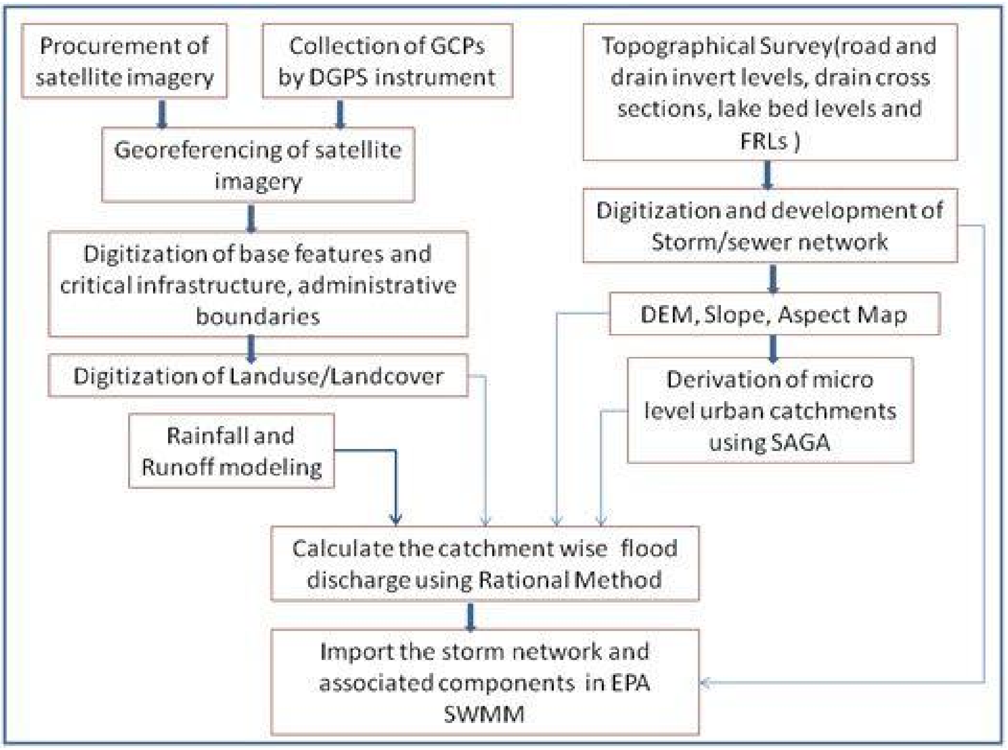

Figure (2):Tasks in Remote Sensing and GIS

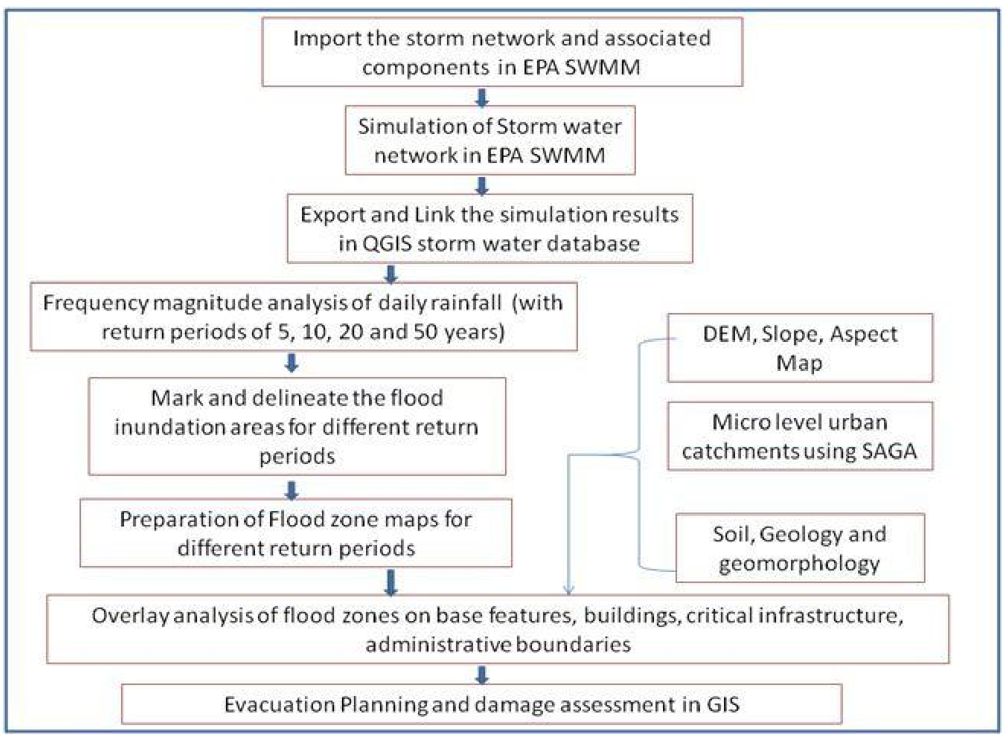

Figure (3): Steps in EPA SWMM, SAGA and GIS for flood modeling

Conclusion

GIS software effectively works as a decision making tool in flood mitigation and management process. It is capable of creating, storing, analyzing and modeling of large quantities of diverse data sets from remote sensing process, climate modeling and hydraulic simulation. Using a combination of open source softwares helps students and academicians in doing research not only in flood mitigation and modeling and also focus on multi disciplinary areas. These tools are robust and flexible and are quite capable to handle large data sets and can perform lot of functions without any additional cost. It is desirable to have an integrated approach that recognizes urban drainage system complexity and inter-connectivity of its elements and parameters such as landuse/landcover, soil, catchment characteristics, slope, natural and man-made drainage system, water supply, sewerage and wastewater, water reuse etc. Presently the study is in geo spatial data development stage and it requires accurate ground surface, surface and sub surface drain elevation data.

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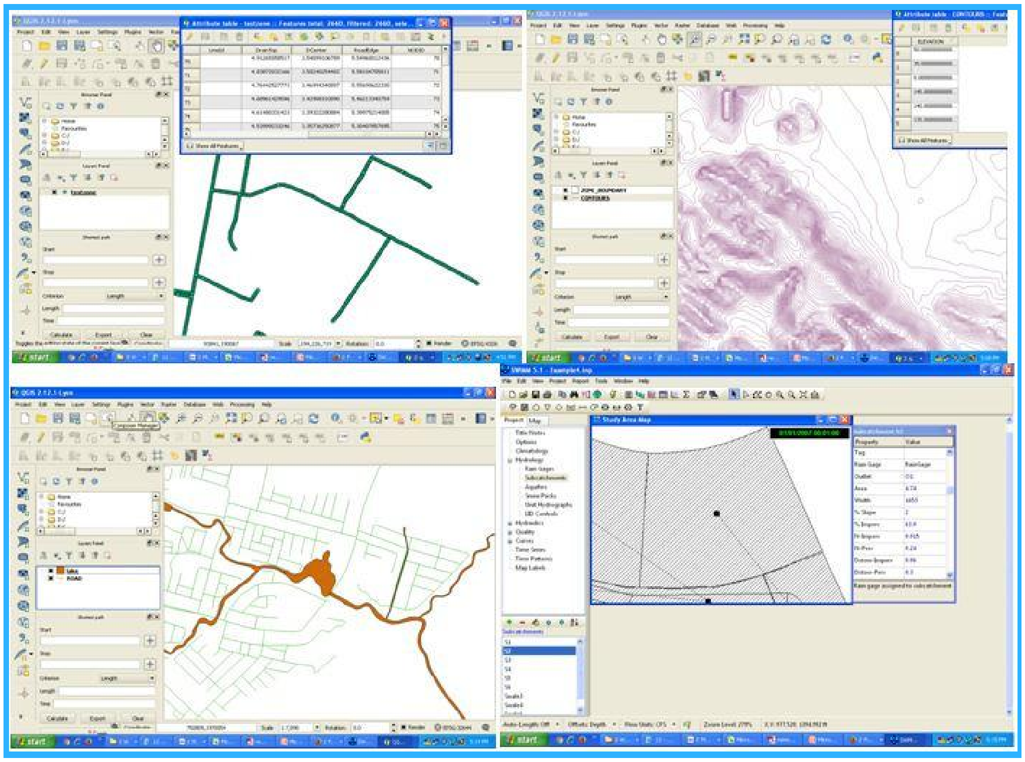

Figure (4): Geo Spatial database in QGIS and in EPA SWMM for Flood Modeling

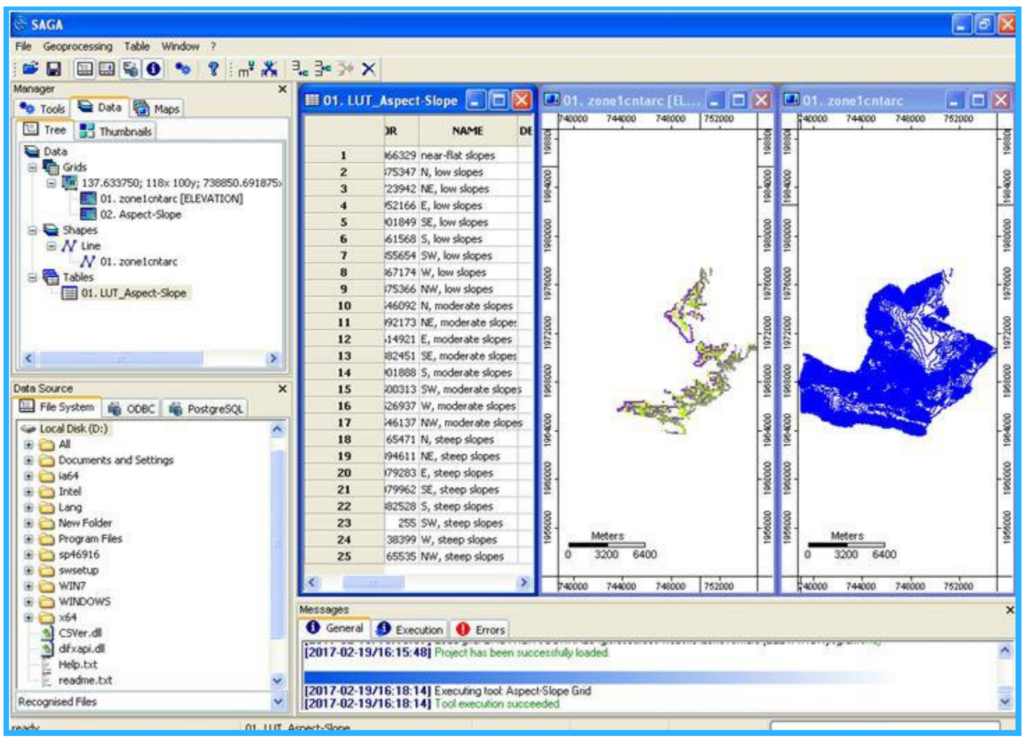

Figure (5): Slope and grid analysis in SAGA

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Application of Remote Sensing and Geographical Information Systems in Flood Mapping Management

Image Courtesy: Walter P Moore

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India is prone to natural calamities and the frequency of these events have been more in the recent years. Floods are one of the most wide spread and destructive natural disasters. It is an overflow of water that submerges land which is usually dry. Heavy rainfall raises the water level. When the water level is higher than the river bank, the water comes out from the river, there will then be flooding.These distributed hazards around the world and their management is an important issue of concern among all the stakeholders. The aim of this review is to collate and compile the state of art literature in the application of Geographical Information Systems (GIS) and Remote Sensing (RS) techniques in all the flood management stages (pre-flood, during flood and post-flood stages).The principal reasons for flood are prevailing natural ecological systems in the country and these are heavy rainfall with temporal and spatial variation, highly silted river systems and inadequate capacity to carry the high flood discharge, inadequate drainage to carry away the rainwater quickly to streams/rivers. Many times typhoons and cyclones also cause floods.Flash floods are caused by steep and highly erodible mountains, particularly in Himalayan ranges. Most of the floods occur during the monsoon period and are usually associated with tropical storms, depressions and active monsoon conditions.

Floods are difficult to control like any other natural disasters, but its impacts can be minimized using state-of-the-art modern technologies in modern computers like modeling& simulation. RS and GIS have particularly been handy in flood management. Using Flood Models combined with RS and GIS, floods can be predicated and flood vulnerability as well as flood risk areas can be mapped out. This flood risk model information is not only important to the policy makers, planners and other authorities but also to the public especially in the affected areas, in terms of providing early warnings, evacuation and general preparedness. Post flood analyses can also be done using RS and GIS .

techniques and in this way an idea in terms of damage to vital installations (energy grids, communications and drinking water),infrastructural damages, economic losses and cost of reconstructions and rehabilitation can be computed.

Flood management involves four stages of prediction, preparation, prevention and mitigation and damage assessment (Konadu and Fosu, 2009). RS and GIS techniques have been reported to be handy in all these stages. With the flood problem expected to escalate due to increasing climate variability and change (Berz et al., 2001; IPCC, 2001; WHO, 2010) and increased land use change (Milly et al., 2002), the ability to provide fast and accurate flood information will be critical in order to minimize flood damages.

Types of Flood

Floods are classified into following types:

Coastal floods: These floods occur when ocean water is pushed inland. Hurricanes and tropical storms can cause large waves and actually raise the sea level, creating storm surge along beaches. Earthquakes can displace large amounts of water and produces tsunami waves which rush to inland and resulted in flooding. On a much smaller scale, extremely high tides associated with a full moon can also cause minor coastal flooding.

Flash floods: It gives the least amount of warning time. They are characterized as a rapid and significant rise in water level due to a sudden and intense heavy rainfall event. These floods occur when rainfall rates are so high that the ground cannot absorb the water quickly enough to prevent significant runoff and are especially common in areas with steep slopes. Flash floods can also occur due to a dam failure. These floods can occur in less than an hour and can destroy structures, down trees and wash out roads with little to no warning time. Although flash floods may not last as long or cover as large of an area as other floods, the sudden onset and strength of the water give them the ability to create devastation in a very short period of time.

River floods: It often occurs on a slower time scale than flash flooding. They are caused when water runoff collects in rivers and streams and eventually reaches levels that overflow the banks. When this occurs, the flood can cover an enormous area and affect downstream areas even if they didn't receive much rain themselves. Although river flooding can be predicted, its effects, even over a longer period of time, can cause extensive damage to residents living near rivers and streams.

Urban floods: These can be caused by flash, river or coastal flooding but most commonly, it is caused by high rainfall rates over developed/ constructed areas that do not have the ability to absorb the water. Urbanization can increase water runoff as much as 2 to 6 times over what would occur on natural terrain. These floods can cause high economic damages to businesses and homes

Areal flooding: These results in standing water in low-lying areas and open fields. They often occur due to heavy rainfall over a larger area in a brief period of time. Additionally, a prolonged period of rainfall can also lead to flooding, often causing dangerous inundation of low lying areas. Agricultural losses can occur with these floods and in addition, stagnant water can serve as a breeding ground for insects and disease.

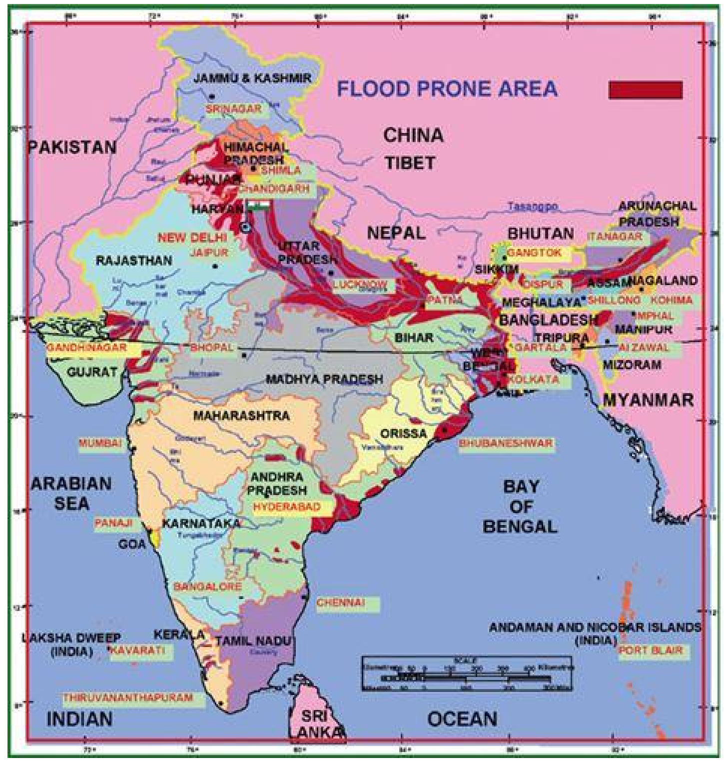

Figure (1): India Flood Prone Area Map
Courtesy: Central Water Commission, India

Concepts of Flood Management

Flood hazard: Flood hazard is defined as the probability of the occurrence of a potentially damaging flood event of a certain magnitude in a given area within a specific period of time (Crichton, 2002; Kron, 2005). Dang et al. (2010) have identified several factors that contribute to the damaging potential of flood hazards. They report that these factors depend on indicators such as flood depth, duration, velocity, impulse (product of water level and velocity) and the rate of the rise of water levels, warning time and the frequency of occurrence.

Flood vulnerability: Vulnerability is certainly one of the most important concepts that have widely been studied in hazard risk management. With reference to flood hazard management, Adelekan (2011) suggests that sound assessment of community vulnerability to floods is required. Flood vulnerability has been defined in several ways in several studies (Alcantara-Ayala, 2002; Pelling, 2003; ISDR, 2004; Barroca et al., 2006), but generally used to refer to conditions that can be physical, social, economic and environmental, that make a given population more susceptible to the impact of flood hazard.

Flood damage: Flood damage is widely accepted as the main indicator for the impact of damaging floods (Pielke and Downton 2000; Munich and Topics, 2005). Dutta et al. (2003) have classified flood related damages as either tangible or intangible. Tangible damages are further divided into direct damages such as agricultural and environmental damages caused by direct contact with flood and indirect tangible damages such as business interruption, impact of floods on regional or national economy. Intangible damages on the other hand include health and psychological losses. It is worth noting that both types can be expressed in monetary terms, for example Huang et al. (2008) computed flood damages in monetary terms having classified property loss due to floods as a direct tangible damage and income loss calculated as the difference in income between the year preceding the flood and the year of the flood, as an indirect tangible damage.

Flood risk: Risk is generally described as the uncertain product of a hazard and its potential loss (Crichton, 2002; Kron, 2005). Flood risk has been defined as a degree of the overall adverse effects of flooding. It incorporates the concepts of threat to life and limb, the difficulty and danger of evacuating people and their possessions during a flood, the potential of damage to the structure and contents of buildings, social interruption, loss of production and damage to public property (Dang et al., 2010). Like other studies (Karim et al., 2005; Kron, 2005; Apel et al., 2009), Dang et al. (2010) defined flood risk as a product of flood hazard and flood vulnerability, equation (1); where flood vulnerability includes exposure:

Flood Risk = Flood hazard * Flood vulnerability------(1)

Essentially this definition shows a direct influence that flood hazard and the level of flood vulnerability have on flood risk, the higher the values of these two, the higher will be the level of flood risk.

Application of RS and GIS in Flood Management

Advancements in the remote sensing technology and the Geographic Information Systems (GIS) help in real time monitoring, early warning and quick damage assessment of flood disasters.Geographic Information System is a tool that can assist floodplain managers in identifying flood prone areas in their community. With a GIS, geographical information is stored in a database that can be queried and graphically displayed for analysis. By overlaying or intersecting different geographical layers, flood prone areas can be identified and targeted for mitigation or stricter floodplain management practices. Remote sensing on the other hand is generally defined as the science of acquiring information about the earth's surface without actually being in physical contact with it. Together with RS and modelling, GIS provide a wide range of applications in agriculture, geology natural disaster management, hydrology, weather monitoring, business and service planning, government, logistics and transportation and environmental management. In this review however, emphasis is put on the role and applications of these techniques in flood management.

Flood simulation using GIS: Early preparations and planning results in effective and efficient response thus minimizing and or mitigating the after flood effects. There has been wide spread development or updating and use of hydrological models with a flood prediction component. These models are in most cases either loosely or tightly coupled with GIS and remotely sensed data (Chormanski et al., 2008).

Most of these models require different types of data input such as LU/ LC (land cover/land use), river discharge rate, rainfall amount, surface roughness, Digital Elevation Models (DEM) and size of drainage basin among others. In this case RS techniques can be used to obtain spatial and temporal information needed for parameterization of the distributed hydrological models (Chormanski et al., 2008). GIS tools on the other hand provide storage, analytical and data presentation capabilities. Integrating GIS with hydrological models (Figure 2) according to De Roo et al. (2000) provides an ideal environment for modelling processes in a landscape.

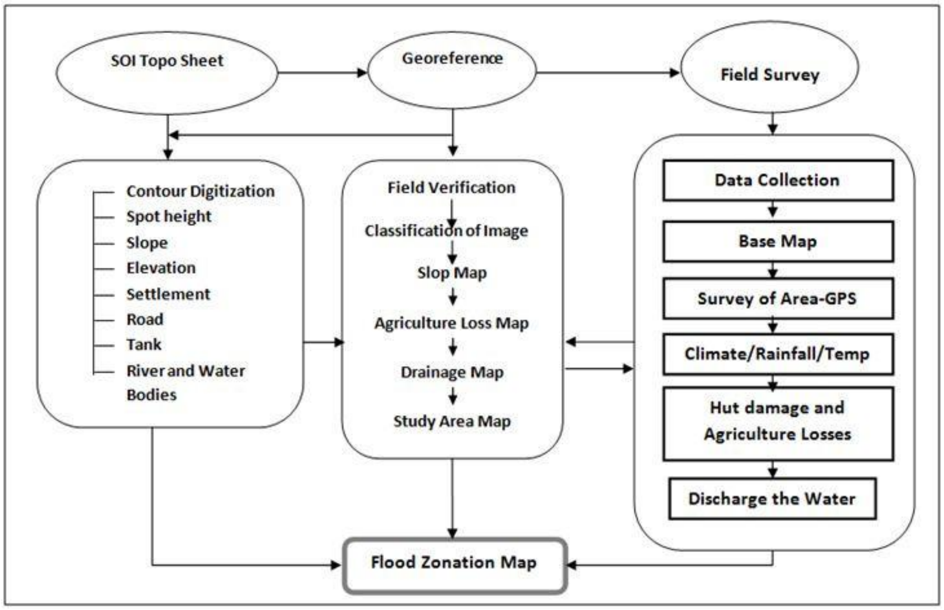

Figure (2): Integration of hydrologic model outputs and GIS info-layers for preparing flood-risk maps

RESEARCH

A vector based GIS and DEM in order to delineate watershed boundaries and predict areas of possible inundation during a flood event. The digital contours can be generated from the topographic map which can be utilized for DEM generation. The generated DEM provides the terrain representation and information in terms of the direction in which water that enters into an area will flow. GIS tools are embedded in the hydrological models to facilitate in data analysis, querying and presentation of information in a more simplified way, thus they form critical part of the distributed hydrological models used for flood prediction. Figure 3 provide a summary of how GIS and RS respectively can be used in flood management.

Flood Database Creation and Design

Database design involves major database elements, naming convention, attributes schema, data model, datum /projection, coordinate precision and the tolerances.

Multi-layer GIS database for the study Area are created using Satellite Image data, topographic data, census data, field observations etc. and organized properly for efficient query, analysis and retrieval.GIS database creation mainly involves data collection, mapping, digitization, GIS error handling, attaching attributes data and making GIS data usable.

Thematic layer	Land Use, Drainage System, Water Bodies
Administrative layer	District Boundary, Taluka Boundary, Village Boundary, Land Parcel, Watershed Boundary
Topographic	Road, Railway , Digital Elevation Model, River, Canal, Drainage
Facilities	Relief Centers, Schools, Temples, Anganwadis, Bus Station, Health Centers, Panchayat, Mosque etc

Table (1): Flood database thematic layers

Flood Hazard, Vulnerability and Flood Risk Mapping

Mapping of flood risk areas is not only important for the location of these areas but also for government, Non-governmental Organizations (NGO's) and other planners to get an idea of where priority should be given when allocating resources. Evacuation exercises, insurance companies as well as relief providers also require knowledge of spatial extent of inundated areas (Brivio et al., 2002). This could be information about roads that may or may not be passable, worst affected areas and areas suitable for camping during flood periods. RS and GIS have yet proved resourceful in this stage of flood management. For example Konadu and Fosu (2009) having predicted areas of potential flood risk, were able to utilize the overlaying function of a GIS to combine land cover maps with the flood-predicted zones. The resultant maps provided simplified information on the flood hazard (depth, velocity, direction of flow), elements at risk, their exposure and vulnerability. In addition, flood hazard, vulnerability and risk maps were drawn showing areas at low or high flood risk.

Flood Prevention and Mitigation

RS and GIS techniques have been resourceful in flood prevention and mitigation. GIS and modeling approaches in particular have been used in investigating the possible effects of land use changes in flood generation. In a number of studies (Liu et al., 2005; Chormanski et al., 2008) land use scenarios have been hypothesized and possible impacts of these scenarios in the generation of runoffs and consequently flooding have been investigated. This information can be useful in developing policy guidelines and recommendations for urban planning, land use planning as well as settlements and types of buildings. In this way, flood impacts can be prevented or even mitigated.Results from the model simulation indicated urbanization land use to be associated with large negative impacts in terms of increasing peak discharge, flood volume and time to the peak. Deforestation as well was reported to be associated with negative impacts while afforestation land use gave moderate positive impacts in terms flood generation prevention.

Flood Damage Assessment

Knowledge of damage inflicted by flood is required by the authorities and Insurance companies in order to effect compensation as well as to have an estimate of the cost of reconstruction. GIS has a function of overlaying layers and through this function, layers on inundated areas can be over laid with land use maps, land cover layers, infrastructure layers among others. RS in this case is a very valuable tool to obtain images before, during and after flooding (Townsend and Walsh, 1998). These images are there after processed and analyzed in order to obtain information of the land cover, buildings, roads, schools and other infrastructures of the area under normal hydrological conditions (before flooding), inundated areas and flood extent (during flooding) and flood effects, deposits and debris (after flooding). When the comparison of these images together with pre-flood data is carried out, the extent of flood damage can be estimated.

Conclusions

Satellite Remote Sensing and GIS techniques have emerged as a powerful tool to deal with various aspects of flood management. Remote sensing and GIS are used operationally for early warning and decision support systems for authorities during disaster. Monitoring of cyclones, tsunami, Heavy rain fall, storm surge are often results in flood which creates loss of property & human life. It is required to appropriately choose RS data with required spatial and temporal resolution for information extraction and integrating it with field survey data using GIS framework. Flood management is a three phase procedure that includes pre-flood, during flood and post-flood activities.

These three phases can further be subdivided into flood prediction, flood prevention and mitigation, flood risk identification and mapping and flood damage assessment. The lesson we learn from here is that flood management is very diverse and it requires multidisciplinary involvement. As an example flood prediction, mapping and damage assessment require disciplines of hydrology, soil science and geography. Flood prevention, mitigation and flood damage assessment require efforts from government, insurance companies, professionals and above all the general public.

However all these different stake holders need to start from somewhere, they need data and information in order to answer questions like where will the hazard occur? When is the flood likely to occur? What extent will it be? Who will be affected among other questions? Fortunately, the preceding discussion in this review has explored how advancements in RS and GIS techniques coupled with computer modeling have been handy in answering most of these questions. It can be deduced that application of these techniques are critical in all the various stages of flood management that include prediction, prevention, mitigation, flood risk identification and flood damage assessment.

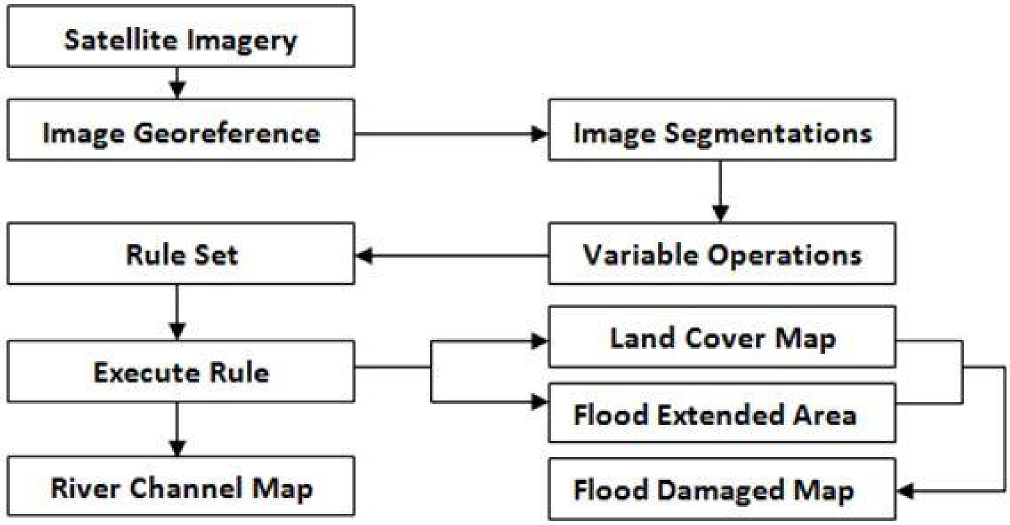

Figure (3): Flowchart showing steps on how RS data can be processed for use in flood damage assessment (Source: Uddin and Shrestha, 2011)

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(N.B.-This paper is a compilation of research works taken from various publications on the subject, and is compiled in an easier way for the readers understanding)

RESEARCH

Training and Capacity-Building in LiDAR : Enabling Multiplier Effect Across the Philippines

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A few days after the Davao bombing in Southern Philippines, the Phil-LiDAR 1 Team pushed through with the Mindanao Cluster Conference held in Davao early September 2016, to strengthen collaboration between the Davao City Disaster Risk Reduction Management Office (CDRRMO) and Phil-LiDAR 1 Program partner university, University of the Philippines Mindanao. A Memorandum of Commitment (MOC) was signed by the local government of Davao and UP Mindanao for the latter to provide LiDAR-based information to the Davao City local government as well as other relevant stakeholders. This includes a basic orientation and map appreciation on the flood hazard maps distributed and the brief seminar on how to use the portal called LiPAD where LiDAR data can be downloaded through the use of the internet. UP Mindanao shall give technical assistance for the Davao CDRRMO personnel to fully understand and utilize the flood hazard maps with the knowledge on the amount of rainfall from the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA). These flood hazard maps are highly useful in providing early warning to civilians in areas with flood risk.

As part of its role in Phil-LIDAR 1, the Training Component of the Disaster Risk Exposure and Assessment for Mitigation (DREAM)/ Phil-LiDAR 1 Program organizes meetings with local government stakeholders and regional partners in the academe for information dissemination regarding Light Detection and Ranging (LiDAR)-based flood hazard maps.

The Program, based in the University of the Philippines Diliman, focuses on the generation, validation, and processing of LiDAR data followed by the flood modeling and the production of flood hazard maps of flood plains in the Philippines. The fruit of these processes are the flood hazard maps that are central to the external trainings, seminars, and orientations conducted by the Phil-LiDAR 1 Program Training Component. With changes in climate and the environment increasingly felt through heavy flooding especially in urban areas, the local demand and interest for up-to-date, reliable, and versatile LiDAR technology outputs has remarkably gone up. Localities welcome initiatives to propagate the beneficial use of LiDAR for disaster risk reduction, and even natural resource management as part of its other applications. Provincial, City, and Municipal Disaster Risk Reduction and Management (DRRM) Offices are most willing to work hand-in-hand with the Phil-LiDAR 1 Program in combating the worst effects of disasters to citizens.

Different regions across the Philippines have become recipients of the useful flood hazard maps - cities and municipalities in Region 2 in the northern Philippines,Region 8 in

Central Philippines, and Region 11 (Davao Region) in Southern Philippines, among others, have received flood hazard maps and are using these to save lives especially with the typhoon season battering provinces in the Philippines with strong winds, heavy rainfall, flashfloods, and landslides beginning a few months ago.

"Information, Education, and Communication Campaigns (IEECs) are necessary for capacity-building of local stakeholders and other national government agencies," says Program Leader of the Phil-LiDAR 1 Program and Project Leader of the Training Component Dr. Enrico C. Paringit. "Our goal is to increase the level of awareness regarding LiDAR-based outputs as well as develop competencies for disaster risk reduction offices to help communities."

A key step in scaling up the capacity was through partnership with a mixture of 14 other universities in the Philippines. The Phil-LiDAR 1 Program shared its knowledge and experience with University of the Philippines Los Banos, Central Luzon State University, University of the Philippines, Baguio, MAPUA Institute of Technology, Ateneo de Naga University, and Isabela State University. In Visayas, the partners are Visayas State University, University of the Philippines, Cebu, and University of San Carlos. In Mindanao, we have Mindanao State University-Iligan Institute of Technology, Central Mindanao University, CARAGA State University, University of the Philippines, Mindanao, and Ateneo de Zamboanga University. This strategy induced a so-called multiplier effect because not only are the universities shared with knowledge and data, but also new and innovative techniques and approaches are subsequently developed through research. These are also the very same institutions that will deliver degree programs, conduct extension to local community. It is expected that these activities will then bring in multifold benefits from the Phil_LIDAR.

Fostering Linkages in the Academe

In the beginning of the Phil-LiDAR 1 Program, a series of technical trainings in data validation, data processing and flood modeling were conducted for the partner universities in the National Engineering Center in the University of the Philippines, Diliman. After the first round of trainings, rounds of supplementary mentoring in the respective universities of the partner institutions were conducted, with members of the UP Diliman data validation, data processing, and flood modeling teams visiting the partner universities for coaching sessions and hands-on workshops, which strengthened the capacities of the partner State Universities and Colleges (SUCs) and Higher Education Institutions (HEIs).

Feedback and evaluation mechanisms highlighted points for improvement that were used to determine any weaknesses in producing quality LiDAR data outputs, thereby allowing for these weaknesses to be targeted accordingly and prioritized in the training process. During the three-year stint of the Phil-LiDAR 1 Program, the partner universities have regularly consulted with UP Diliman as to the different LiDAR processes and workflows, and have leveled up some LiDAR applications, lending credence to the "multiplier effect" that has ensued with the training and mentoring activities.

Now, not only UP Diliman, but 14 other SUCs/HEIs possess the capability to deliver quality LiDAR-based information, across the Philippines that have slowly but surely gained expertise in the field of LiDAR technology.

Learning by doing is the fundamental practice at work, with the LiDAR outputs of each pioneer partner

"Our goal is to increase the level of awareness regarding LiDAR-based outputs as well as develop competencies for disaster risk reduction offices to help communities." - Dr. Enrico C. Paringit

institution being used in their own localities for the benefit of their local governments and community members.

Reaching Out Through Virtual Platforms

To be relevant in this age of globalization and connectivity, the Training Component regularly updates the DREAM Website to keep followers apprised of its current events and news updates.

The website is also used to provide information necessary for disaster management. The Water Level Forecast System (WLFS) found in *https://dream.upd.edu.ph/products/water-level-forecast/* is located in the DREAM Website, now also used as the Phil-LiDAR 1 Website. The WLFS is linked to water level sensors in hundreds of rivers across the Philippines. The water level sensors transmit data on river height that are converted into readable data and charts found in the WLFS webpage. The sensors can detect if the water in the rivers have reached or are near the spilling level on the left and right banks of the river.Automatic real-time updates of water height in the river occur every 10 minutes shown graphically in the WLFS webpage. The updates include realistic 12-hour forecasts depicted in the water level charts, based on the rainfall data and typhoon warning updates of PAGASA. The early warning information placed in the WLFS charts allow the citizens to prepare for accurate flood levels during the next 12 hours and evacuate as necessary. The ample lead time provided by the water level sensors in the uplands are able to give enough warning for residents in the floodplains to know how much water will be rushing down to their localities based on the amount of rainfall in the upland areas.

The popular social media application, Facebook, and text messaging through mobile cellphones are also used as tools to deliver critical information on flooded areas, including the height of the flood by using visual terms e.g. gutter-deep, tire-deep floods, that is more user-friendly. This is as opposed to giving flood heights using numbers in the metric system—for example, civilians would have trouble visualizing how high would be half a metre of flood. As a vital communication method amidst heavy rainfall and typooons, the Urban Flooding Alert System (UFAS) is on its pilot stage for the Metro Manila area. It releases a list of flooded areas and areas to be flooded, to help citizens navigate and know which roads to avoid due to floods. Community members can then be safer and more secure in being informed of areas that are flooded in real time. Local governments can protect their residents better with the effective communication of accurate and relevant disaster risk data. DRRM Offices can focus their resources on which flooded areas need their attention and response as to the dangers posed by the depth of the floodwaters. With more developments in the future, the same system, or improved versions of it are envisioned to be replicated across the Philippines, led by the partner universities. In this way, the multiplier effect is again evident, as highly beneficial practices are echoed and even refined to help save lives of fellow Filipinos.

At present, the Training Component of the Phil-LiDAR 1 Program experiences its own share of challenges —be it financial, manpower, or strategy-wise. Operating on a budget from government funds and within a limited time frame, it is important to be cognizant of priorities and action points that will determine the success of information campaigns and the like. Truly, when we see on the news of LGUs capacitated and enabled to save the lives of its citizens guided by proper LiDAR-based data, it is reward enough. To have contributed to a higher standard of disaster risk reduction gives a sense of fulfillment for the members of the Training Component, in knowing that we played a pivotal role in bringing the Phil-LiDAR 1 Program closer to the local governments resulting in Filipino leadership that can utilize flood hazard maps knowledgeably and effectively for the people.

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Drone Photogrammetry for Flood Preparedness

Image Courtesy: Public Technology

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United States of America

Among natural disasters, flooding presents a substantial threat, with an average of over 100 events occurring every year (Guha-Sapir et al. 2015). According to the CRED/OFDA International Disaster Database, nearly 7,000 human beings are killed and around 100 million affected annually by flood events, with economic costs estimated at 14 billion US dollars (Guha-Sapir et al. 2015). Exact damage to infrastructure, water potability, public services, agriculture and the economy are difficult to quantify, not to mention the negative effect flooding has on society due to loss of human live and hardship inflicted on survivors.

The factors of flooding and flood-risk involve a unique combination of environmental and man-made forces. Some of the most obvious are related to the amount of rainfall, the elevation and shape of terrain, and type and location of existing water bodies in the region. Other contributing factors to flood risk are soil type and permeability; the location and quantity of buildings, infrastructure and man-made tunnels; as well as the type and location of vegetation. Physically at-risk areas notwithstanding, populations are not equally vulnerable to the effects of water disasters. Social, economic, environmental and physical factors affect a system's vulnerability to floods (UNESCO, System).

Those living in flood-prone areas with limited access to weather services, flood management structures or warning systems live in higher danger of being caught defenseless or unprepared by a flood (Begum et al. 2007). Populations exposed to poverty and conflict situations, especially, live in augmented risk due in large part to lack of services or information. High population dense areas also have increased vulnerability to flooding, as well as those who earn a living dependent on favorable environmental conditions, like farmers and agriculturalists (UNESCO, Indices).

Apart from efficient disaster response management, the public and private bodies responsible for flood riskmanagement have the complex task of assessing and mapping flood risk areas in order to implement both preparedness planning and efficient warning systems. Reducing flood damage requires this identification and estimation of potential flood severity and timing, knowledge which is driven and supported by detailed flood models on a global and local scale (Morita 2014). Constructing flood defenses, controlling development in danger zones, planning disaster response action and issuing timely warnings depends on such information (Understanding 2011).

Flood prediction is currently based on a variety of complex behavioral prediction models, which are used by hydrologists and emergency management administration to estimate flood scale, timing and risk for specific areas (WMO 2011). Specialized, tailored models are needed due to variability in topography and interaction of contributing flood factors. In addition to a calibrated model, quality hydrological, meteorological and geological data is essential (Sulebak 2000). Meteorology stations collect data from ground equipment to satellite, adding it to recorded information and creating weather forecasts: the large amount of climate information provided by satellite and remote sensing as well as ground observations is vital to support long and short-term flood prediction models (WMO 2011).

A basic requirement for these prediction models is a Digital Elevation Model (DEM): a 3D topographic map that shows the elevation data, contour lines and slope of an area in digital format (Mioc 2008). These are traditionally obtained via airborne surveys, satellite imagery and LiDAR sensing. Accurate DEMs facilitate reliable flood inundation modeling, as flood model predictions are affected by both DEM scale and resolution (Sulebak 2000)(Aktaruzzaman 2011).

The topography of many floodplains in the developing world has been surveyed with high resolution sensors, providing high quality DEMs of a majority of populated areas. Access to this data is limited, however, due to the costs associated in obtaining and analyzing it, as well as the reluctance of the authorities to release it for either security reasons or the potential impact it could have on property prices and the local economy (Sampson et al. 2016)(Coumans 2016).

For remote areas and spaces in many developing countries, quality terrain data is often obsolete or simply not available (Isma'il 2013). Publicly accessible or free data sets, notably the global digital elevation models provided by the Shuttle Radar Topography Mission (SRTM) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), have a raw data resolution of between one arcsecond (30m) and three arcseconds (90m), which has limitations due to the resolution and present errors (Nikolakopoulos et al. 2006).

For flood assessment and prediction to be as accurate as possible, the DEM must contain a large amount of terrain information and be up-to-date. This means high-resolution, or Ground Surface Distance (GSD) and correctly-scaled data that is current with changes in vegetation, landscape and building development.

Global datasets like SRTM, for example, are nearing 20 years old and risk being outdated, especially in developing countries and areas that have seen drastic change (Sampson et al. 2016). Acquiring this data along with the use of calibrated prediction models has traditionally been expensive and limited, making proper flood analysis and weather prediction limited to highly populated areas in wealthy nations (Sampson et al. 2016).

Drone technology, photogrammetry software, and the development of open-source flood simulation models create new possibilities in remote sensing and management of hazard-prone areas. Easy to operate and globally accessible, drones are now capable of acquiring high-resolution aerial imagery at low cost. Other surveying options to acquire high resolution DSMs, TLS for example, costs two or three times that of a UAV survey (Mancini et al. 2013). This imagery, taken specifically for

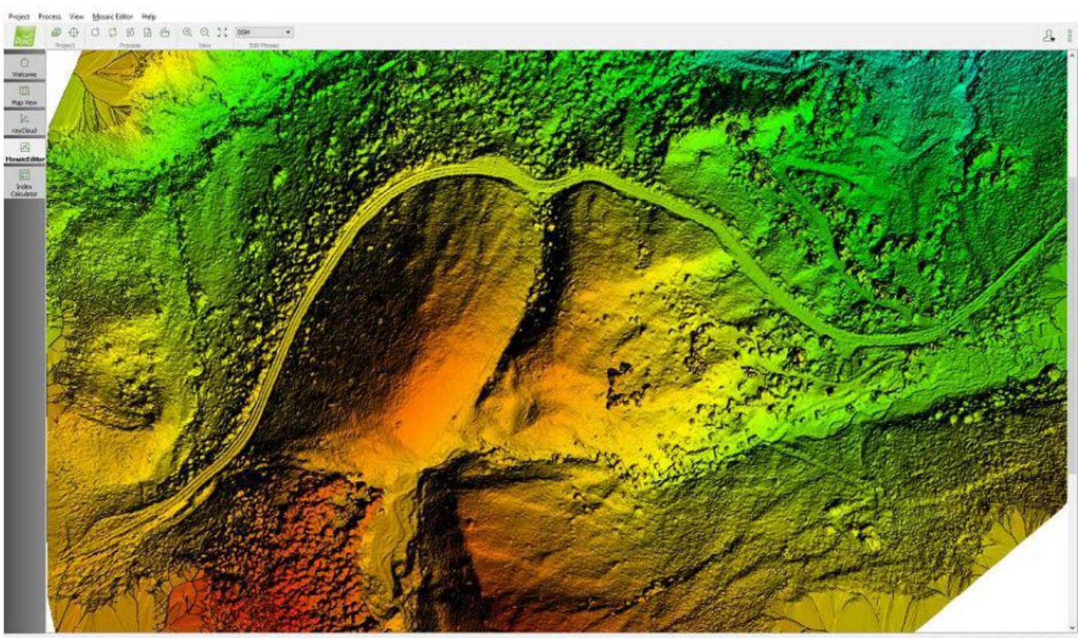

Figure (1). DSM produced in Pix4Dmapper of topography in Venezuela, with color representing elevation differences.

mapping, is used in advanced photogrammetric software to produce topographic maps and models. One such software, Pix4Dmapper, uses computer vision principles to convert overlapping images into precise 3D point clouds and digital surface models (DSMs), with vertical resolution that can reach centimeter-level accuracy. This enables buildings, riverbanks, ditches and vegetation detail to be captured and accounted for in a flow model. Drone imagery is acquired beneath the cloud coverage line, avoiding the need for satellite VHR imagery for generating DEMs.

An example of this use can be found in a research project done by the Disaster Prevention Research Center of Taiwan, who used a UAVER drone, Samsung NX1000 camera and Pix4Dmapper to produce digital surface models of the BaTz river creek. Modeling was done before and after the flood periods between 2012 and 2014, and DSMs were compared over time in order to monitor and further control river stability as seen in Figure 2 (Yen 2015). The drone imagery provided an affordable option for frequent data collection as vegetation coverage varied up to 36 percent. In order to check accuracy, elevation differences of the generated DSMs were compared with surveyed ground points, with an average difference value of 0.08 meters and standard deviation of 0.096 meters; this matches the ground truth data enough to be considered reliable (Yen 2015).

Another particularly useful application of drone-imagery DSMs is for coastal mapping: areas at risk for flooding where the constantly changing coastal geomorphology requires accurate and highly detailed topographic information in order to provide trustworthy flood risk evaluation. Researchers from the University of Bologna, Technical University of Bari and SAL Engineering tested UAV imagery and photogrammetric software in order to produce highly accurate DSMs of a foredune in Ravenna, Italy on the North Adriatic coast. They found the workflow promising and highly automated, giving fast data access with topographic quality and vertical accuracy comparable to GNSS survey data.

These high-resolution maps can then be placed into flood simulators like Terrain Flow, a free and open source modeling system currently being developed by Microsoft, that predict rainfall and water behavior in 3D. TerrainFlow will provide a visualization of water absorption, collection and path using topographic maps as inputs. For those who are unable to invest significant resources in soil testing and customized professional models, TerrainFlow is accessible and offers insight on water and land interaction without requiring specialized training. Users will be able to select variables such as soil type, rainfall intensity and duration, as well as simulate the effect of land modifications (like the building of a pond, channel or trench) and artificial water sources. Requiring only GeoTIFF elevation maps (DEMs) and available public data as inputs, the barrier to entry would be lowered significantly. The 3D simulation will be viewable in real time with adjustable speed and perspective, providing data for a quick understanding of potential flood hazards, improvements in water management, or further investment needs.

The low cost and learning curve of drone technology, Pix4Dmapper and TerrainFlow enable those with little access to high-resolution data or the resources to invest in flood prediction models to gather their own accurate topographical data for regular updates of rapidly changing and high flood-risk areas. Although not capable of replacing traditional remote sensing and flood prediction techniques, this workflow has enormous potential in both providing high quality DSMs and analyzing land and water interaction for disaster preparedness purposes and more: Environmental resources monitoring, Agricultural management, Civil engineering/city planning, Water management, and Insurance purposes.

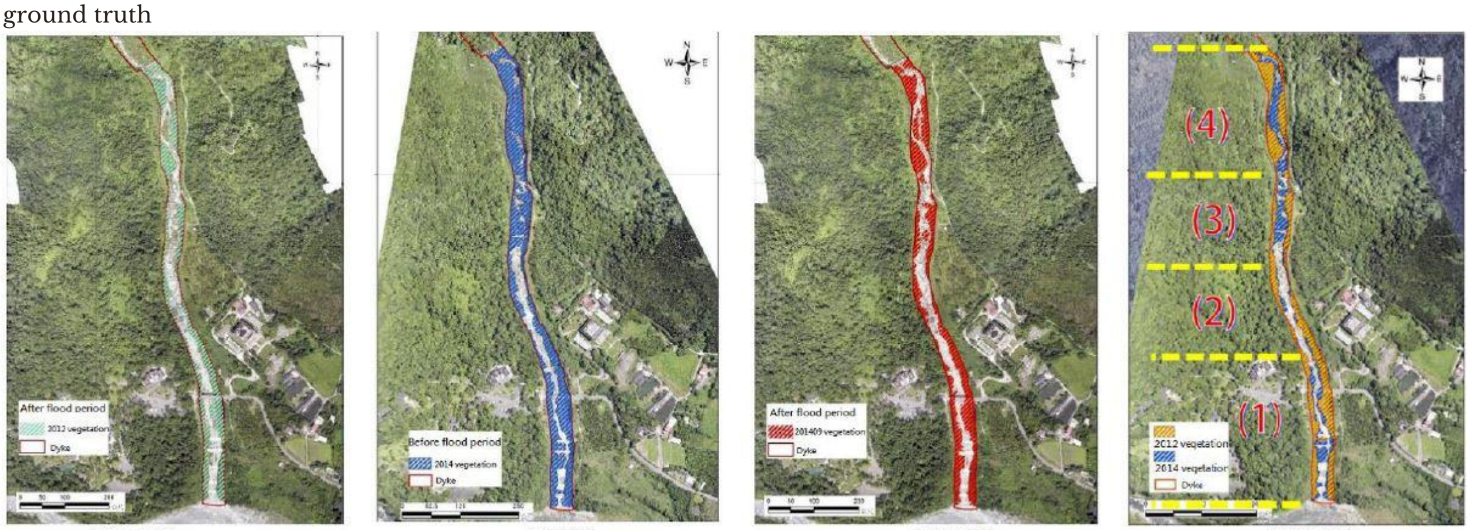

Figure (2). Highlighted orthomosaic data of Ba-Tz River for analysis and monitoring, produced using drone imagery and Pix4Dmapper software.

For future research, local floodplain knowledge gained via this workflow can serve to compliment large scale topographical information from satellite data, and even be integrated together. Small and high resolution predictions could be combined with broader satellite data in databases or complex meteorological simulation models for a more holistic view of water behavior, as well as contribute to long-term information usage. In the future, topographical information, flood behavior patterns and best practices might also increasingly be available online, compatible to industry integration and open to collaboration for better disaster preparedness practices worldwide.

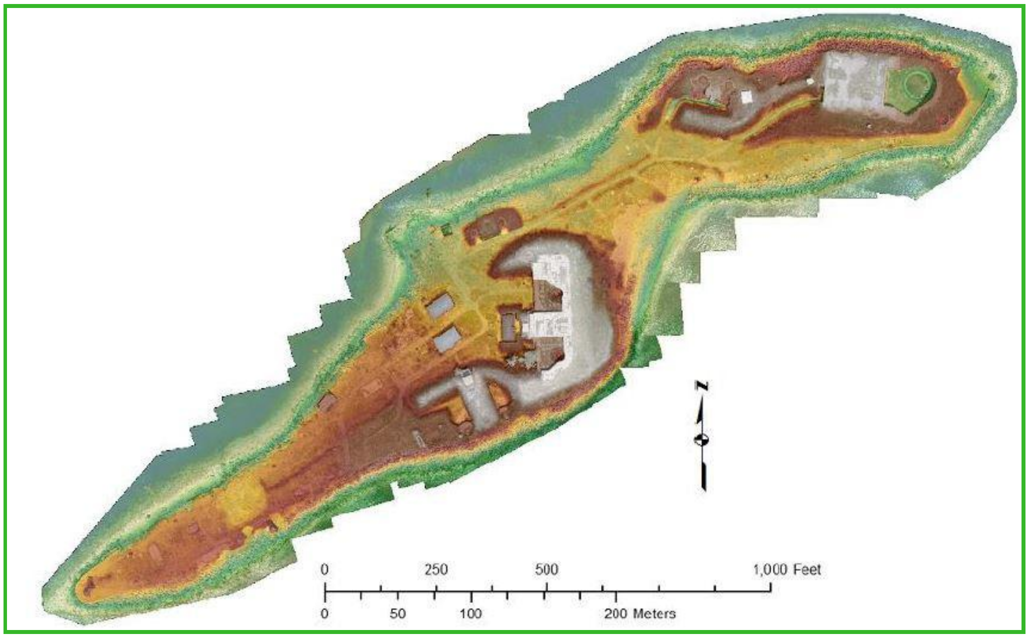

Figure (3). DSM of a small island, produced in Pix4Dmapper using drone-acquired imagery.

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Using SuperGIS to Estimate the Rainfall

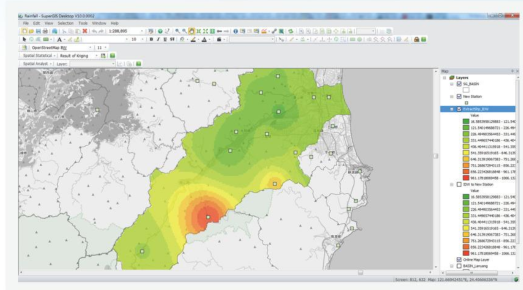
Three Methods

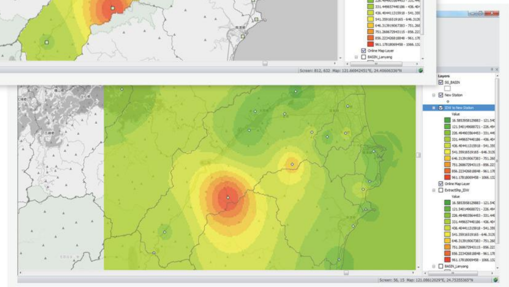
To understand the characteristics of flood thoroughly or to build a flood prediction model accurately, it is important to know the total precipitation in a certain area first. In this article, we show you how to use SuperGIS Desktop and its extensions to achieve this goal. We select three commonly used methods: **Inverse Distance Weighting, Kriging,** and **Thiessen Polygons.** And for the study area, we choose the watershed of Lanyang River in Taiwan because the weather observation stations distribute more evenly in this region. The date is August 8th, 2015, during the landfall of Typhoon Soudelor.

Inverse Distance Weighting

The first is a method called Inverse Distance Weighting (IDW). It is a popular method to estimate the unknown cell values with a set of known points. The values to unknown cells are estimated with a inverse distance function from the neighboring known values. Since the function is an inverse distance function, a closer neighboring point has more influence than a farther one, and contrarily, the farther one has less.

SuperGIS Spatial Analyst supports IDW interpolation. Other than the settings for output, when we run this analysis, there is an important parameter have to be set- the power K. It is an exponent that determines the degree of local influence. The higher the power, the stronger the influence.



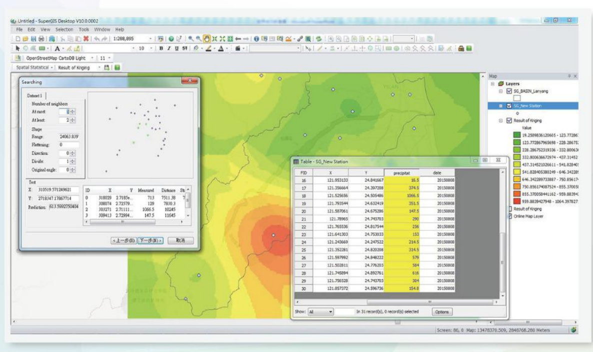


Estimating the rainfall in the watershed of Lanyang River with IDW (Aug. 8th, 2015)

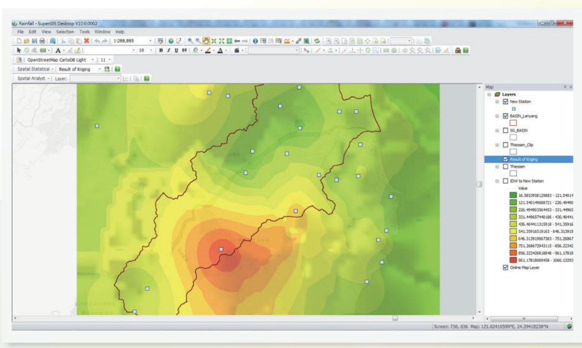
Kriging

Instead of using a deterministic rule like other interpolation methods, Kriging is a method predicts unknown cell values with statistical models. Before conducting it, users should examine the data with a **semivariogram** to decide the statistical model. The semivariogram is tool to display the differences in distance and value between two sample points. Usually, the pattern will follow the general principle of geography, which is the difference in value will smaller when the distance is closer. After examining the pattern, users should select a model that fits the data, including Spherical, Exponential, Gaussian, Circular, Linear, and more.

In SuperGIS Desktop 10, users could run Kriging with the extension of Spatial Statistical Analyst, which offers various options for users to make a better estimation. Except for the statistical model, users could also adjust settings like direction, nugget, sill, range, etc. to fit the data.



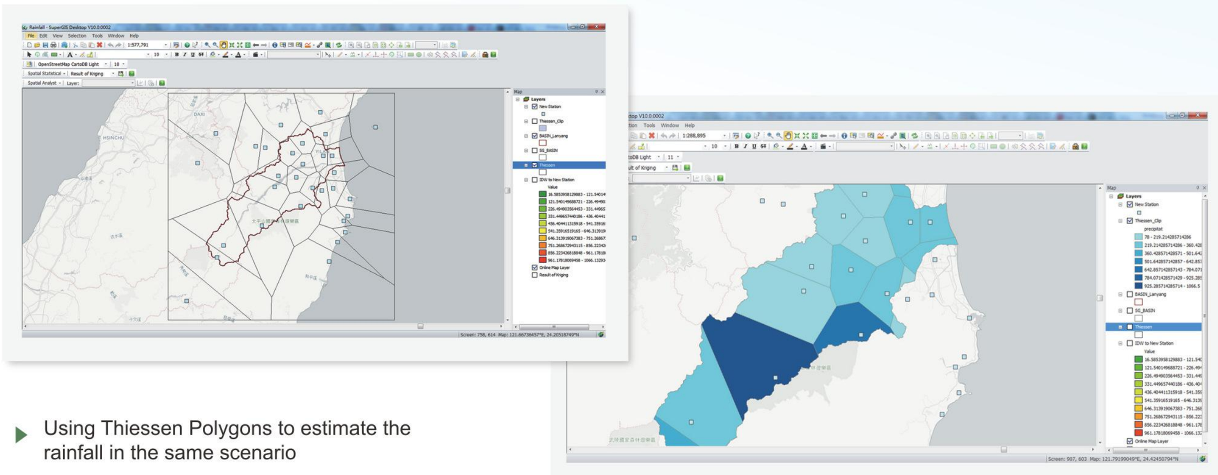
Using Kriging to estimate the rainfall in the same scenario



Thiessen Polygons

Thiessen polygons (also called Voronoi diagram) are a simple but powerful method to understand spatial relationships. This method will generate a series of polygons from point data, and each polygons will contain only one point. From any location within the polygon, it is closer to the polygon's point than to other polygons' point. Each Thiessen polygon will have the attributes of that point. Therefore, when using this method to estimate the rainfall, it assumes that any location within the polygon has the same rainfall as the weather observation station, making it an intuitive and efficient tool for estimation.

In SuperGIS Desktop 10, users can create Thiessen polygons by the extension- Spatial Analyst and use geoprocessing tools like intersect or clip to finish the calculation.



Using Thiessen Polygons to estimate the rainfall in the same scenario

Quick Summary

This article briefly introduces three popular interpolation methods for rainfall estimation and how to use **SuperGIS** products to conduct them. Each method has its pros and cons. It is clear that Kriging and IDW can do the estimation in a more precise and realistic way while Thiessen Polygons have speed.
Also, when using IDW or Kriging, users are suggested to know more about the characteristics of the rainfall to decide parameters like the power or the statistical model more accurately.

Why SuperGIS?

Developing SuperGIS series independently for over a decade, Supergeo now provides **complete GIS products** from Mobile GIS and Desktop GIS to Server GIS, which can help users from collecting raw data to sharing it online seamlessly. Winning international geospatial awards for 7 times and having users from over 100 countries, the quality and reliability of SuperGIS has been tested and validated over time. Since Supergeo believes the geospatial insight is powerful and should be accessible to everyone, in the future Supergeo will continuously dedicate to developing more **practical, professional,** and **affordable** GIS products.

For more information about three estimation methods, SuperGIS products, or suggestions, please contact us by **staff@supergeo.com.tw**

High Altitude – High Volume – High Quality:

The UltraCam Condor from Vexcel Imaging

Jerry Skaw
Sales Director North America
VEXCEL IMAGING

The UltraCam Condor is the most recent offering in Vexcel Imaging's suite of high-performance UltraCam digital aerial systems. Released in April 2016, the Condor addresses a very specific application: high altitude ortho image generation with exceptional image quality. Producing a camera system that meets all the requirements of high altitude ortho production presented several complex challenges in the design of the lens system, the electronics and the storage system, as well as significant investment in the UltraMap processing software to handle necessary radiometric corrections and eliminate artifacts. The UltraCam Condor is positioned to redefine the efficiency/quality ratio in large area/nationwide collection efforts and transform user expectations for project timelines and refresh cycles.

Meeting the Technical Challenges

To reach its goal of manufacturing the best high altitude ortho image system on the market today, Vexcel Imaging started the development process with a set of requirements that the UltraCam Condor must address.

First, a larger footprint size was desirable to increase the volume of data collected. Given the extraordinary footprint size across the flight strip, a higher flight altitude was required to minimize lean at the edges of images and maintain full usability of the image footprint. The higher flight altitude created several challenges that needed to be resolved to ensure outstanding image quality.

Second, to provide additional flying efficiency and flexibility, the camera needed to be functional in turboprops and jets. The higher flight speed of jets requires a faster frame rate to capture the desired resolution with adequate forward overlap for DSM/DTM generation. The UltraCam Condor lens system has been designed so that RGB, NIR and PAN data is collected simultaneously and all are exposed at the same fast frame rate.

Third, the system had to collect and store uncompressed raw data possessing a wide image dynamic range and high signal-to-noise ratio, so that the color shifts attributable to the atmosphere could be corrected without generating artifacts. The custom CCDs used in the UltraCam Condor, with a signal-to-noise ratio of >72dB, are key to the excellent image quality.

And last but not least, the camera had to fit into the existing environment of mounts and airplanes to minimize upfront costs to users.

Building on Existing Technology in Innovative Ways

The underlying technology of digital aerial camera systems has rapidly evolved since the introduction of the first UltraCam aerial platform, the UltraCamD, in 2003. Remarkable advances in electronics, storage, software, and lenses have revolutionized data collection by improving the quantity and quality of the imagery, and the efficiency and ease of use of the entire series of UltraCam products.

The UltraCam Condor is based on the 3rd generation UltraCam architecture, made available to the public in the UltraCam Eagle in 2011, featuring a modular housing with integrated SSD storage, exchangeable lenses, improved CCDs, low noise electronics, an integrated flight management and georeferencing system, and an ultra-large footprint. The UltraCam Condor also leverages the technology and operational experience gained during the Microsoft Bing Maps Global Ortho Program, during which an unprecedented 10.5 million km2 were collected at 30cm and 15cm resolution in less than two years. This 2010–2012 imagery of Western Europe and the contiguous United States provided a continuous and consistent coverage acquired by ten UltraCam Giant (UCG) cameras. Although the UCG was exclusively developed and operated by Microsoft for its Global Ortho project and not sold commercially, the lessons learned provided an excellent basis with which to meet future product development challenges.

The basic idea of the UltraCam Condor design uses multiple detector arrays (CCD sensor arrays) and multiple optical systems of different lengths to build one large-format camera system. Due to the compact size of this design, the camera can be operated with a standard mount and single-hole aircraft.

The output of the camera is a single rectangular panchromatic image of 13,280 x 9,000 pixels at a smaller scale, which serves as the photogrammetric backbone to enable automated aero-triangulation (AAT). A set of smaller color images are stitched together by software and co-registered onto the panchromatic image. The color images together form a rectangular footprint on the ground with a very large cross-track dimension of 38,000 pixels and a

smaller long-track dimension of 5,000 pixels. The panchromatic image is enhanced by the large format color image in such a way that parts of the footprint of the panchromatic system are superimposed by the higher resolution RGB image to improve manual measurements.

The basic photogrammetric information can be derived from the panchromatic image via multiple huge forward overlaps (85%), which support robust automated dense-matching and DSM/DTM generation and make additional LiDAR data collection obsolete. This capability ensures utmost data consistency between the elevation and image data. The color (RGB) images are collected with a smaller forward overlap (20%) and cover the entire terrain along the flight path without gaps. An additional camera head is used to capture NIR images, and the NIR channel is co-registered onto the panchromatic images as well. The 80% overlap of the NIR channel further supports classification.

In addition to the hardware and electronics improvements incorporated into the UltraCam Condor, significant changes were made in the UltraMap processing software to better accommodate high altitude data. The highly automated workflow eliminates artifacts and performs all the radiometric corrections necessary. This was an especially crucial endeavor for the team, as the color shifts attributed to high altitude and changing atmospheric conditions needed to be modeled precisely in the UltraMap software, thus allowing the software to correct the color shifts without generating artifacts.

In addition to developing the software algorithms, it was essential that the team design the UltraCam Condor with the ability to store uncompressed raw images that maintain full color information of all color channels. This enables the user to apply color corrections as necessary.

Long Term Value to Geospatial Professionals and the Public

The UltraCam Condor provides the ability to capture digital data for the production of ortho images over large geographic areas in a fraction of the time it takes with smaller cameras. For example, a 1° by 1° area at 45 ° Latitude (e.g., Minneapolis, 8,700 km2) can be covered by 10 flight lines in four or five hours. These base maps are used by commercial businesses and government organizations for a multitude of applications, including public safety, planning, emergency response, construction, transportation, oil and gas and real estate.

The cost of acquiring large area coverage with frequent updates has a long-standing problem for public and private entities with limited budgets. Costs associated with collecting statewide/nationwide data should decrease as a result of the UltraCam Condor's larger footprint and faster flying times. At lower cost, there is also the potential for more frequent updates. Benefits of up-to-date imagery include improved situational awareness for first responders and more accurate change detection for applications such as environmental analysis and crop monitoring.

Customer expectations change as technology changes. This camera collects data for wide-area mapping faster than smaller cameras, so the marketplace will create a new benchmark for how long a project should take and how much a project should cost. While higher altitude cameras for ortho image collections are not new, the existing cameras suffer from significant issues. The UltraCam Condor is redefining the efficiency / quality ratio in this segment. High quality nationwide capture is attainable, as demonstrated in the Bing Maps Global Ortho Program.
The current 3rd generation UltraCam architecture will be used as a platform and further developed in future UltraCam products. The software algorithms developed for the UltraCam Condor, primarily de-hazing and improved color balancing, are now included in the UltraMap suite and other sensors will benefit from the same processes. Digital aerial mapping has seen tremendous growth and progress in the past 13 years, and the technological innovation is not likely to stop anytime soon.

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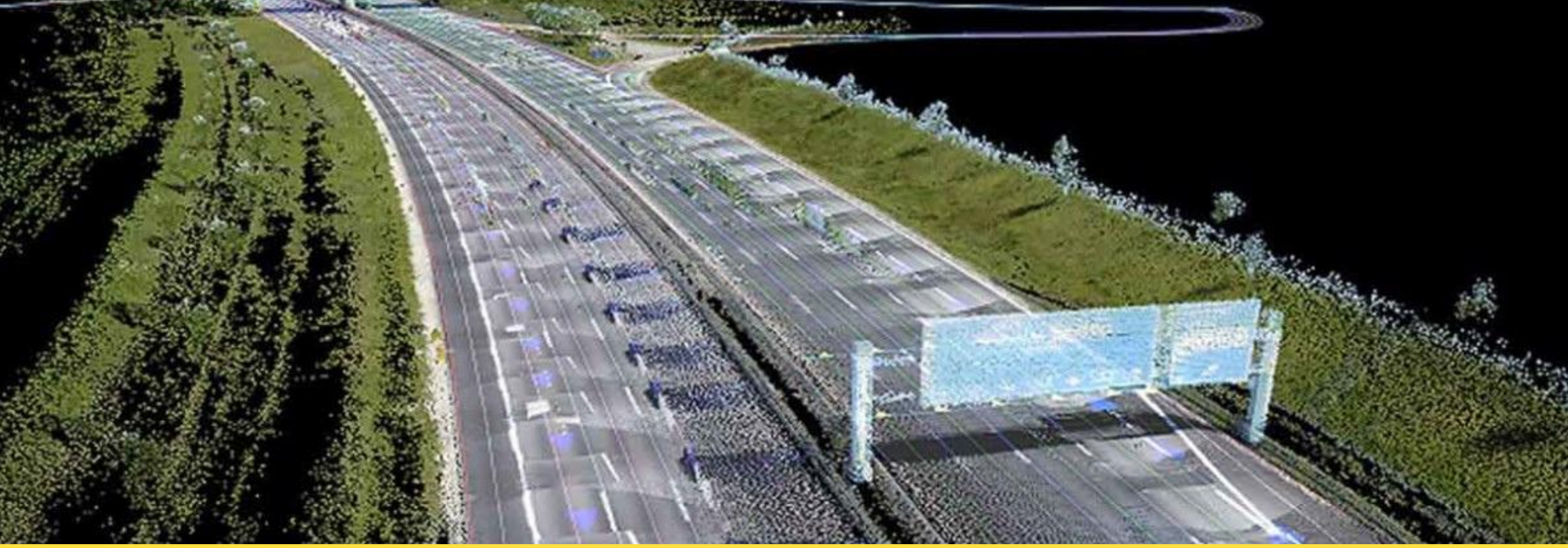

LiDAR Technology in India: Opportunities, Challenges, and Approach

Image Courtesy: Mercedes-Benz

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India

Needless to say LiDAR is one of the technology which makes its presence larger in geospatial world in short span of time. A Robust technology that capture coordinates with high speed in short span of time with greater accuracy as compared with other traditional method. Gradually Indian domestic market is accepting this fact and adopting this technology in various infrastructure based project, disaster management and others. However if we compare the acceptance of this technology in India with reference to other developed countries the result may surprise us as its penetration in domestic market is slow due to various factors like cost, time, policies, understanding of technology etc. In next section these factors were analyzed in details to understand the facts about its usage and level of acceptance in Indian domestic market.

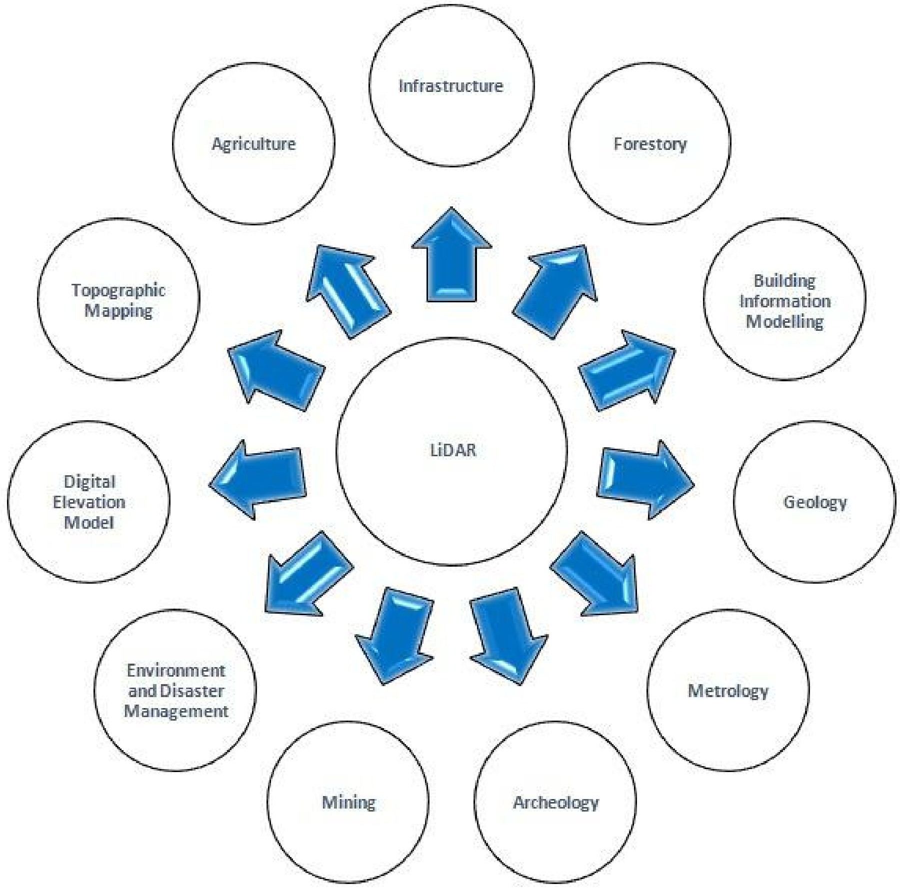
Introduction

LiDAR as a technology was used in scientific investigation however its commercial usage and acceptance in geospatial market advanced slowly. One of the major reason was the lack of technology for further computation and analysis of LiDARdata in terms of accuracy. In recent past, this technology emerges as a boon for the geospatial industry where it's widespread application was recognized globally. With evidence of the fact it is now established as a technology having a potential of collecting high-accuracy elevation data in short span of time in low operational cost. With the advancement of the laser scanner of different make and technology for further computation for extraction of required output, the technology has made its presence in various sectors. Having ease of capturing elevation data with high accuracy due to customization of sensors platform (Aerial, Terrestrial, Mobile) nowadays this technology is being commercially accepted and adopted based on its usage and application.

Usage of LiDAR

LiDAR data can be used in projects where analysis of earth surface, shape and features are involved. This means in topographical mapping LiDAR data can be used to extract features, preparation of Contour Map, slope and aspect analysis, flood inundation, understanding the line of sight forestry, disaster management etc.

With advancement in LiDAR scanner of different make nowadays LiDAR point cloud data is being captured with high-quality digital photographs which in turns is being used in its colorization. Colorized point cloud data represents a virtual reality of actual ground scenario on the desktop. Currently, tripod based terrestrial lidar scanner is being utilized to capture details in building facades. A true representation of the current building condition can be used as the basis for it digital restoration for future reference in producing a prototype. The usage is not limited to the building information system from exterior, tripod based scanner is also being used to capture point clouds of the actual interior condition of the buildings or archaeological properties to understand the internal structure. There are several results which can be drawn after scanning the interior or exterior portion of the building based on requirements.



Current Market Approach

Technology innovation and having capability of developing wide range of geospatial products is what every organization is looking for. However strategy to make them effective varies from Organization to Organization. There are few organization who first develop their expertise, invest in new technology, synthesize the wide range of products and then come into market for business development with innovative ideas. On the other hand there are various organization who applies various strategy to get a project first and then think of investment in terms of skilled work force, equipment's expertise etc. Above mentioned two approach is common in geospatial market. First approach led towards a positive path and can make revolution in the Geospatial Industry, whereas second approach cannot be a good option for any of the organization having long term planning towards a successful path.

Expertise in LiDAR

When we think about expertise it does not mean how many numbers of aircraft or number of LiDAR scanner an organization is having. Having technology is not enough until and unless we have the skilled driving force who will actually execute the same on the ground. Capturing LiDAR data and interpretation of the same to produce a required deliverable is one of the major challenges. Understanding the terrain and placing a tripod based scanner to capture data and seamless integration of the same to produce contour sounds easy and can be done in less time as compared with other traditional methods. However, it will be possible only when a surveyor can understand the idiocracy of field pattern, nature and range of laser scanner, its limitation, undulated topography and finally the required output. Currently, as a practice role of a surveyor is limited up to the capturing of data only whereas data processing and preparation of deliverable is being done by someone else. This is one of the major gap areas which creates a disconnect between what is required after survey and what is being delivered to work for. Unavailability of the skilled workforce who can understand the complete life cycle of a LiDAR-based project from laser data acquisition till preparation of deliverable creates a major challenge. Out of three different platforms of LiDAR (Tripod, Mobile Van & Aircraft), two of them can be seen in Indian domestic market i.e Tripod based terrestrial LiDAR scanner and Van based Mobile LiDAR scanner. The third platform has a dependency on foreign-based mapping agencies and limited utilization till government based project only.Since past few years, Indian domestic market has witnessed the availability of two common platforms of LiDAR scanner and project based on the same. However, the establishment of the LiDAR technology in terms of expertise, where major dependency lies on the data capturing and producing deliverable based on that has not been quantified. Understanding of the usage of LiDAR point cloud data is not percolated in the government sectors who is having major responsibility of infrastructure based project where this can be utilized in several ways.

Good Practice Vs Bad Practice

As a good practice LiDAR must be used in the project where in real means project demands for that. Although it utilizes less time to have point cloud data for larger area with Panorama for colorization of the same as compared with the traditional method of surveying. However, the operational cost is high. This technology is cost effective only when point cloud data has complete utilization in producing various deliverable or when there is a requirement of seamless data having accuracy.

As a bad practice having a LiDAR-based scanner is being utilized as a match winning criteria for various

OUTLOOK

government based projects. The commitment of error free and high accuracy data using LiDAR is common phrase word which is being welcomed. It is to be noted that producing high-quality deliverable using LiDAR is possible however commitment of accuracy for entire project area irrespective of nature of work, deliverable, terrain, skilled workforce is impossible. Having a lack of understanding about the usage of LiDAR on either side make the result with no meaning after execution of the project. This results in no go practice where implementing agencies restrain themselves from adopting this technology further.

Policy and Law

In terms of Geospatial industry, India is a country with policy without having law or law without policy. The government is trying to adopt new technology and also having an aforesaid policy but there is a lack of supportive law to accomplish the mission. Capturing LiDAR data using tripod based LiDAR, Mobile van LiDAR, or aerial LiDAR is a challenge as planner and decision-makers in the domestic market have no idea whether they will get required administrative permission to accomplish the task. Obtaining permission from authority to get flying permission is a challenge due to lack of clarity about the required formalities. Here it is to be noted that our policy makers came across with a long time to understand that In India managing environment and disaster requires a law and then Environmental Protection act came into existence in 1986. Even after the Environment Protection act, it took 19 long years to understand that to effectively manage disaster in India a separate law is required and that is why Disaster Management act came into existence in the year 2005. Lack of vision, requirement based policy and customization of law accordingly is one of the major drawbacks which entails challenges in adopting new technologies. Currently, every state is having disaster management authorities where usage of GIS & Remote sensing, application of LiDAR can play a vital role for decision makers. LiDAR data can be effectively utilized in scientific investigation and analysis of terrain where slope stability analysis is required. The various state government has a project related with hydropower, disaster management, however, due to lack of policy and guidelines effective utilization of technology is a challenge.

Conclusion

LiDAR technology is aggressively helping in various sectors across the India. The key to its usage lies in data acquisition and visualization. Government sector in India is one the fastest growing GIS market due to rapidly growing infrastructure and investment into GIS at all levels.In coming years if policy governs the law in a positive way the adoption of new technology like LiDAR will get faster with a high quality of data having better accuracy. As a good practice, the usage and application of LiDAR must get suggested or penetrated into the project where it really required. The current level of adoption of the various form of LiDAR technologies in the country and the future business prospects using the same technology may have a possibility to go exponential..

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