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Flood Inundation Mapping Using Multi Temporal Datasets

Original Article

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Floods are considered the most frequent natural catastrophic events, which effect the human lives and infrastructure. Flooding causes tremendous loss of life and property every year. We used satellite imagery to map flood inundation in Jehlum river for the both pre and post flood scenarios and classified it into major land use including vegetation, water body, buildup land and the bare soil. The results show that about 40% area was agricultural land, 29% was bare soil, 16% was build up land and 12% area was noted as water body. The categorization of the post flood areas, showed that flood has destroyed the buildup and agriculture lands. The superimposition proposed that agricultural land was 43% before the flood which reduced up to 31%,the normal flow of water was 12% before flood which was increased up to 33%, build up area and bare soil was also decreased up to 10% and 25% respectively. Remote sensing and GIS proved efficient in convergence of optimistic results

Keywords: Natural Disasters, Pre and Post Flood, Land use, Land cover.

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Introduction

Natural disasters are common phenomenon occurring worldwide. Flood is one of the most destructive [1], devastating and frequently widespread calamity among different types of natural disasters [2,3]. Almost $500 billion is lost every year in rehabilitation of natural disasters caused by climate changes. Particularly, floods being the most frequent natural catastrophic event, have affected human lives and infrastructure. Flooding causes tremendous loss of life and property every year [3]. According to the directive of European Union (EU), flood is defined as an interim arrangement of water on a piece of land which is normally devoid of water. River flood is a phenomenon usually occurs when water level of a river rises beyond its capacity due to rainfall and melting snow or ice. Thus, rivers overflow during monsoon season causing extensive floods. The Himalayan region of India was spotted with unrivalled flooding in the last few years, such as flood of Ganga in 2010, flood of Brahmaputra 2012 and Jhelum floods in 2014.

The floods leave long term effects on regions which witness downpour for a long period or tremendous water flows from the rivers. Flood extent is determined through data collected by optical and radar satellites. The data which is collected through in-situ collection can be inadequate, impractical and expensive. Aerial imagery can prove expensive and provide data which have limited spatial and temporal resolution. Moreover, the height of water is determined through gauge station but gauge station is unable to measure extent of flood. Whereas, the extent of flood can be determined in frequent intervals of time through the satellite imagery over a vast geographical extent [4].

The effects of floods can be minimized and reduced through proper redeem, relief and allocation of resources for rehabilitation and retrieval of destructed land but floods cannot be avoided. The first available satellite imagery is acquired for the collection of data needed to map the lands under floods. Satellite imageries are extensively used to evaluate temporal changes worldwide due to their compendious coverage. In order to establish a quick response plan and to reduce the natural disasters, it is very important to organize accurate inundation mapping in frequent intervals of time [5,6,7].

Ground surveys were considered a major source of information but these are now time consuming and wastage of resources and cannot persuade a quick response when a natural calamity spreads to a large scale. Moreover, data obtained through aerial surveillance can be inaccurate in some extreme atmospheric conditions, and the density of gauging stations is inadequate in various scenarios [8]. The Satellite Remote Sensing (SRS) is commonly used [9] due to widespread accessibility in terms of time and cost [10]. Progress of floods can be monitored through multi-temporal images.

Microwave remote sensing provides real time earth observations regardless of weather conditions and indispensable for observation of flood because of its capacity. Various techniques have been devised for mapping inundation using multi-temporal satellite images. Normalized Difference Water Index (NDWI) generated by Mc Feeters [11] is an indices to map water bodies, which provides effective results for inundated lands [12]. For example, Wang et al. [13] initiated Otsu's algorithm for selection of water bodies automatically. The effectiveness of Otsu's algorithm is reduced because of the mixed pixels in satellite images and recurrent illumination differences, especially for some complicated sequences.

The extent of flood is determined from the change analysis using segmentation techniques. Rahman et al. [14], combined the multi-temporal NDWI images into single file and processed it to analyze through Principal Component Analysis (PCA). All these techniques are based on spectral responses and the capacity of each method can fluctuate with changing of spectral features, these methods are applied to different cases by the use of different sensors.

Chen et al. [15] devised a method to monitor water surface using spectro-temporal images. Moderate Resolution Imaging Spectroradiometer (MODIS) data is considered adequate and valid to over large extents using unsupervised classification. However, the statistical equality depends upon uni-dimensional features, which are basically the avenue of temporally adjoining pixels. Moreover, the performance of MODIS data has been reduced due to low spatial resolution in spatial dimension.

This study aims at determining the flood extent using freely available satellite images. It also aims at investigation of rehabilitation activities in post flood scenarios.

Material and Methods

Investigation site

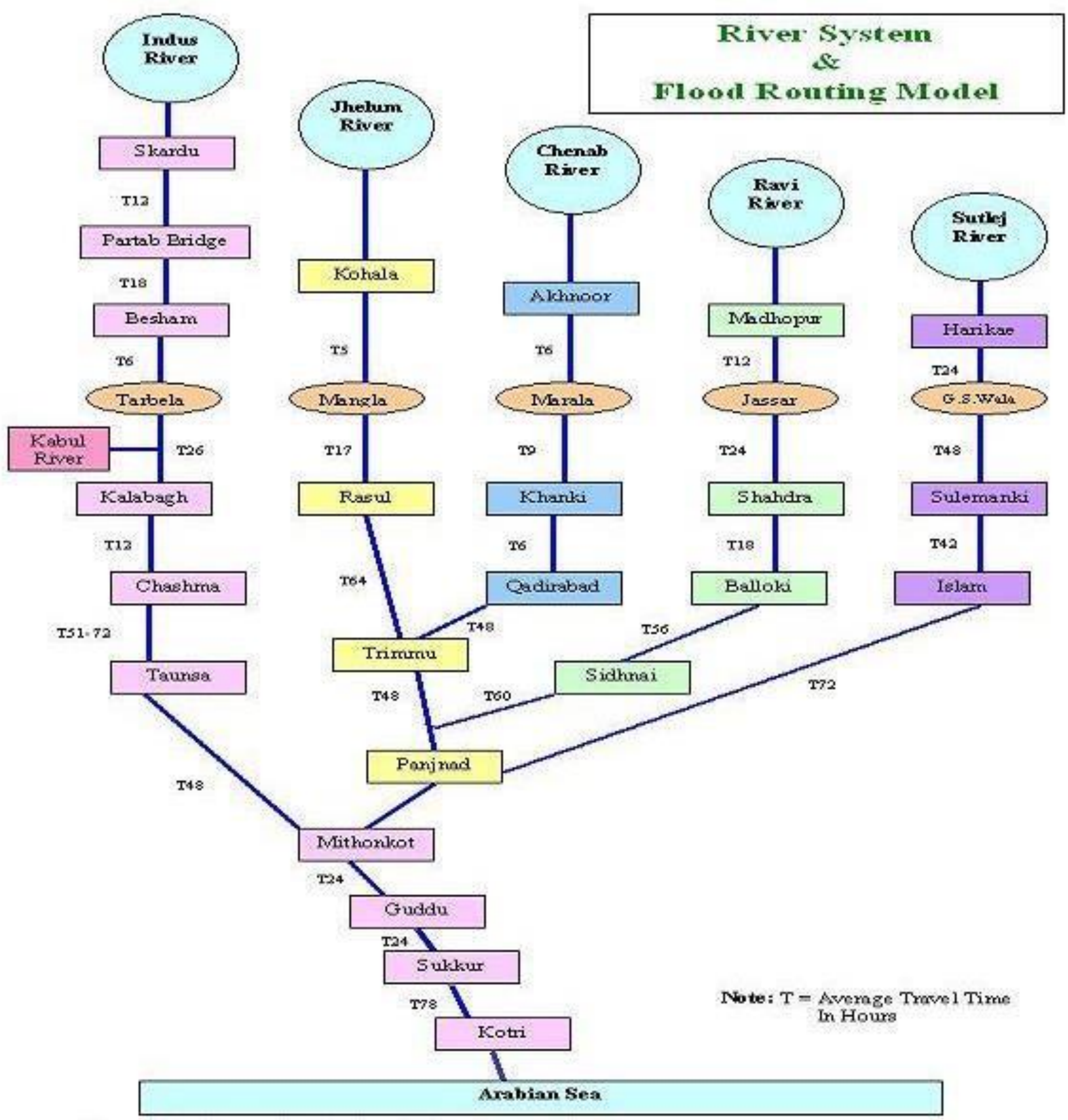

Figure 1. Spatial location of Jehlum River

Source: https://www.pakimag.com/misc/pakistan-river-system-map-with-headworks.html/attachment/river-map-pakistan

Verinag spring is the starting point of Jhelum River located in south eastern Kashmir's valley adjacent to PirPanjal situated in India. The river passes through Srinagar and through stony barriers of Wular-Lake before entering the territory of Pakistan [16]. River Jhelum flows along the district Jhelum and passes by south of Pakistan. Jhelum is located at west bank of river of Punjab and it was discovered by Alaxander in 325 BC. It is controlled by snow melt from glaciers of Kashmir in spring season. This snowmelt is the main supplier of water in this river. The water level in river substantially rises in monsoon season from June to September due to heavy rainfall which causes heavy water flow into the river. The water discharge and flow speed in Jhelum river exceeds upto 1,000,000 cubic per second. Due to minor rainfall in winter season, the water level of river falls substantially. Thus, water level of river Jhelum is high in summer and low in winter season. The river launch into Punjab province through Jhelum district and then flow towards the plain areas of Punjab and prolong towards Sagar doab [17].

The river passes through Jhelum, Muzaffarabad, Khushab, Mandi Bahauddin, Jhang, Malakwal, Multan, Muzaffargarh, and Sahiwal [9]. The annual average flow of river can be calculated through the combination of daily average flows of the river. The average flow recorded on annual basis is about 12 MAF i.e., with 3.65 MAF in Kharif and Rabi seasons respectively and 8 MAF in season [10]

Material and methods

USGS website was used to obtain Landsat-8 images which are freely available to download. Flood alluvion data for the dates August 25, 2014 (pre flood) and September 10, 2014(post flood) was downloaded from USGS website. The downloaded images were composed of 11 spectral bands which were confined through layer stack utility embedded in Erdas Imagine. Fluctuations in sensor's functionality causes geometric distortions which were inspected and catered in Erdas Image 9.2 in order to make data error free. Supervised classification was applied to classify satellite images into major classes as buildup area, bare soil and the water body. Subsetting was performed to extract the desired area from large datasets using masking algorithm in Arc GIS10.1. Sub setting is performed to increase the processing speed which saves time and lead to the better performance of work stations. Classified raster datasets were converted to polygons and integrated in order to measure the extent of systematic water flow in comparison to the extent of flood inundation.

Result and discussion.

The classified images were categorized into major groups which include agricultural land, built up, bare soil and the water body. Urban areas include the constructive structures of residents such as apartments, educational institutes, public buildings and commercial markets etc. The major crop plants across the fields include the agricultural land.

Table 1. Statistics before flood.

Agriculture	Bare soil	Build up area	Water body
2732 SqKm	1464SqKm	819 SqKm	196SqKm

The statistics describe that about 40% area was agricultural land and 29% was bare soil and 16% was build up land and 12% water body was noted.The categorization of the post flood areas, showed that flood has destroyed the buildup and agriculture area. The post flood classified image is shown below.

Table 2 Statistics in Post-flood conditions.

Agriculture	Bare soil	Build up area	Water body
2511 SqKm	1325 SqKm	409 SqKm	1193 SqKm

Pre and post flood analysis

The following results were obtained by superimposition of the pre and post flood categorized images for flood inundation mapping. The superimposition proposed that agricultural land was 43% before the flood which reduced up to 31% , the normal flow of water was 12% before flood which was increased up to 33%, build up area and bare soil was also decreased up to 10% and 25% respectively.

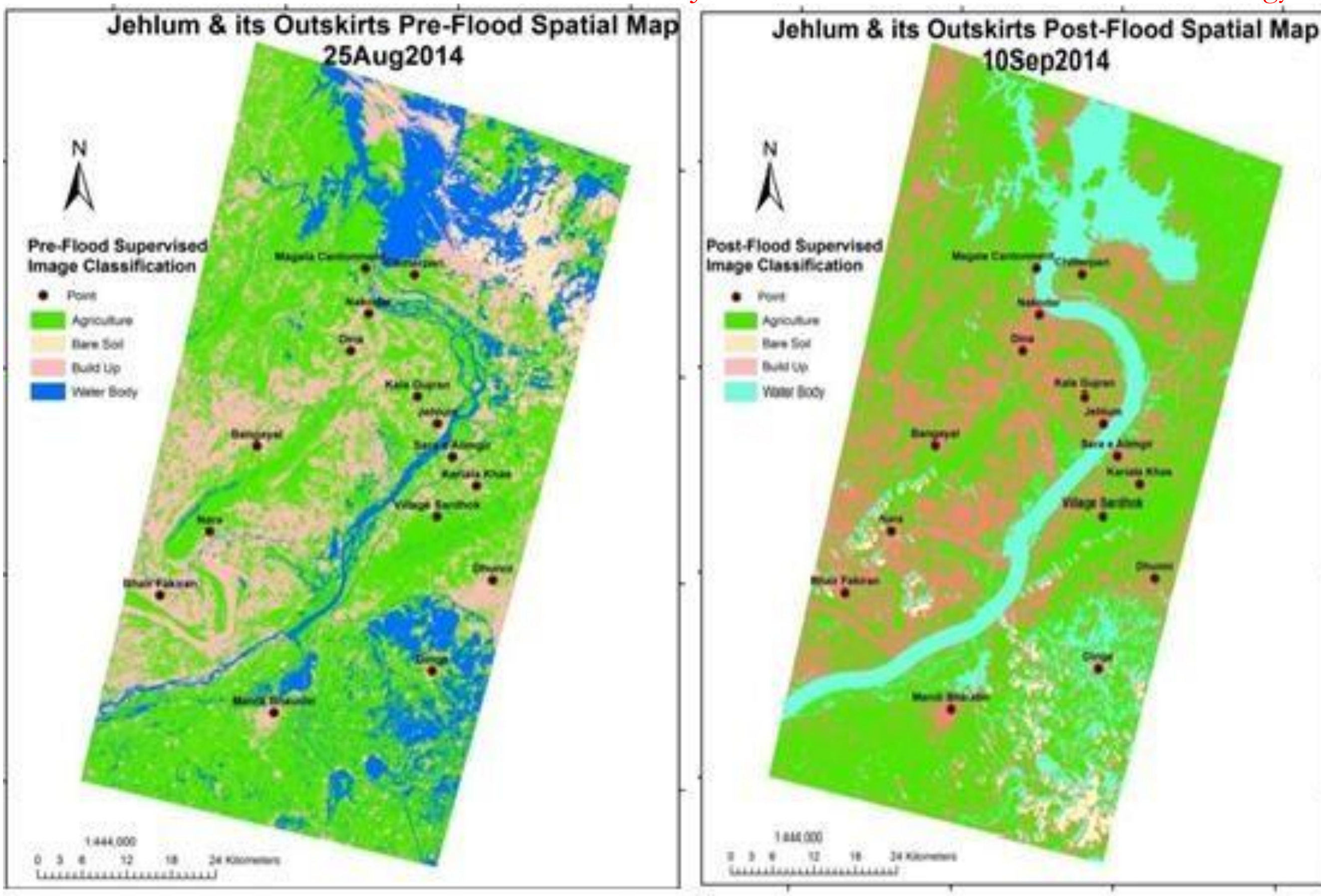

Figure 2. Pre and Post flood classified maps of river Jhelum.

Aftermath of flood

Flood being, a natural calamity, has hit many areas indiscriminately. The geography of the Jehlum and its outskirts was observed interrupted badly in post flood situations. The flood caused life losses and demolishing of infrastructure effecting the economy badly. The rehabilitation and reconstruction of these demolished built-up areas require long time and amount.

Flood affected the study site and a large variety of hazardous substances and chemicals were transported and entered in to the study site. It caused various kinds of diseases but on the crop, productivity was enhanced up to many folds in upcoming years in post flood situations.

Agronomist consider floods a sign of goodness because flood water transport rich minerals which are the best for productivity. The overall flora and fauna of this region was affected badly. The observations showed that transportation system of the study area was destroyed by the flood. It also destroyed the residential structures including schools, industrial zone, infrastructure and sanitation facilities.

Flood proved to be vulnerable for the residents of study site who lost their lives and property. Flood also had psychodynamic effects in a community. Economic development was also reduced by flood. Moreover, the destruction by flood also resulted in the mass migration.

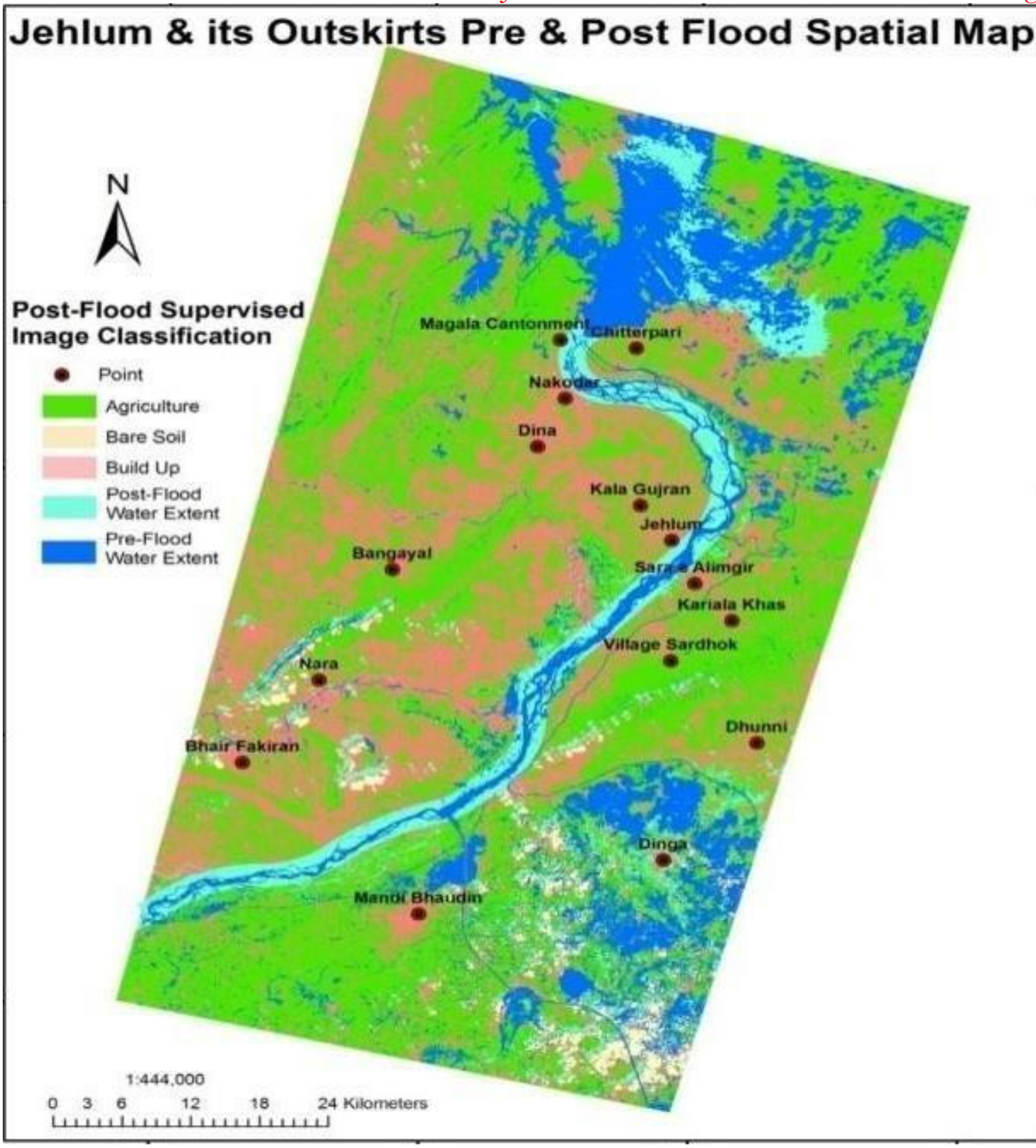

Figure 3. Pre and post flood classified superimposed map.

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