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Flood severity assessment in Jhelum water shed of Punjab Province, Pakistan

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Key words: Flood 2010, Rainfall, GIS, RS, Jhelum water shed, Punjab, Pakistan

Abstract

Current study evaluated the severity and damages of 2010 and 2014 flood in the Jhelum Water Shed of Punjab, Pakistan. For this, Jhelum watershed was selected as a study area. Simultaneously, field observation was also done and snaps of the destroyed fields and houses were captured through digital camera. Findings revealed that in study area majority of the inhabitants had lost almost all of their possessions to furious flood. The Jhelum watershed starts from the areas of the Khola (Jamu-Kashmir) and diminishes at Trimu Barrage (Jhang). The main purpose of the study is to assess the severity of flood in Jhelum River shed of Punjab and to find the causes of the flood in Jhelum River. Satellite images of Jhelum watershed were downloaded from USGS website for the year's 2010 and 2014 at Landsat 5 (TM), Pixel ratio of Land sat 5 (TM) at 30*30 meter for every band. The supervised classification technique in Erdas Imagin was applied on these satellite images using inverse distance weight (IDW) in Arc GIS 10.1. The analyses on maps were performed in Arc-GIS which were in the flow direction, watershed, Hillshade, slope and aspect map. The secondary data of all parameters was obtained from the Statistical Department of Bureau, Lahore. The socio-economic conditions like affected area, houses, villages, persons, injured persons, dead persons, dead animals and crop area were also discussed. The analysis revealed that the floods of 2010 and 2014 had badly affected to the eleven districts including Jhelum watershed and the rainfall had been decreased 18.76 inches during the flood of 2014. All indicators remained highest in 2010 flood and decreased in 2014 flood. The study suggests that dams should be built on suitable locations because the needs of dams are more necessary for the control and storage of excess water.

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Introduction

Fresh water is one of the major sources of river water; it also contributed a great work in the formation of human civilizations. Rivers of Asia have been affected due to climate change since previous 20-30 years (Haq. A., & Zaidi AS., *et al*., 2010). In Pakistan, the major causes of floods are heavy and drawn out monsoon rain accompanied by excessive snow or glacier melting during summer (Wang, 2004). Pakistan has five main tributaries which is the combination of its eastern side located are the Jhelum, Chenab, Ravi, Beas and Sutlej (Bonn *et al*., 2014). The human interventions have altered the flow direction of rivers (Ali KF., 2007). Floods mostly occur in this region during the season of the monsoon from July to late September. Approximately, 41 million peoples have been affected during the major nine floods from 1973 to 2014. In 2010, the season of Monsoon heavy rainfall occurred in the major parts of Pakistan. This heavy rainfall became the cause of flood. According to the EM-DAT (2010) report, more than 1961 people were died and the estimated loss was 9,500,000 $ due to flood of Jhelum River. The government of Pakistan referred the flood of 2010 as a "Supper Flood" (Mahboob, *et al*., 2015).Indus is the primary source of water, which donates 65% of water provisions, with Jhelum providing 17% and Chenab 19%. For the mapping of flooded or scratched area, data was collected and analysed by creating maps through the expertise of Geographic information system. Technique of Geographic information system and remote sensing has been used to highlight the flood affected areas (Sanyal and Lu *et al*., 2014). A lot of problems are concerned with the arrival

The aim of the research was to assess the flood severity of 2010 and 2014. In order to accomplish the aim of the research the data of rainfall, inflow and outflow of water, socio-economic and demographic conditions of the inhabitants were acquired on spatio-temporal basis. Besides the aims of the study were to explore the severity of flood hazard assessment besides to study the causes of higher vulnerable severely affected areas. The study also aimed to make the suggestions for minimizing the vulnerabilities of flood hazards and enhance the social resilience by adopting suitable measures to combat the effect of such type of flood hazards. The causes of floods usually are melting of glaciers, river torrents and heavy rains that brought by monsoon winds.

Material and methods

To achieve the desired objective of the study both primary and secondary data was employed. A detailed field survey was conducted in 2014 to the flood affected areas of the Jhelum watershed. District Jhang was one of the affected areas. The rainfall maps of 2010 and 2014 were created and analysed.

Data Type

The data of three main phenomena rainfall, inflow and outflow of water, and socio-economic conditions, which was collected from different Departments, Pakistan Meteorological department, Islamabad, Flood data from the flood department of Jhang District and the data of socio-economic conditions from the Statistical Department of Bureau, Lahore was secondary data.

Data Management

As these secondary data have been collected from the different departments. The data of all phenomena were than properly arranged in MS Excel for the proper tabulation and calculation of data. The data of rainfall during the flood of 2010 and 2014 have been collected from the Pakistan Meteorological department. Islamabad.

Satellite Image

Landset satellite imageries were obtained from United States Geological Survey (USGS) website. The pixel sizes of the images were 30×30m. From these images, land sat image of the study area, aspect maps, hill shade map

Image processing

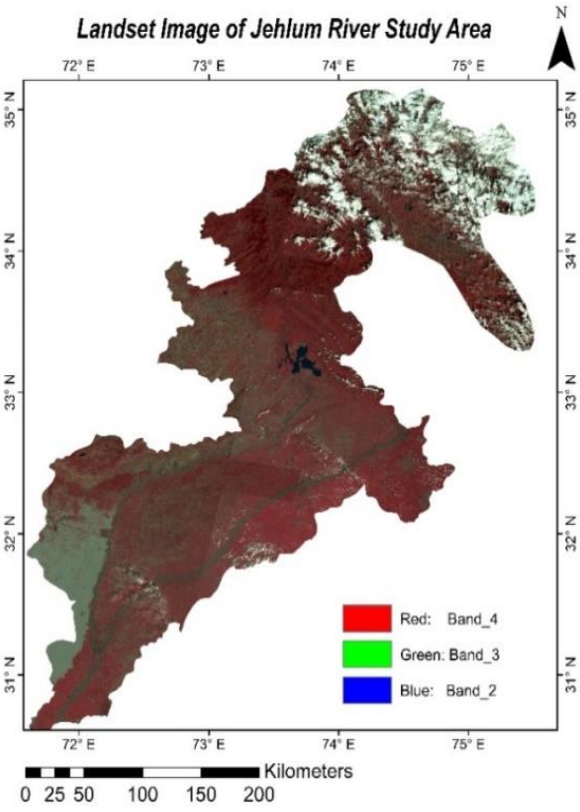
The landset images were added in Erdas Imagine 2013 for the process of classification and then added in ArcGIS 10.3 for the proper presentation of maps with proper layout.

Spatial Analysis

The rainfall maps of 2010 and 2014 were created and analysed. The demographic maps of the people affected, people injured and persons died during the flood of 2010 and 2014 were created and were comprised for the monitoring and assessment of the severity of these floods.

Study Area

The eastern portion of the nation is dominated by the surge fields of the waterway Indus and its branches namely rivers Jhelum, Chenab, Ravi and Sutlej (Saeed *et al.*, 2006). Jhelum watershed has fertile soil suitable for vegetation and plantation. Its soil and climatic conditions support all types of crops.



Common land use types are forest, Alpine pasture, arable land (cropping land) and fruit orchard. In agricultural land, farmers grow two crops per year and the agricultural land is located at somewhat lower elevations as compared to forest and pasture. Economy of the area is based on agriculture and it has a special place for the production of many crops i.e. Wheat, Cotton, and Sugarcane etc.

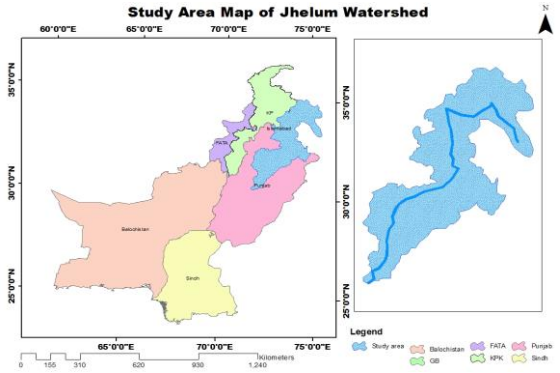


Fig. 1. Study area map of Jhelum water shed. Fig. 1a. Landsat image of Jhelum River.

Analysis

Comparison of Rainfall of 2010 and 2014

In order to compare the rainfall during the flood of 2010 and 2014 in the Jhelum shed, Fig. 3 & 4 shows that highest rainfall has been found in the area of central eastern part of Muzafarabad district during the both flooded period of 2010 and 2014 but the rainfall was 110 inches in 2014 and 160 inches in 2010 (Redd *et al.*, 2012).

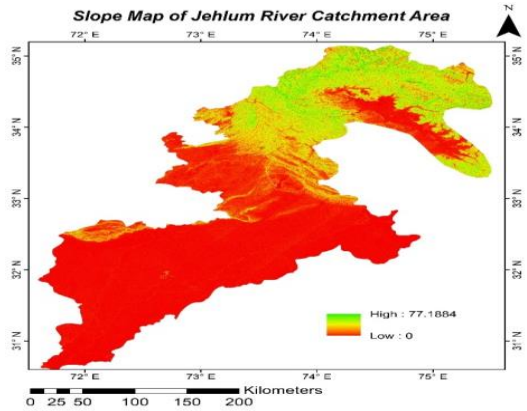


Fig. 2. Slope map of Jhelum Shed of Pakistan

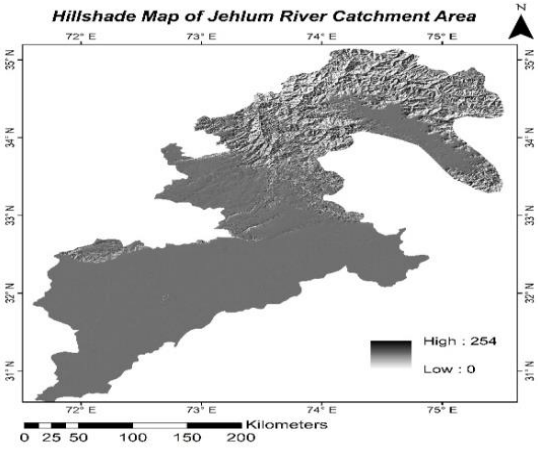


Fig. 2. Hilshade map of Jhelum Shed of Pakistan

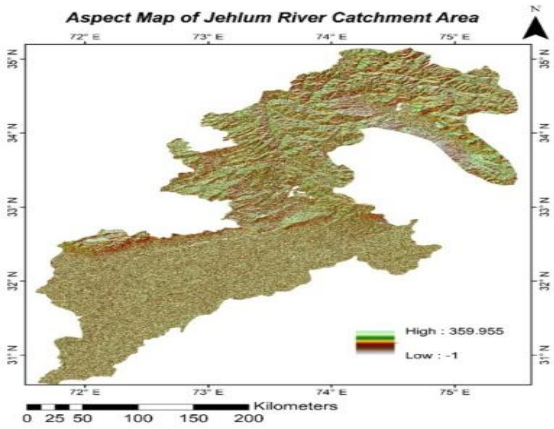


Fig. 3. Aspect map of Jhelum shed of Pakistan

Comparison of Flood Water of 2010 and 2014

The inflow and outflow of water at the three main points of Jhelum Shed of Pakistan have been fluctuated. Fig. 5 & 6 graphs have shown the fluctuation of inflow and outflow of water during the peak flood month August (1st to 31st) during the both flooded years of 2010 and 2014.

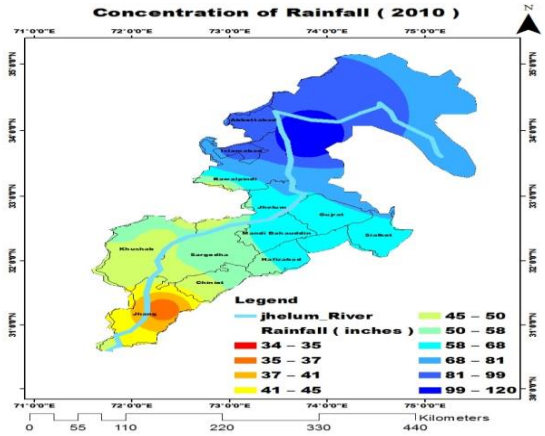


Fig. 5. Rainfall of the year of 2014 in the Jhelum Shed of Pakistan

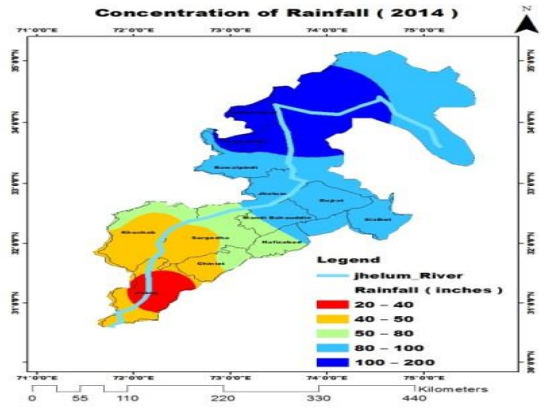


Fig. 6. Rainfall of the year of 2010 in the Jhelum Shed of Paksitan

Mangla Inflow during 2010 and 2014

The Fig. 7 & 8 is showing the receiving (inflow) water capacity in Mangla Dam during the flood of 2010. Average inflow of water in this month is 77390cusec m3/month in Mangla Dam during 2010.

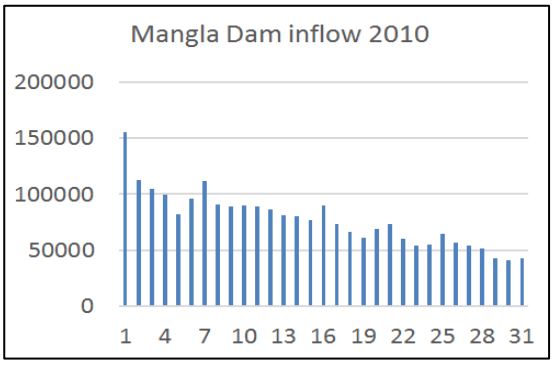


Fig. 7. Water as inflow in Mangla Dam during the flood of 2014.

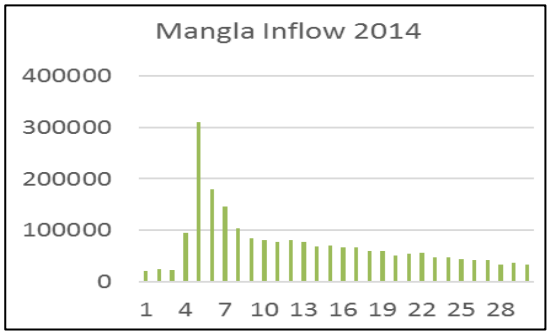


Fig. 8. Water as inflow in mangla dam during the flood of 2010.

Mangla Outflow during 2010 and 2014

The Fig. 9 & 10 is showing the outflow of water in Mangla Dam during the flood of 2010. Mangla outflow mean that the water flow out from the dam which has been received in Mangla Dam by river Jhelum as inflow in the month of peak flood period of 2010.

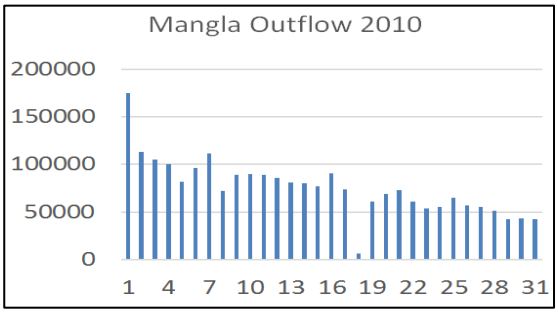


Fig. 9. Water as outflow in Mangla Dam during the flood of 2010

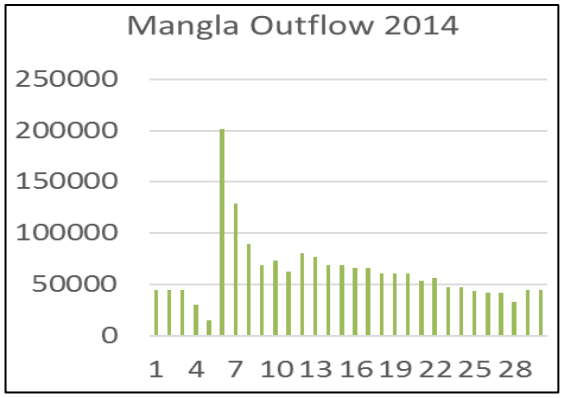


Fig. 10. Water as outflow in Mangla dam during the flood of 2014.

Rasool Barrage Inflow during 2010 and 2014

The Fig. 11 & 12 shows the receiving (inflow) water capacity in Rasool Barrage during the flood of 2010. Rasool Barrage is a barrage on the River Jehlum between Jhelum District and Mandi Bahauddin District of the Punjab province of Pakistan (Gaurav *et al.,* 2011). Average inflow of water in this month is 80372.67742 cusec m3/month in Rasool Barrage during 2010

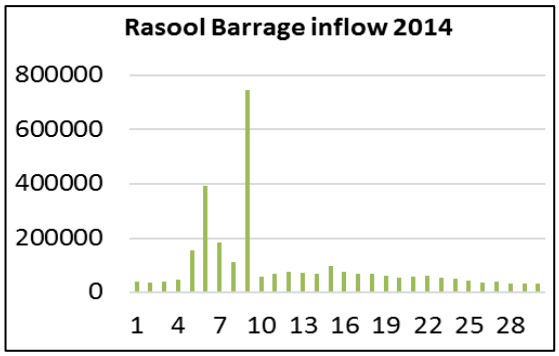


Fig. 11. Water as inflow at Rasool Barrage during the flood of 2010.

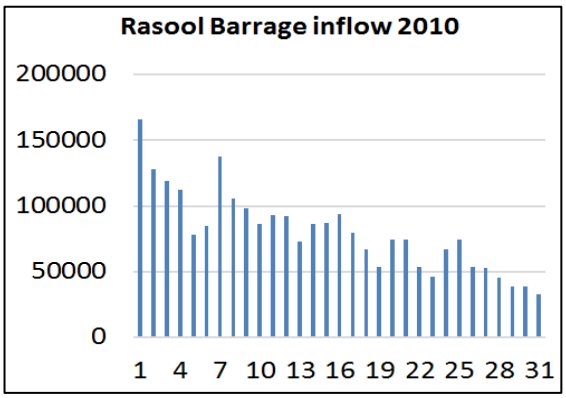


Fig. 12. Water as inflow at Rasool Barrage during the flood of 2014

Rasool Barrage Outflow During 2010 and 2014

The Fig. 13 & 14 is showing the outflow of water from the Rasool barrage through the Rasool-Qadirabad Link Canal, which discharge water of river Jhelum from Rasool barrage to Qadirabad barrage in River Chenab, during the flood of 2010.

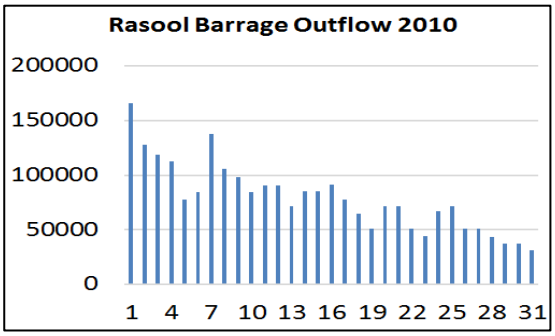


Fig. 13. Water as outflow at Rasool Berrage during the flood of 2010.

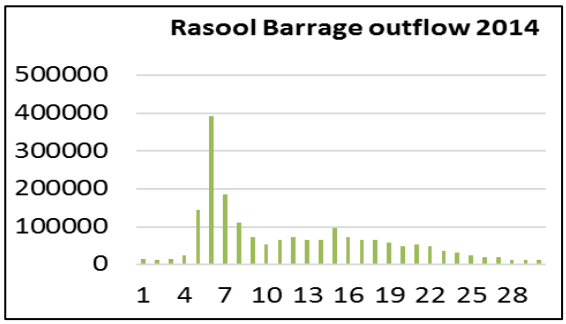


Fig. 14. Water as outflow at Rasool Berrage during the flood of 2014.

Trimu Inflow during 2010 and 2014

The Fig. 15 & 16 is showing the inflow of water from Trimmu barrage is situated in Jhang near the village of Athara Hazari where the River Jhelum flows into the River Chenab, which discharge water of river Jhelum and Chenab from Trimu barrage to merge on Trimu berrag during the flood of 2014.

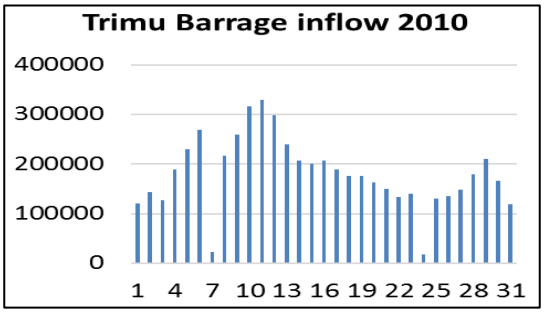


Fig. 15. Water as inflow at Trimmu Barrage during the flood of 2010.

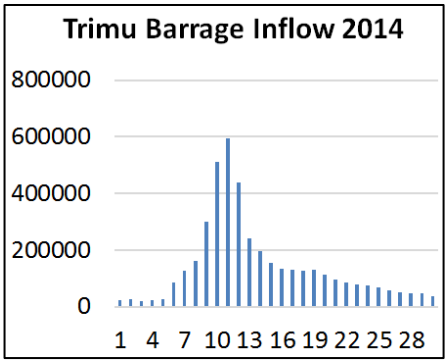


Fig. 16. Water as inflow at Trimmu Barrage during the flood of 2014.

Trimu Outflow during 2010 and 2014

The Fig. 17 & 18 is showing the outflow of water from Trimmu Barrage is situated in Jhang near the village of Athara Hazari where the River Jhelum flows into the River Chenab, which discharge water of river Jhelum and Chenab from Trimmu Barrage to merge on Trimmu Barrage during the flood of 2010.

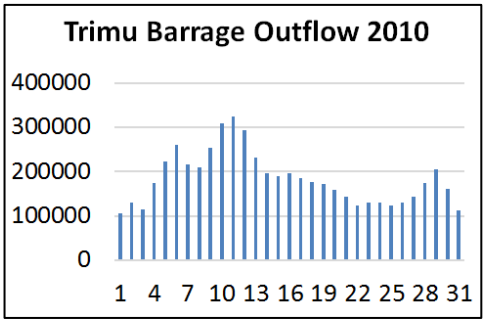


Fig. 17. Water as outflow at Trimmu Barrage during the flood of 2010.

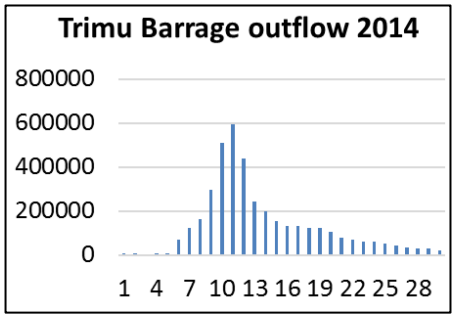


Fig. 18. Water as outflow at Trimmu Barrage during the flood of 2014.

Comparison of Socio-Economic Conditions During The Flood of 2010 and 2014

Socio-economic conditions of the study area were analysed spatially.

Area Affected by Jhelum Watershed during 2010 and 2014

The Fig. 19 & 20 indicated the affected area during the flood of 2010. The most affected areas were Rawalpindi, Jhelum, Gujrat, Bhimber, Mirpur, Kotli, Mandi Bahauddin, in which Mirpur remained at highest range of 440,000 acr affected area.

All these most affected area were located in the central part of study area. The least affected areas were Khushab, Sargodha and Jhang with the average affected area of 120,000 acr. So, all the least affected areas were found in the most southern part of the study area.

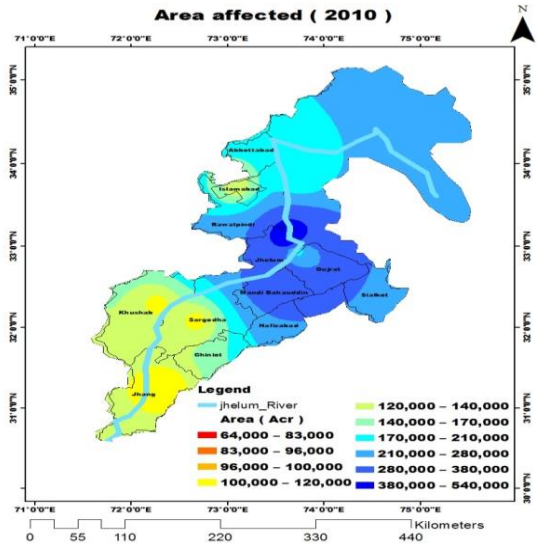


Fig. 19. Affected area in flood of 2010 in the Jhelum Shed of Pakistan

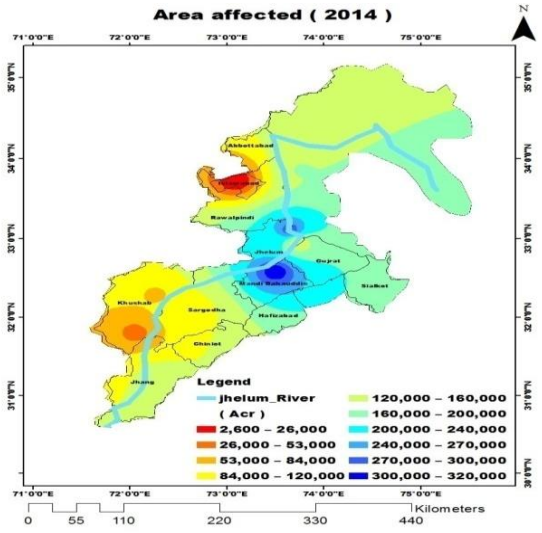


Fig. 20. Affected area in flood of 2014 in the Jhelum Shed of Pakistan.

Houses effected during 2010 and 2014

The Fig. 21 & 22 is shown the affected houses during the flooding period of 2010. The most affected houses were found in Mandi Bahauddin, Mirpur, Jhelum and Bhimber with the highest range of 6,300 affected houses. All these most affected houses were located in the central part of study area. The lowest numbers of affected houses were found in the area of Jhang district with the average affected houses of 1,200. So, the least affected houses were located in the southern part of the study area.

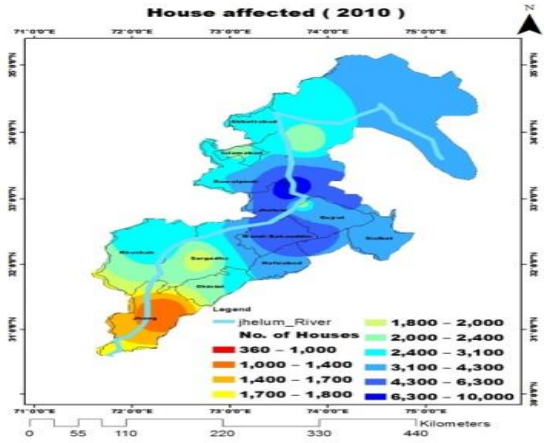


Fig. 21. Affected houses in flood of 2010 in Jhelum Shed of Pakistan

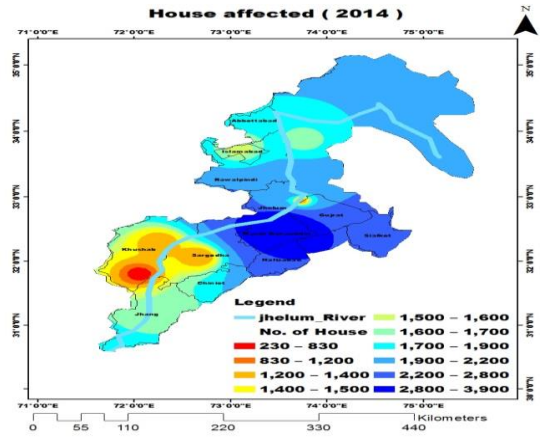


Fig. 22. Affected Houses in flood of 2014 in Jhelum Shed of Pakistan.

Villages Affected during 2010 and 2014 Flood

The Fig. 23 & 24 is shown the affected villages during the flooding period of 2010. The most affected villages were found in Mandi Bahauddin and Jhelum with the highest range of 260 affected villages. So, the least affected houses were located in the west central part of the study area.

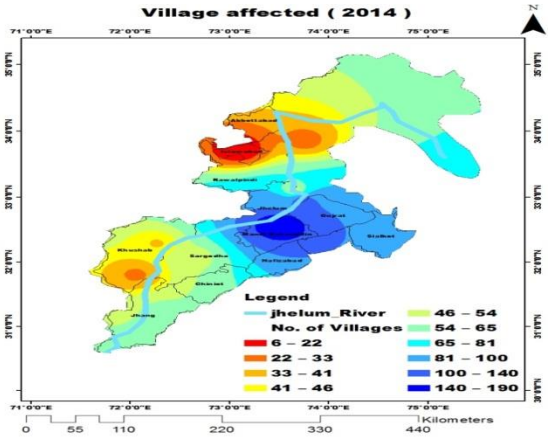


Fig. 23. Affected villages during flood of 2010 in Jhelum.

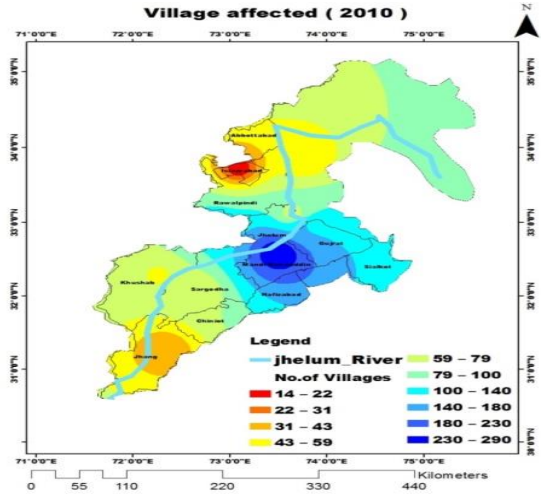


Fig. 24. Affected villages during flood of 2014 in Jhelum Shed of Shed of Pakistan

Crop Effected During 2010 Flood

The Fig. 25 & 26 the affected crop area during the flooding period of 2010 and Abottabad district with the average affected area 50,000 acr areas. So, the least affected crop area was located in the North western part of the study area.

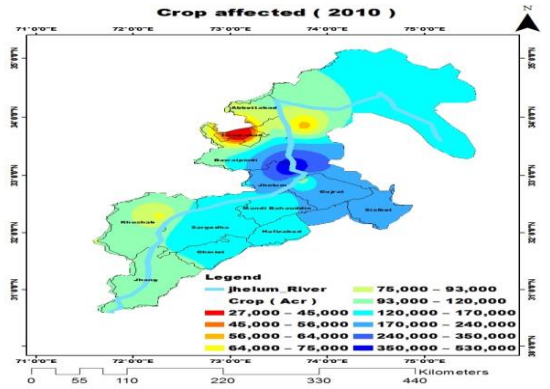


Fig. 25. Affected crop area during flood of 2010 in Jhelum Shed of Pakistan.

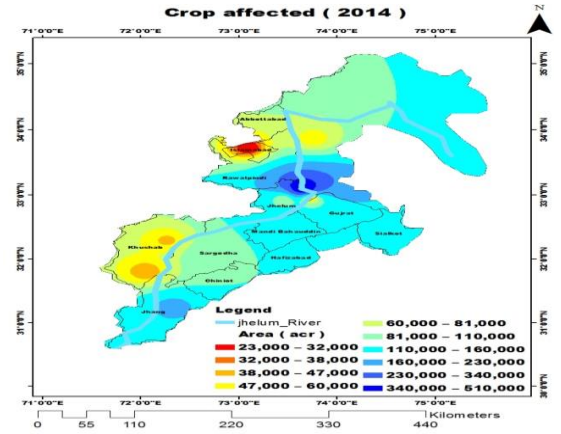


Fig. 26. Affected crop area during the flood of 2014 in Jhelum Shed of Pakistan.

Person Injured During 2010 and 2014

The Fig. 27 & 28 had shown the injured persons during the flooding period of 2010. The lowest numbers of persons injured were found in the area of Islamabad, with the average 3 injured persons. So, the lowest numbers of people were found in the North Western part of the study area.

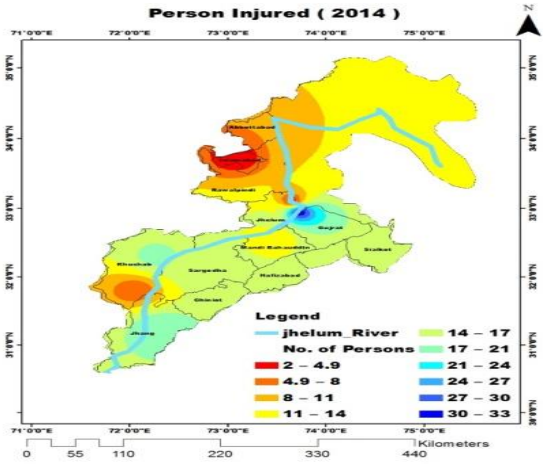


Fig. 27. Person injured during flood of 2010 in the Jhelum shed of Pakistan

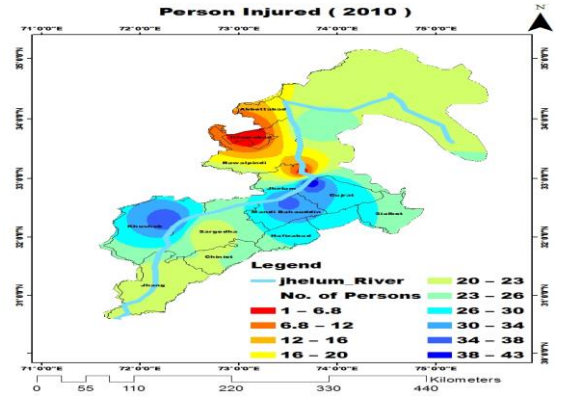


Fig. 28. Person injured during flood of 2014 in the Jhelum shed of Pakistan

Person Died During 2010 and 2014

The Fig. 29 & 30 is shown died persons during the flooding period of 2010. The area, where the most persons were died is Khushab and Jhang with the highest range of 27 average died persons 37 is shown died persons during the flooding period of 2014. The area, where the most persons were died are Khushab with the highest range of 27 average died persons.

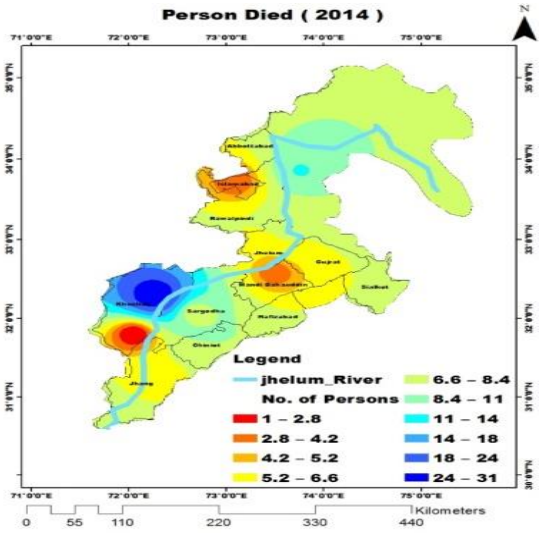


Fig. 29. Persons injured during the flood of 2014 in the Jhelum Shed of Pakistan

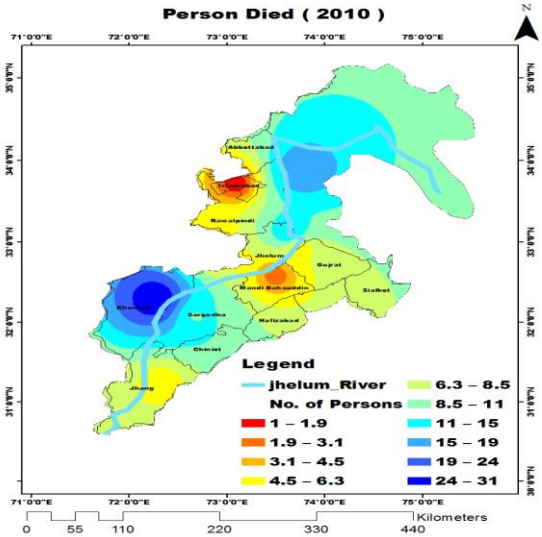


Fig. 30. Persons Died during The Flood of 2014 In the Jhelum Shed Of Pakistan

Animal Died During 2010 and 2014

The Fig. 31 & 32 is shown died animals during the flooding period of 2010. So, the lowest numbers of people were died in the north western, south western and cental part of the study area.

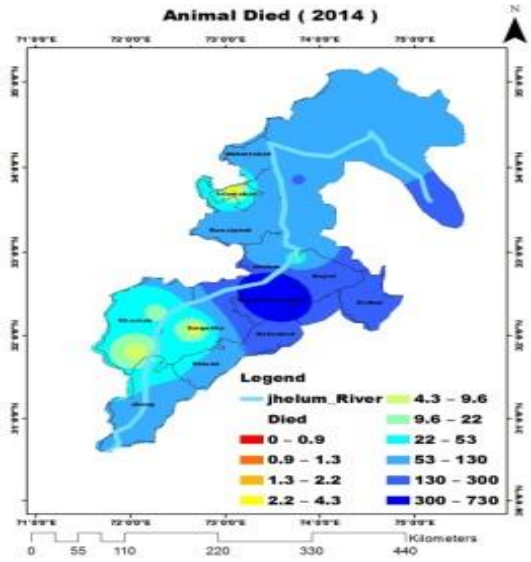


Fig. 31. Animal died during the flood of 2010 in Jhelum.

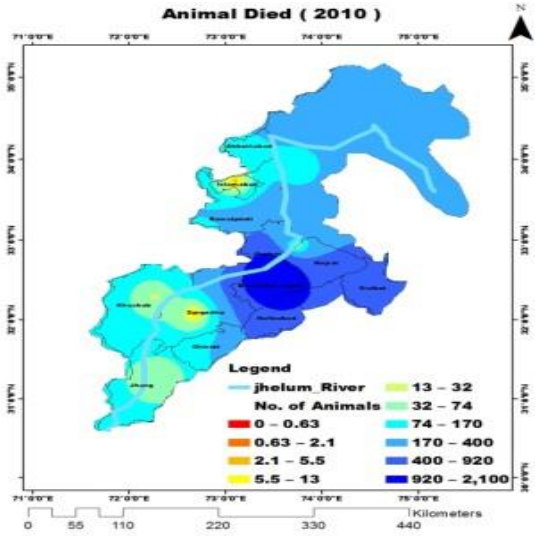


Fig. 32. Animal Died During The Flood Of 2010 In the Jhelum Shed of Pakistan

Vulnerability During The Flood of 2010 and 2014

Flood vulnerability has been discuused in terms of loss of property, lives of human beings etc.

Comparison of Houses Affected in 2010 and 2014

The spatial and statistical pattern of both flooded period have been changed. Fig. 33. The highest number of affected houses during the flood of 2010 Mandi Bahauddin, Mirpur, Jhelum and Bhimber but during the 2014 flood, the highest number of affected houses were located in Mandi Bahauddin, Jhelum and Gujrat. The highest number of 63,000 houses were affected in 2010 but 3,350 houses in 2014.

The least affected area of 2010 flood was Jhang but in 2014 was Khushab with the average affected houses of 1,200 in 2010 and 830 in 2014. So, spatial trend of affected area has been changed during these two flooded period and statistically, the average affected area has been increased in 2014 flood.

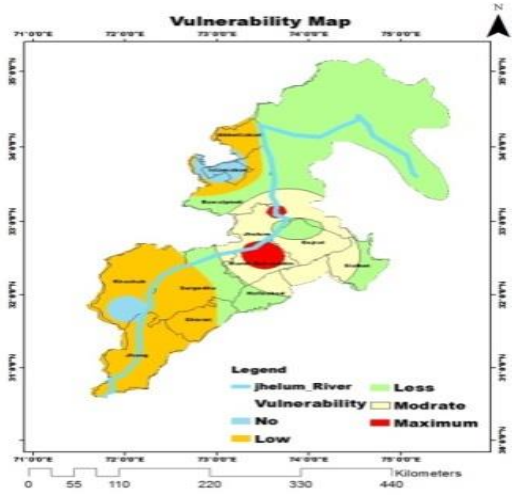


Fig. 33. Vulnerability during the flood of 2010 and 2014 in the Jhelum Shed of Pakistan.

Villages Affected During 2010 Flood 2014

The Fig. 34 & 35 is shown the affected villages during the flooding period of 2010. The most affected villages were found in Mandi Bahauddin and Jhelum with the highest range of 260 affected villages. All these most affected villages were located in the south central part of study area. The lowest numbers of affected villages were found in the area of Islamabad and Abottabad district with the average affected villages of 18 villages. So, the least affected houses were located in the western central part of the study area.

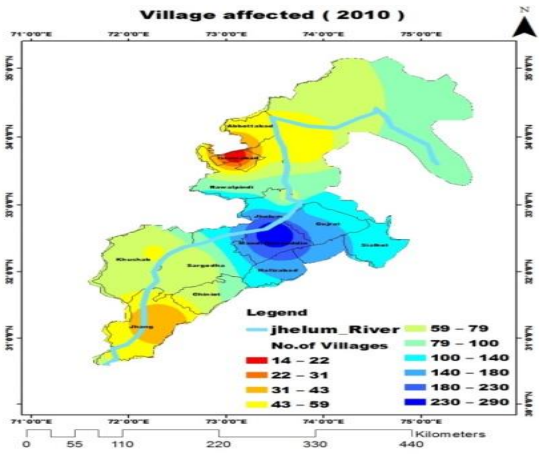


Fig. 34. Affected villages during the flood of 2010 in the Jhelum Shed.

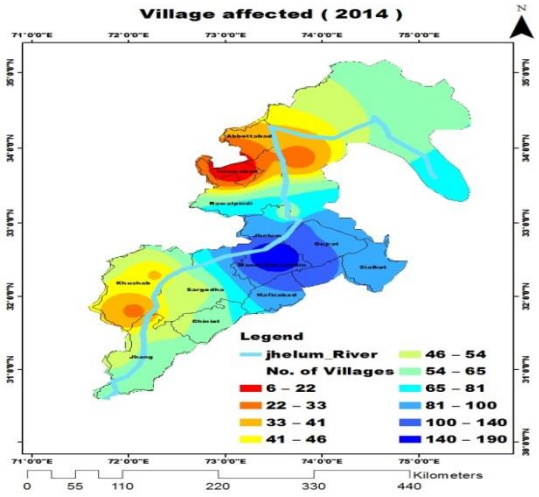


Fig. 35. Affected villages during the flood of 2014 of Pakistan in the Jhelum shed of Pakistan.

Results

These results showed that majority of dwellers in study area belonged to middle class farmers, many people lived under poverty line. These results revealed that flood of 2010 caused great damage to the farmer's houses and belongings.

Comparison of Rainfall

The highest rainfall has been recorded in the central eastern area of Muzafarabad district, from where the river Jhelum flow northeast to south and the lowest rainfall has been received in the east central part of Jhang district.

Comparison of Flood Water

Flood water greatly disturbed the Jhelum water shed of Pakistan during both the years of 2010 & 2014. But the flood of 2010 destroyed the agri lands of Jhang greatly.

Inflow & Outflow at Rasool Barrage

Outflow at Rasool Barrage was highest in 2010. Inflow was highest at Trimmu Barrage. All the most affected area was located in the central part of study area. While the outflow at Rasool Barrage increased in 2010 but decreased in 2014

Inflow & Outflow at Mangla Barrage

Average inflow & outflow of water in 2010 was highest in Mangla Dam than 2014. Rasool Barrage inflow was less in 2010 and more in 2014.

Inflow & Outflow at Trummu Barrage

Trimmu Barrage inflow was 232685.096 in 2010 and outflow was highest in 2010 than 2014.

Area Affected in Jhelum Water shed

The least affected areas were Khushab, Sargodha and Jhang with the average affected area of 120,000 Acr. So, all the least affected areas were found in the most southern part of the study area. The most affected areas during the flood of 2010 were Rawalpindi, Jhelum, Gujrat, Bhimber, Mirpur, Kotli, Mandi Bahauddin but during the 2014 flood, the most affected ares were parts of Khushab, Jhang, Mandi Banauddin and Mirpur

Villages & Houses Affected during 2010 & 2014

Villages in Mandi Bahauddin, Jhelum and Jhang were greatly affected in the flood of the 2010. Houses were also destroyed in Mir Pur Distric and Bhimber greatly.

Crops Affected During 2010 & 2014

Crops were greatly affected in 2010 as compared to 2014 flood

Persons Died during 2010 & 2014

The most died persons during the flood of 2010 were in khushab and Jhang but during the 2014 flood, the most died persons were found in Khushab

Animals Died during 2010 & 2014

The most died animals during the flood of 2010 and 2014were in jehlum, gujrat and mandi bahauddin.

Discussion

The spatial and statistical pattern of both flooded period have been fluctuated in 2010 and 2014.The least vulnerable areas during the both floods were Khushab, Islamabad and Rawalpindi. The moderately affected areas were all the northern areas of Jhelum Shed of Pakistan, Mandi Bahuddin, Sialkot and northern part of Sargodha. The most vulnerable areas during the period of both floods were central part of Jhelum shed of Pakistan especially Jhelum. The flood of the 2010 was more severe as compared to 2014 as maximum casualties happened during the 2010 flood. Both the inflow and outflow of water at the point of Mangla Dam has been decreased in 2014 flood than 2010 flood.

Conclusion

Assessment of severity was studied both statistically and spatially. The average annual rainfall during the flood of 2010 was recorded 79.81 inches and 61.34 in 2014 flood. So, the average decrease of 18.47 inches was notified during the flood of 2014. Heavy rainfall has been recorded in the months of July and August. August is the peak flood month of both flooded years (2010 and 2014). The inflow and outflow of water volume in the Jhelum Shed on these six points have also been changed with each other during the both flooded years of 2010 and 2014. The average water as inflow in Mangla Dam in the month of August was recorded 77390 cusec meters in 2010 and 72765.9 cusec meters in 2014. So, the average decrease of 4625 cusec meters in the water volume has been identified during the flood of 2014. The water received on the Mangla dam was low in 2014 flood as compared to the flood of 2010. Parameters selected for study were rainfall, affected area, person, houses, villages, crop area, injured persons, dead animals and persons. It has been analysed that flood of 2010 was more severe as compared to the flood of 2014 because all the Fig. and indicators were remained highest in 2010 and lower on 2014.. Effective flood preventive strategies should be conveyed to public so that flood damages should be reduced.

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