1. Introduction

Natural hazards are inescapable events that result from a combination of natural, geological and anthropogenic disturbances. According to United Nation’s report since 1995, floods accounted for 47 percent of all weather-related disasters, affecting 2.3 billion people, killing 1.57 lacs and damages about US$19.3 billion and US$0.83 billion for Asia and Africa respectively. Flooding is one of the main natural hazards and occurs frequently all over the world especially in Asia and Africa than other countries. Flooding causes such devastation as a result of increased settlement along levees, unexpected high rainfall, deforestation, river channel changes, and sediment deposition.

The complex processes of river and floodplain have been assessed through numerical modeling by several researchers which can provide spatial and temporal changes over large areas and simplification of a complex reality. However, the modeling techniques also have some uncertainties which effect accuracy and efficiency of numerical models. Mentioned some uncertainties in hydrological modelling which include uncertainties in input and model parameters. Meteorological and hydrological components such as precipitation, temperature, wind characteristics, relative humidity,
evapotranspiration, infiltration and runoff are one of the basic inputs and model parameters for any hydrological modelling but their poor spatial distribution can affect the model accuracy. For instance, precipitation has uncertainty in its spatial distribution in complex topography because of uplifting air masses by the wind. Considered precipitation's spacial discontinuity and used different occurrence/non-occurrence estimation approach to improve the spatial distribution of precipitation. The spatial distribution of input and model parameters affects the accuracy of river such as selection of their spacing and channel shape.

In this review, input and model parameters are studied with the role of remote sensing, hydrological and geophysical methods, and evaluate their effectiveness. We discuss the flooding parameters, and their related methods which were used in previous flood analysis studies. The aim is to identify the combination of flooding parameters and integrated methods that would lead to improvements in modeling techniques for flood risk assessment and monitoring.

2. The Role of Remote Sensing in Flood Analysis

Any flood-related study requires some initial considerations, namely, the areas to be analyzed, the parameters to be measured during field data collection, the procedure and the actual collection of field data. Remote sensing and GIS play an important role in the initial stages of flood analysis. They are reportedly used over other techniques because of their broad reach in data-sparse environments. Satellite remote sensing provides useful geospatial data and is increasingly being used to expand useful sources of information for a wide array of applications while GIS can deliver a synoptic view of large areas which is very useful in analyzing drainage morphometry and spatial-temporal mapping. Remote sensing and GIS are also useful for input data preparation either in data availability or in data-sparse environments. Therefore, remote sensing and GIS are both crucial techniques in the initial stages of flood analysis.

Flooding is primarily the result of heavy and continuous rainfall exceeding the absorption capacity of the soil and the flow capacity of river channel and streams. In order to achieve accurate flow magnitudes and water levels, flood models need to use parameters that accurately describe the channel and flood plain geometries. Airborne LIDAR (Light Imaging, Detection, And Ranging) bathymetry (ALB) technology (up to 2.5 m resolution topographical data) has recently been developed, with significant advancements during the past two decades. The recent advancements have allowed for unlimited data collection and better measurements that have greater depth penetration, are free from shadows or surface disturbance error, and are not affected by sun angle and glint on the water surface. Typically, LIDAR based Digital Elevation Model (DEM) is divided into topographic LIDAR and bathymetry LIDAR. Topographic LIDAR uses infra-red laser which is not able to penetrate into water while bathymetry LIDAR uses infra-red to detect water surface and green laser to identify under water floor which is helpful in accurate measurement of river cross-section.

Space-borne Thermal Emission and Reflection Radiometer Global Digital Elevation Model (ASTER GDEM) is a freely available data (30 m resolution) source and it can be processed through GIS by converting it into raster and grid formats. However, ASTER GDEM data has vertical errors that are enhanced by the GIS conversion. Therefore, this method is useful to measure the river cross-sections, but only up to water surface level, Figure 1 shows the detailed floodplain information from surveying, when high resolution aerial images are not available but in water depth data must be required if ASTER GDEM is taken into account for bathymetry measurements. Although, LIDAR based DEM are useful in accurate bathymetry measurement because of higher resolution and greater penetration ability in water, the ASTER GDEM can be used for floodplain modeling (which is a basic input in hydrological modeling) to reduce the cost and processing time.

In river modeling, cross-section shape selection is the most important task in data sparse region. Some common shapes such as the trapezoid and rectangular (horizontal bottom), semicircle, parabolic, catenary and semi-cubic parabolic, egg and circular sections (Curved bottom) are generally used in different situations such as the hydraulic, economical, hydrogeological and seepage situations. Curved channel, especially parabolic shape has advantages such as slope stability and lacking of sharp edges mentioned that the best hydraulic section is
those which are having the least wetted perimeter for a given cross-sectional area has the maximum hydraulic radius. As far as channel cross-section spacing is concern, 27 presented several guidelines for the choice of cross-section and distance between them on the basis of river geometry and flows. 15 investigate the guidelines and their results confirmed the validity of these rules on the optimal spacing between cross sections. They also mentioned different equations for cross-section spacing based on different situations.

Figure 1. A cross-section showing the limit of DEM measurement.

Many studies have investigated the spatial-temporal changes of the earth surface, which could be used in place of field work data 28–31. Landsat data, which is freely available in 30 m resolution with 15 m panchromatic (Landsat 7 & 8), has been used to study the spatial-temporal changes in land use/land cover. This data is useful because Landsat sensors records blue, green, and red light along with the near-infrared, mid-infrared, and thermal-infrared light. Landsat data has been used to monitor water quality, glacier recession, sea ice movement, invasive species encroachment, coral reef health, land use change, deforestation rates and population growth. Landsat is also helpful in assessing the damage from natural disasters such as fires, floods, and tsunamis, and subsequently help in planning disaster relief and flood control programs (NASA).

The SPOT program, which consists of a series of optical remote sensing satellites, has been widely used for applications in the areas of agriculture, environmental protection and land use/land cover. SPOT’s HRV (High Resolution Visible) and HRVIR (High Resolution Visible IR) instruments provide higher resolution. SPOT-5 is generally used high resolution data because it has advantages over its predecessors. SPOT-5 can cover vast areas in a single pass at high resolution (5 m to 2.5 m), which is a cost-effective imaging solutions (EESA). It has also been used in urban and rural planning 32 and natural disaster management 33. Both the Landsat and SPOT instruments are important for providing a long-term series of earth observation data.

3. The Role of Hydrology in Flood Analysis

In hydrological modeling, along with the model inputs, model parameters selection is an important task for researchers. Therefore, in this section, basic flooding parameters and their importance in flooding will be discuss to know the behavior, effect and the controlling factors of these parameters.

3.1 Precipitation

Precipitation is one of the most important variables in hydrological modeling and its dynamic behavior and spacial distribution due to climate changes is a major factor of concern in recent studies. The changes in climatic extremes, especially precipitation extremes, may affect the occurrence, duration, and intensity of floods and droughts 36,37. The impacts of precipitation, flood and climate change on hydrology have been widely investigated in many watershed studies around the globe 38. These studies have analyzed the effects of rise in temperature and decrease in rainfall 38,39, seasonal shifting of precipitation and increase in temperature 40 and increase in extreme precipitation in different seasons: in winter 41,42, in autumn, winter and spring 43,44, while decrease in summer 44,45,46. Studied the trend between extreme precipitation and hydrological floods in Europe, using observations and future climate projections, to estimate impacts of climate change on flood risk. They found potential increase in extreme precipitation in the future, by the climate model projections, and positive and negative changes in the peak flows and flood frequency, by the hydrological projections. Therefore, seasonal shifting of precipitation,
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3.2 Infiltration
Precipitated water first encounters intercepting surfaces, such as foliage and man-made structures, then infiltration starts when surface water interacts with soil or bed rock. It first restores the soil moisture deficiency and then percolates downward by the force of gravity and reaches the water table. During this process soil properties and bed rock properties play an important role in the movement of water. Explained in detail the control of soil properties on the spatial-temporal variability of infiltration and soil moisture processes. On the other hand, explained the influence of land use on soil moisture, studied the effects of seasonal variability on soil conditions and subsequently its effect on infiltration. They found that during the winter, low suction field in the soil reduced infiltration and enhanced evaporation, while during the summer, high water-driving gradients in the shallow soils reduced evaporation and increased rainfall infiltration. Determined the seasonal infiltration rate in natural and cultivated sandy soil with water repellency due to the soil properties and lime content. They found similar result of greater infiltration in dry condition than wet condition. They also found that calcite is effective in alleviating the water repellency in the tested soils.

Decomposing plant material on the forest floor also plays a crucial role in hydrological processes. Litter (fresh leaves) and duff (fermented humus) are the two layers on the forest floor. Infiltration is also influenced by different slopes, as discussed by in pine and rain forests. Therefore, it can be concluded that land use and land cover change and soil properties are the major factors which affect the rate of infiltration.

3.3 Evapotranspiration
Evaporation loss occurs from free water surfaces (e.g., lake or soil surfaces) and transpiration loss from vegetation. The rate of both are mostly affected by air and water temperature, relative humidity, wind velocity and exposed surface area, and is least affected by barometric pressure and salinity of the water. The evaporative process is primarily driven by radiative and aerodynamic components. The former is related to the energy available to evaporate water, which depends on solar radiation, land surface albedo, air and surface temperatures and vapor pressure. While the latter is related to the capacity of the air to store water, which depends on air temperature, humidity and wind speed. The rate also affected by tall and short vegetation because of their higher aerodynamic conductance in tall vegetation and vice versa. As far as soil evaporation is concern, it is dominant in areas with a shallow groundwater table, hot and dry climate, and bare surfaces exposed to sunlight and wind. Soil evaporation can have worsened if the area is composed of a uniform fine-grained soil and has sparse vegetation. The rate of soil evaporation is controlled by atmospheric conditions, if the surface has moisture while the rate of water movement to the surface through the soil profile and the water table in non-moisture surface. Therefore, it can be concluded that meteorological components, soil properties and types of vegetation are the leading factors controlling evapotranspiration. However, it can be hypothesizing that, in case of flash flood simulation, high intensity with long duration of precipitation, evapotranspiration is not an effective parameter in hydrological modeling because radiative and aerodynamic components are negligible during that period.

3.4 Runoff
Surface runoff generation is mainly affected by climatic factors, topography, soil type, land use/land cover, vegetation, existing moisture condition, and infiltration. Climatic factors include types of precipitation, intensity, duration and distribution of precipitation, and intensity and direction of prevailing wind. Rainfall spatial variability can control peak runoff discharge at the catchment scale, which depends on the combined influences of rainfall, slope and size of the catchment, and runoff generation processes. Topography is another important parameter that affects overland flow dynamics. It was found in previous studies that soil saturation is more observed near streams, due to lateral subsurface flows from upslope or groundwater table rise. Therefore, it can be concluded that the characteristics of precipitation and topography have a major role in surface water flow while other factors, as mentioned above, are dependent on the characteristics of precipitation and topography.
4. The Role of Geophysical Methods in Flood Analysis

Subsurface investigations are very important in identifying the hydrogeological characteristics such as hydraulic conductivity, porosity, permeability and ground water table that can affect flooding parameters as discussed in previous section. To investigate these, an integrated branch of geophysics, called hydrogeophysics, has evolved in recent years to explore the potential that geophysical methods hold for improving the quantification of subsurface properties and processes relevant for hydrological investigations. Some geophysical methods such as seismic, electrical resistivity, gravity and magnetic methods are generally used to extract subsurface heterogeneity information. Seismic and resistivity methods are widely used in hydrogeological investigations. Because of the advantages and disadvantages inherent in individual geophysical methods, data from different geophysical methods should be combined to increase the accuracy of the data. So in the following section, these two methods, which are useful in identifying accurate hydrological flood affecting parameters, will be discussed.

4.1 Seismic Method

A simple subsurface requires measurements from a few monitoring wells, in order to describe the groundwater level over a large area. However, a complex subsurface needs closely spaced monitoring wells, which is expansive or almost impossible. To measure the shallow groundwater level, applied integrated electromagnetic and seismic surveys in an arid environment. They found that common mid-point seismic reflection and refraction methods integrated with shallow piezometer control, provided detailed subsurface information and measured the ground water level with an error less than 5 m. applied high-resolution seismic reflection methods to know the pre-conditions for landslides. They found that a profile with a highly permeable sandy-silty layer, which can infiltrate surface water through it, situated between quick clay layers and then bedrock is a pre-condition for landslides. They showed how high-resolution reflection techniques can be used to determine such detailed structures.

4.2 Electrical Resistivity Methods

Electrical resistivity methods such as electrical resistivity (ER), induced polarization (IP), electromagnetic induction (EMI), ground penetrating radar (GPR), and time-domain reflectometry (TDR), are generally used in engineering and hydro-geophysical high resolution investigations of the subsurface structure and electrical properties. Theoretical and empirical discussion is beyond the scope of this paper, instead the use of these methods in estimating hydrogeological subsurface condition will be discussed.

Subsurface heterogeneity, which exhibits electrical properties of the subsurface material, affects the potential difference. ER tomography alone or in combination with other geophysical methods is widely used in hydrogeological investigations, such as porosity and hydraulic conductivity, groundwater studies and subsurface fissure mapping. used Vertical Electrical Sounding (VES) with a Schlumberger array to determine the porosity and hydraulic conductivity of an aquifer and then correlated the results with Kozeny–Archie equations for porosity, Ohm’s–Darcy’s laws for hydraulic conductivity and pumping test results. They found that bulk resistivity changes can be imaged as the moisture content varies and that saturated hydraulic conductivity ranges from 3 to 9 cm/day.

Subsurface fissures and cracks can affect the hydraulic conductivity of the soil. used a 3D inversion method of ERT to locate subsurface fissure networks. They found that the method can predict individual fissures and their depth in the subsurface, and that the Schlumberger method is better for fissure network mapping. Furthermore introduced new inversion algorithms to improve their results.

Time-lapse ERT is an emerging technique to monitor dynamic processes occurring in the shallow subsurface. used time-lapse ERT to improve the mapping of dense non-aqueous phase liquids by using horizontal boreholes instead of vertical ones. They found that a high resolution image could be achieved by a S2HB ERT configuration in horizontal boreholes. applied this technique in leachate injection monitoring with a new methodology called MICS (multiple inversions and clustering strategy), which improved some of the limitations encountered by previous studies. used time lapse ERT in watershed characterization.
In Induced Polarization (IP), both resistivity and conductivity of the soil are measured using multi-electrode arrangements in either the time-domain or the frequency-domain. IP is widely used in exploration of ore bodies and groundwater (USEPA). It is not widely used in hydro-geophysical investigations. Some hydrogeophysical studies used IP with other geophysical methods to get better results. Researchers either alone or in combination with other geophysical techniques as per the suitability of the investigation.

Ground Penetrating Radar (GPR), a high resolution geophysical technique used to measure subsurface heterogeneity by passing ElectroMagnetic (EM) waves through the subsurface. This technique is used by many researchers either alone or in combination with other geophysical techniques as per the suitability of the investigation. GPR with a Complex Refraction Index Model (CRIM), which is helpful in direct measurement of water table depth, to detect the macro-porosity in unsaturated lime stone. The same technique to detect porosity in an aquifer and found that between two acquisition modes of GPR, common offset and common midpoint; common offset has several advantages over common midpoint. A study by used ERI and GPR to detect cavities and solution features, which affect the groundwater flow direction, 4 - 9 m below the water table. used GPR with a data analysis algorithm called AutoRegressive Moving Average (ARMA) to detect the varying values of compactness and moisture contents in sandy loam. They found that GPR is an effective method in this application, with the advantage of speedy and efficient measurement collection. In another study, used GPR with Frequency Domain Reflectometry (FDR) and a different data analysis algorithm, to estimate the spatial-temporal changes in surface soil moisture content along a hill slope. also used GPR to measure the spatial variation of the moisture content in the active layer. They were able to improve the vegetation cover information and estimate the depth of the cryoturbated soil water content.

Geophysical methods are able to detect surface water and groundwater interactions. used joint analysis of EM and GPR to find fractures in the presence of dissolution-enhanced features and found that the combination of methods improved the results, compared to previous studies. In the same study, used GPR and EMI to understand the complex surface water and groundwater interactions and found that these methods are effective in exploring the bedrock river system and detecting fracture zones. Other researchers, such as used ERT and GPR to detect the geological information, such as fracture and stratification orientations.

The time-domain electromagnetic method that uses inductive loop sources is known as the Transient Electromagnetic (TEM) method. Due to its simple and economical use, TEM is used by many hydro geologists for groundwater exploration. used TEM surveys to analyze the quaternary sediment deposits in an aquifer, over a 55 m deep. used TEM in shallow-depth studies to investigate the advantages and disadvantages of electrical induction methods, and found that it has good sensitivity to heterogeneity at depth, but reduces the useful signal at an early stage. Estimated the maximum depth of penetration of transient electromagnetic soundings by using 10 x 10 m to 400 x 400 m loop sizes. They found that the maximum depth of penetration was deeper than the deepest interface estimated from the inversion of the data.

Based on the above assessment of all the geophysical methods used in hydrogeological investigations, TEM is considered the best method in achieving accurate measurements, in terms of deeper penetration and economy. Resistivity methods would be the next best method after TEM. However, the use of these methods depends on the topographical conditions. For example, it is more difficult to use resistivity methods than TEM in areas where the topography is dynamic (has high slope).

5. Conclusion

Integrated methods of remote sensing and GIS, hydrology and geophysical methods were investigated for the measurement and identification of input and model parameters and their factors in hydrological modeling to simulate accurate flood analysis. In this study, it found that remote sensing and GIS are important tools for the initial study of flood analysis and can facilitate the future planning. Remote sensing and GIS also helps to detect accurate spatio-temporal changes with high resolution data and parameters estimation and have greater use in data sparse environments. Bathymetry and topographic LIDAR based DEMs are best to measure river-cross sections and floodplain data which are the basic input in grid based river and floodplain modeling techniques. Hydrological parameters such as precipitation, infiltration evapotranspiration and runoff with their effecting factors
were discussed in this review and found that intensity and duration of precipitation, land use land cover changes, soil properties, types of vegetation and meteorological parameters should be used as input in hydrological modelling and these also used in model parameter identification. Furthermore, geophysical methods were investigated for the identification of best method for subsurface hydrogeological parameter measurement. Resistivity and TEM were found to be the best methods for subsurface hydrogeological investigations, due to their greater depth penetration, ease in use and their ability to detect changes in saturated regions. These methods can provide data for a small area. Finally, all the above information can be used as inputs for model parameter selection in modeling techniques which can provide accurate causes and effects of flooding.

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