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Evaluating the flood hazard in District Mandi Bahauddin: a comparative study between 2010 and 2014

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Abstract

Fluctuations in climatic conditions enhances flood vulnerability, especially in the agricultural lands that lie alongside the river. This paper evaluates the causes of flood, variations in the spatial extent of flood peak dates and investigates the socio-economic impacts of flood, in district Mandi Bahauddin, Punjab, Pakistan for year 2010 and 2014. Primary data was collected through questionnaires from the farmers owning agricultural lands in the study area. Secondary data was obtained from various government organizations. Results prove that the effects of 2014 flood were more severe than 2010. Tehsil Phalia was badly destroyed in 2014 flood because it is located along side River Chenab. Flood left great effects on socio-economic life of people living in study area. For the prevention from the future floods, it is necessary to take mitigation measures and the policy of the government must be changed from disaster response to disaster mitigation. According to flood victims, structural and non-structural measures both are very important for the flood prevention.

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Introduction

Floods occur often in the region triggered by heavy monsoon precipitation and can cause enormous damages to lives, property, crops and infrastructure. The frequency of extreme floods is on the rise in Pakistan. Past extreme floods fall within the range of climate variability but frequency, magnitude and extent of flooding may increase in future due to climate change (Mirza, 2011). Worldwide, river flooding is a serious matter. Different countries face the highest floods that badly cripple their economy, e.g. floods in Bangladesh from Brahmaputra river (Chowdhury, 2003), Vistula river of Poland (Gupta and Shah, 2008).Flood damages are related with climatic and social factors i.e. highest damages occur due to heavy downpour of precipitation but also due to changes in land cover that occur as a result of population explosion. Different abnormal precipitation events are highly correlated with flood damages (Pielk and Downton, 2000). Floods occur particularly following the continuous rainfall episode or trample of dams. Rivers become swollen and overflow from their margins due to grand flood that might come as a result of heavy rainfall that falls in a short period. The situation gets triggered due to poor infrastructure of dams or barrages (Elizabeth Ferris, 2010).In future, flood hazard is bound to become more severe due to rapid socio- economic developments and climate change (Visser *et al*., 2014).

Flooding is one of the main natural disasters that is not restricted to particular geographical extent and occurs in number of forms like coastal flood, river flood and flash flood etc. All these types of floods are a result of both anthropogenic and natural factors (IPCC, 2010). The most vulnerable region for flood in the world is South Asia. Flood associated damages get exacerbated in this region due to heavy monsoon rainfall, shifts in climate and anthropogenically induced changes in land cover (Mirza, 2011). Climate as well as social level both are associated with the total flood damage also the high precipitation and more population related with flood damage (Pielk and Downton, 2000). Pakistan has faced many disastrous flood events, however most catastrophic were the impacts on lives and property of people caused due to 2010 flood (Atta-ur-Rahman and Khan, 2010). Pakistan is ranked 9th in terms of flood-affected countries worldwide (Baqir *et al*., 2012).Northern Pakistan faced terrible flood due to series of over flows caused by heavy monsoons in 2010. The life, property and the agricultural land of the residents of the affected districts were to face the impacts, for many coming years (Webster *et al*., 2011). Natural hazard like flood disturb the livelihood, cause infrastructural damages, interrupts daily services and creates health issues, affecting the agriculture area and cause severe impacts on the economy (Kirsch *et al*., 2012).

Strengthening of the capacity of local community against flood, has become essential, especially in developing countries like Pakistan (Few, 2003). Due to climatic and socio-economic changes, South Asia faces increased risk of flood frequency and magnitude. Measures that are adopted by the government of these countries are inadequate to address the safety from ever-increasing flood risk. In Pakistan, scientific research shows poor support focused on the flood issues and enhancement of institutional linkages, community participation and thus, evidence-based research becomes necessary. Flood has emerged as an unsolved problem that hits some parts of the country almost every year during monsoon (Azhar *et al*., 2012). After the devastating flood of 2010, an early warning system has been established in Lai Basin, passing through the twin cities of Rawalpindi and Islamabad. It is an effective step taken for timely warnings required during rainy season, to reduce the risk posed to people's lives and property (Mustafa *et al*., 2015).

District Mandi Bahauddin, the study area of the current research, is frequently hit by flood during rainy season, however, there exists no flood management institution in this area. More than 60% of the residents of district Mandi Bahauddin are

employed in agricultural sector. Major cash crops grown in this region are recurrently damaged by flood during rainy season, which leads to a dreadful financial drain on the economy of its residents. Landholding size, education, experience, farmers off-farm income and risk perception affect the farmer's attitude toward hazard. It provides implications for policy makers to provide the farmers with accurate management tools and risk mitigation tools (Saqib and Rana, 2016).

The present study aims to evaluate the flood hazard in district Mandi Bahauddin Punjab Pakistan. This study works on to access the causes of flood hazard along with monitoring the flood effects on socioeconomic life of people. It also aims to calculate the flood extent of two most devastating floods of the district's history, i.e. 2010 and 2014, by using satellite images. The final flood extent maps will be helpful for decision makers to identify the areas at higher risk where proper mitigation measures must be incorporated beforehand.

Material and methods

Study Area

Mandi Bahauddin district has a moderate climate; the climate here is classified as BSh by the Koppen-Geiger system. District receives 50cm as average rainfall. Pakistan has an agrarian economy. Major part of Mandi Bahauddin district is rural area, thus agriculture is main source of income for the people of this district. Sugar cane, wheat, rice and citrus fruits are important cash crops of this area. District Mandi Bahauddin covers 2,673 square kilometers as a district in the Punjab Province of Pakistan (District Pre-Investment Study – 2012). Mandi Bahauddinis about 220 meters above the sea level, and lies between rivers Chenab and Jhelum.

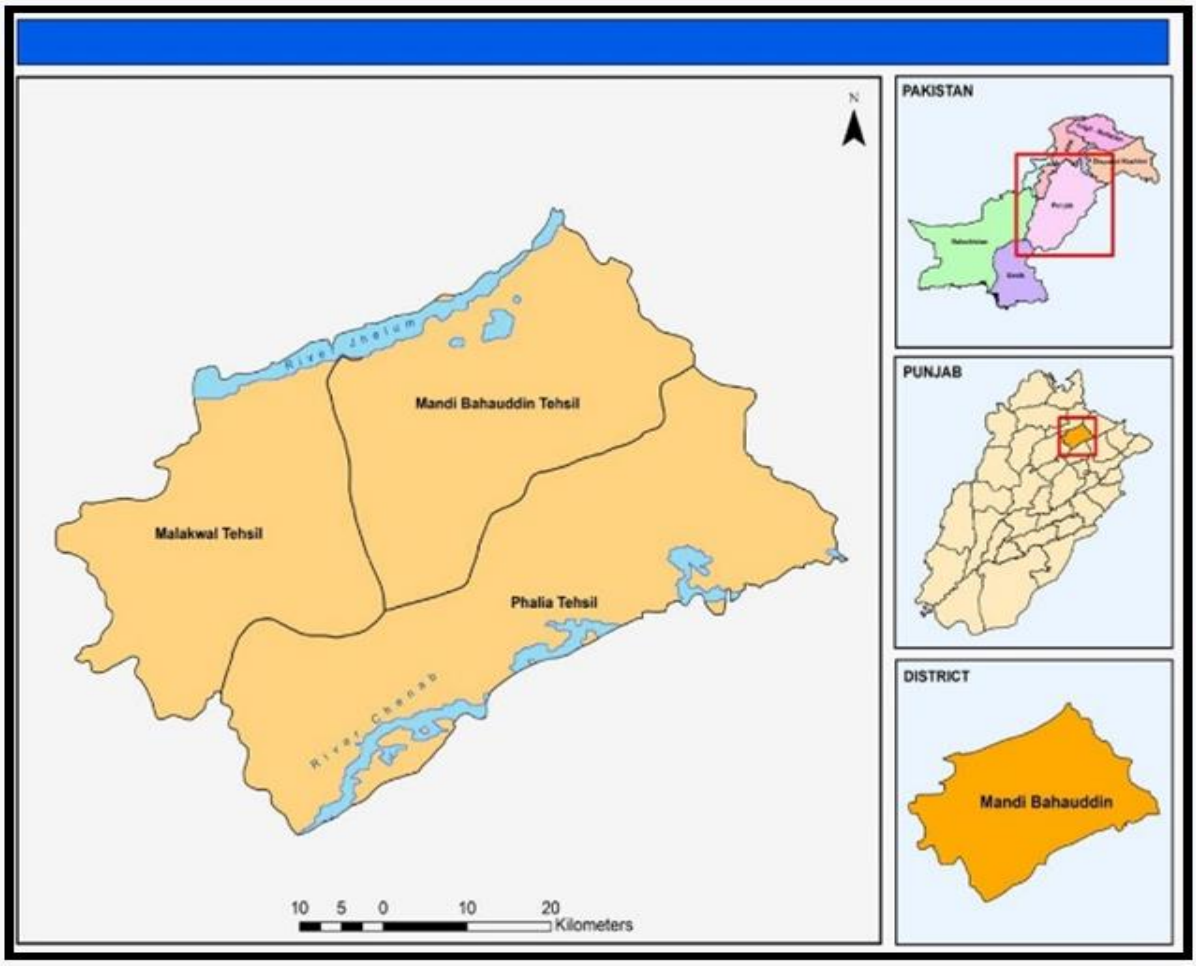

Fig. 1. Study area of District Mandi Bahauddin.

This district is considered as an active flood plan. In the past eight years Mandi Bahauddin has experienced major floods. When Chenab River came under flood during 2010 and 2014 it affected tehsil Phalia's villages, which are about 100 in number, and experienced almost 4 to 5 feet standing water.

These villages are Tariqabad, Makhdoompur, Thatta, Bahoo Manga and Chakari, Bahri, Saida, Farrukhpur, Jago, Bhoa Hassan. Meanwhile, more than 12 villages of Mandi Bahauddin and tehsil Malakwal were affected due to the flood that occurred in Jhelum River in 2010 and 2014. The affected villages include Mong, Khewa and Kotli. Due to flood disaster Mandi Bahauddin district experienced major losses of agricultural land, infrastructural damages and loss of precious human life. (TMA, 2009).

Data Acquisition

Data that was collected in order to meet the objectives of the study was comprised of both primary as well as secondary data. A survey was conducted to fill the questionnaire that was formulated for the flood affected population in order to collect primary data related to causes, effects of floods, perception of community about flood risk and also the comparison of 2014-flood with the flood 2010 experience. Pertinent secondary data sets were obtained from relevant organizations and departments. Data of mean monthly rainfall, maximum and minimum temperature for the time period 2004 to 2014 was collected from Pakistan Meteorological Department Lahore (PMD). Data related to economic and social loss was collected from Punjab Disaster Management Authority and District Revenue office.

Table 1. Status of Education facilities in affected communities.

Status of Education Facilities in affected Communities					
District	Total number of schools in affected area	Number of school available for schooling	Number of school used as temporary settlement	Number of schools fully/ damaged	% Schools damaged partially in affected areas
Mandi Bahauddin	161	140	6	15	9 %

Analysis of data was carried out through GIS based techniques i.e. data clipping that use the PDMA's base map to show the extent of flood, while the charts and graphs are made by using Microsoft Excel. Chi-Square test was applied on primary data to understand the relationship between the flood causes and its associated house damages, extent of flood and economic loss due to flood. Methodological work flow is presented in (Fig. 2).

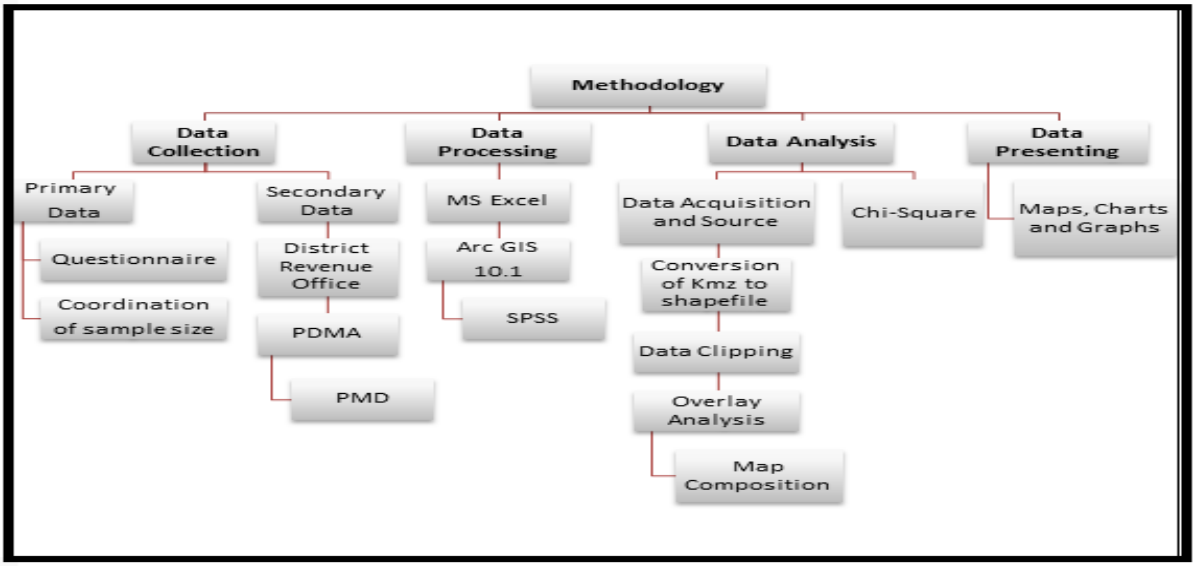

Fig. 2. Methodological framework.

Analysis

Mandi Bahauddin is a semi-arid area where summer season is hot and of largest duration. It usually begins in April and remains till September. The hottest months are May, June and July. The average maximum and minimum temperatures for hottest months remain between 39.7.1 ^0C and 23.4 ^0C [13]. Similarly, maximum rainfall which was caused due to monsoons, and considered to be two third rainfall of annual total, falls in July and August (Figure 3).

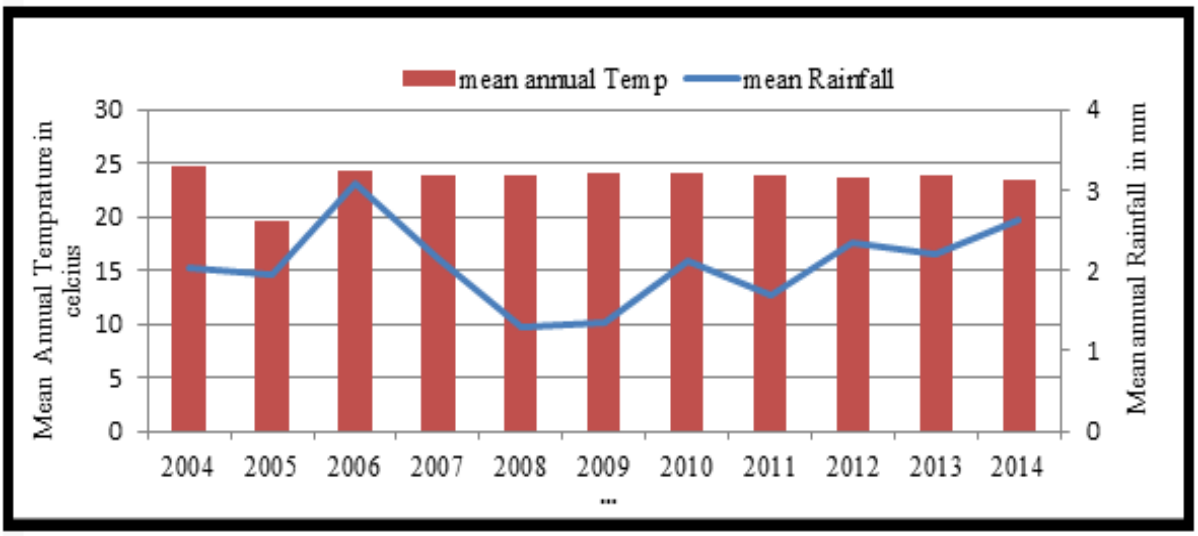

Fig. 3. Rainfall and temperature trend from 2004-2014.

December, January and February are coldest months and winter season starts from November and continues up till March. The highest and lowest temperature for winter period is 21.5 ^0C and 5.5 ^0C respectively (PMD, 2014). While January and February are characterized by moderate rainfall, associated with the western disturbances.

Mandi Bahauddin after 2006, when mean annual rainfall was high i.e.3.06mm, its trend started to decrease till 2009 when the mean annual rainfall was only 1.3mm. After 2009 mean annual rainfall tend to increase. In 2010 rainfall was 2.12mm but the amount of 2014 mean annual rainfall was 2.63mm, which is very high as compared to 2010.

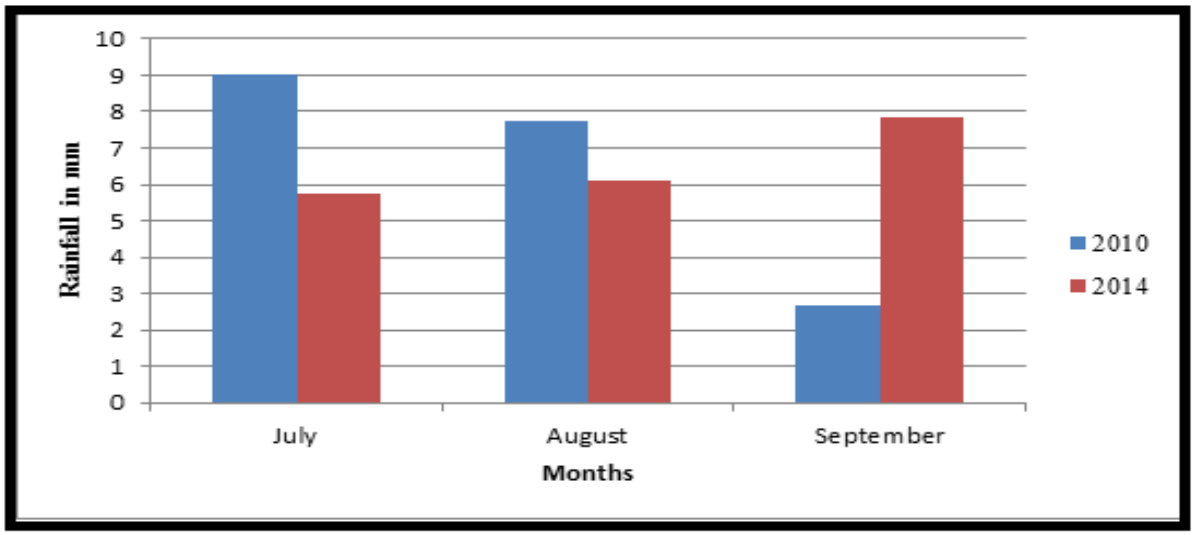

Fig. 4. Comparative Monsoon graph of 2010 and 2014.

This comparison shows that the 2014 flood in the district Mandi Bahauddin was far more severe than 2010 flood. Figure 3 also represents slight fluctuations in mean annual temperature of Mandi Bahauddin during all years.

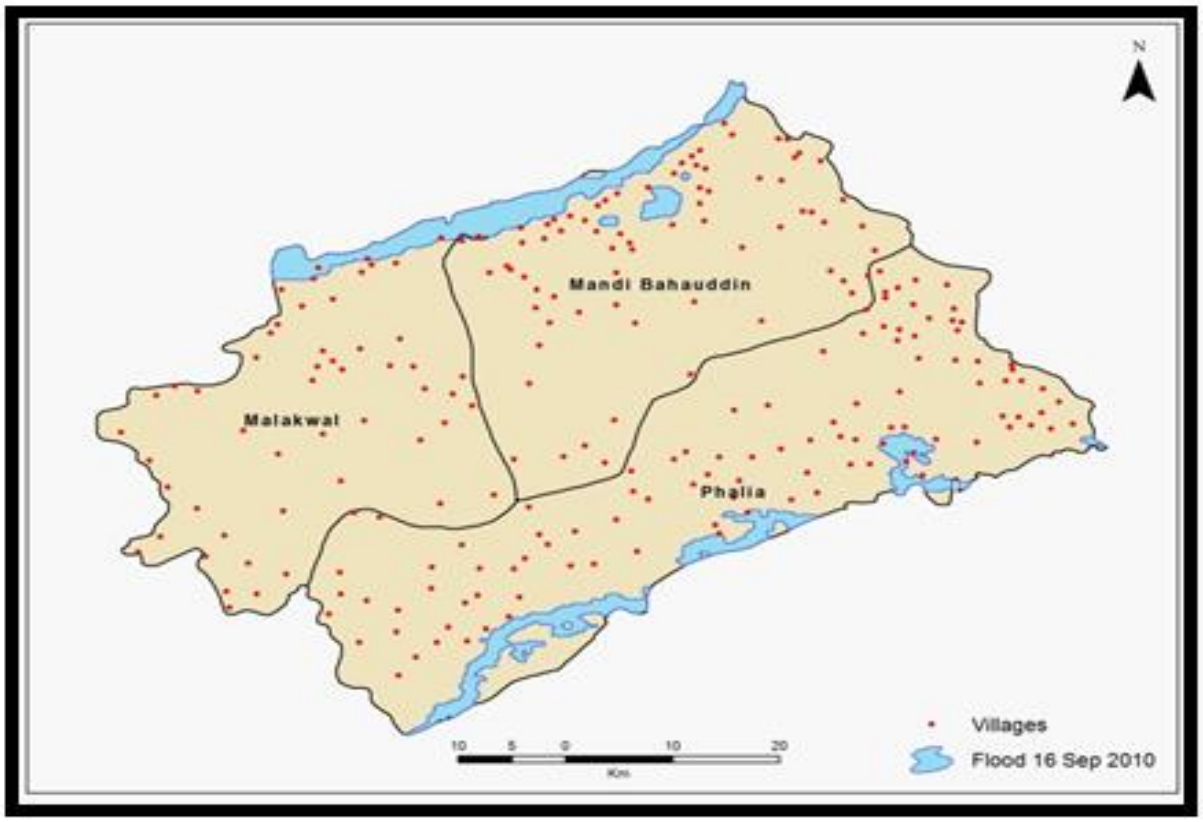

Fig. 5. Extent of 2010 flood.

Causes of Flood hazard in District Mandi Bahauddin

Figure 4 presents the comparison of monsoon months (July-Sep) rainfall for the year 2010 and 2014which presents interesting results that rainfall in July and August was more in 2010 than 2014 while on the other hand, in September the situation reversed, rainfall was devastatingly more in 2014 as compared to 2010. High torrential rainfall in the Gujarat, Mandi Bahauddin, Gujranwala, Hafizabad district of Punjab affected hundreds of villages badly and forced many people to migrate to safer places.

The questionnaire survey results concluded that major cause of floods in this area, according to the perception of the locals, was due to abnormal rainfall events and poor structural measures. Webster *et al.*, (2011) described in their study that over northern Pakistan a catastrophic flood occurs due to a series of monsoonal overflow. 50% of the respondents in this study, considered abnormal rainfall as a cause of flood, 3% considered bad structural measures, while 45% considered rainfall and bad structure both as the major causes of floods. Downton, (2000) and Elizabeth Ferris, (2010) also elaborated the same fact that suddenly after the heavy rainfall episode flood can occur along with crumpling of dams.

Extent of 2010 Flood in District Mandi Bahauddin

At Qadirabad barrage, situated on River Chenab, on 27th August 2010 water level reached 329,483 cusecs. This water inundated Tehsil Pahlia, located south east of river Chenab, and damaged the land area as shown in figure 5. Similarly, at Rasool Barrage on River Jhelum, water level reached 263,796 cusecs on 30th August 2010, which affected Tehsils Mandi Bahauddin and Malakwal.

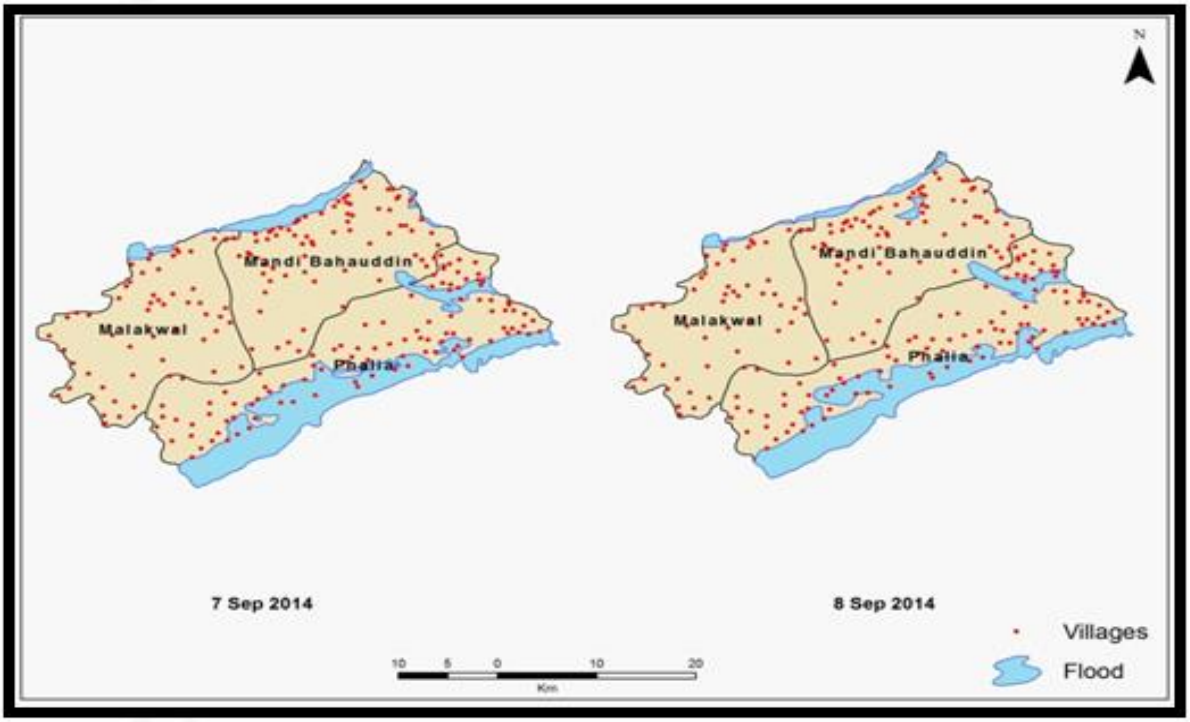

Fig. 6. Extent of 7-8 September 2014 flood.

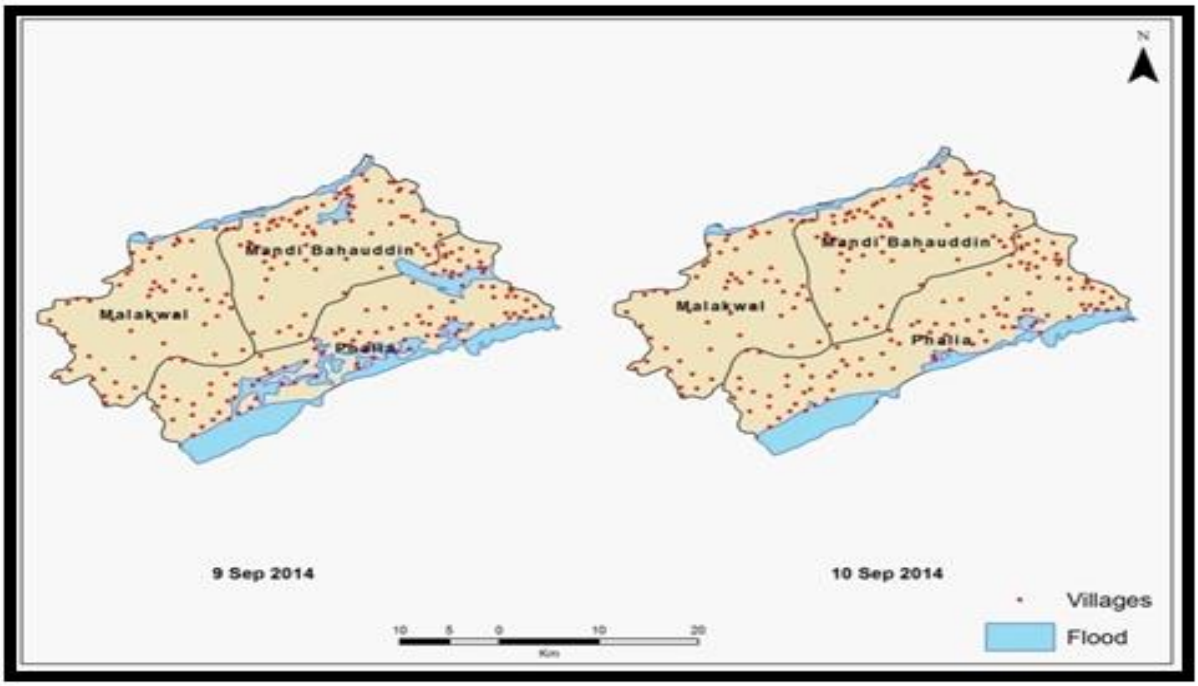

Fig. 7. Extent of 9-10 September 2014 flood.

In Figure 5 water extent on 16th September 2010 is presented, which affected area of 165.46 sq. km.

Extent of 2014 Flood in District Mandi Bahauddin

Figure 6 has shown that flood extent in 2014 was more than 2010 flood with comparison of water peak value on 7th and 8th September 2014. On 7th September 2014, flood expanded more in District Mandi Bahauddin and has shown that it covered more area that is 482.437 sq km of Tehsil Phalia as compared to other two Tehsils. Thus, maximum villages especially in Tehsil Pahlia of District Mandi

Bahauddin were affected badly on 7th September 2014. While on 8th September, very slight change appeared, and water level started to decrease and flood covered less area 440.23 sq km in villages.

Its reason is that water peak level at Qadirabad Barrage (River Chenab) on 7th September was 947,000 cusecs, while on 8th September it was 904,000 cusecs. Furthermore, figure 7 also shows the difference of flood extent in District Mandi Bahuddin on 9th and 10th September 2014. On 9th September flood extent was more in study area that cover 380.653 sq. km and more villages were under flood especially in Tehsil Phalia than 10th September 2014 flood extent that cover 227.425 sq. km.

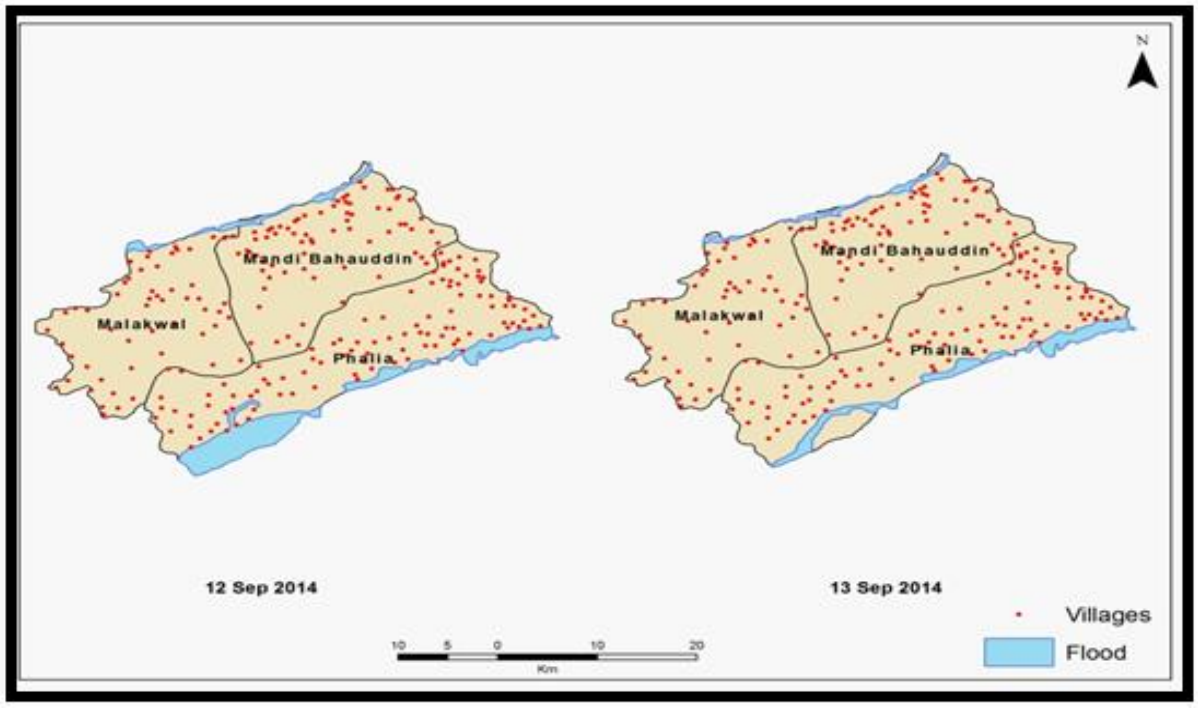

Fig. 8. Extent of 12-13 September 2014 flood.

Moreover, figure 8 shown more difference of water encroachment toward land between 12th and 13th September 2014. Major change appeared in flood extent area of Tehsil Phalia on 12th September that occupies 219.115 sq. km which rapidly decreased in 24 hours to 12.751 sq. km on 13th September.

Its reason is that at Qadirabad Barrage (River Chenab) and Rasool Barrage (River Jhelum), water level started to decrease rapidly which resulted in decline stage of flood extent.

Finally, figure 9 has shown more changes in Tehsil Phalia between 15th and 16th September 2014. On 15thSeptember area that covered with flood was 156.074 sq. km while on 16th September it decreased to 123.029 sq. km. After 16th September, more than 90% area of District Mandi Bahauddin was free from flood extent.

It has been observed that 2014 flood affected more villages in District Mandi Bahauddin than 2010 flood.

Chi-square results show a statistically significant relationship between flood causes and extent of flood. The data set was coded and entered in SPSS so that Chi-square non-parametric test of independence could be applied. The P value was .001 which was less than α (alpha), i.e. 0.05 thus $p < \alpha$, thus H_i will be accepted. Therefore, it can be concluded that if major cause of flood if high rainfall then the flood extent will also be large.

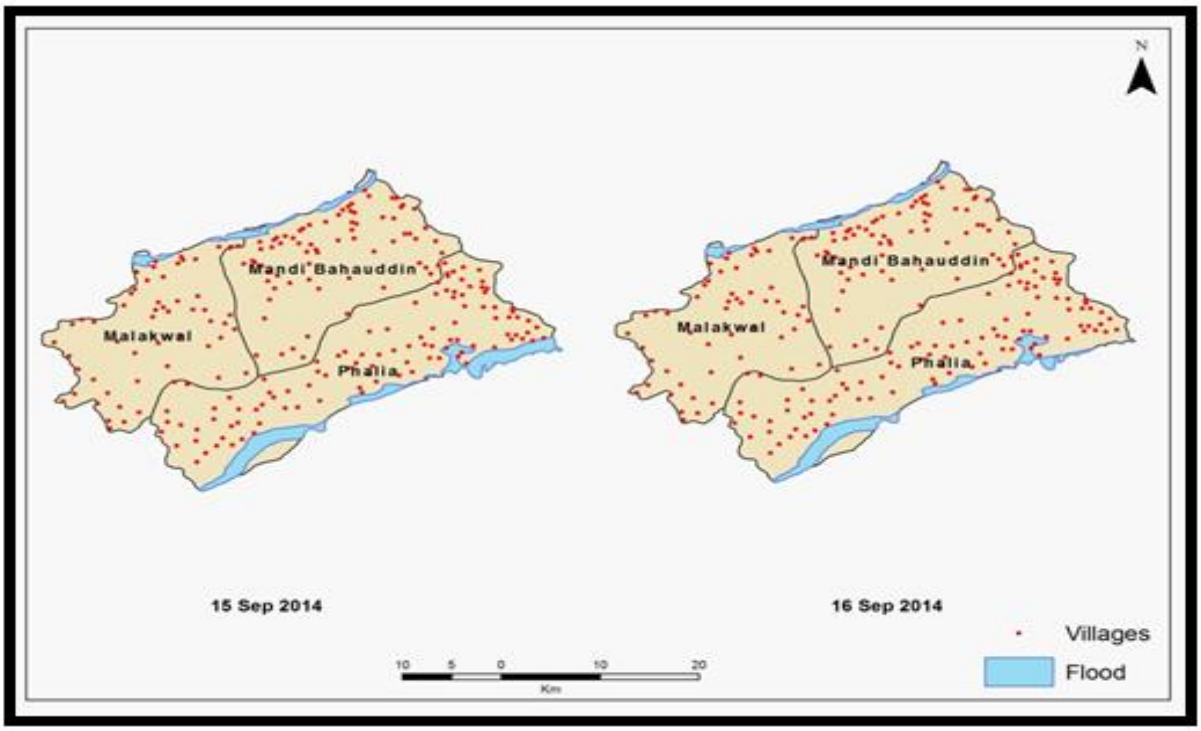

Fig. 9. Extent of 15-16 September 2014 flood.

Effects of flood hazard on socio economic life of people in District Mandi Bahauddin

In 2010 and 2014, an immense farmland area and infrastructures of District Mandi Bahauddin have been destroyed due to flood and this loss occur mostly in those areas that are inhabited by low income people who do not have enough resources to rehabilitate quickly to their previous position. The water started flowing in south eastern direction from river Chenab, and in north western direction from river Jhelum, in response to seasonal monsoon rains of 2010 and 2014, and affected the local community's lives and property. The impact of flood has been classified in the following categories:

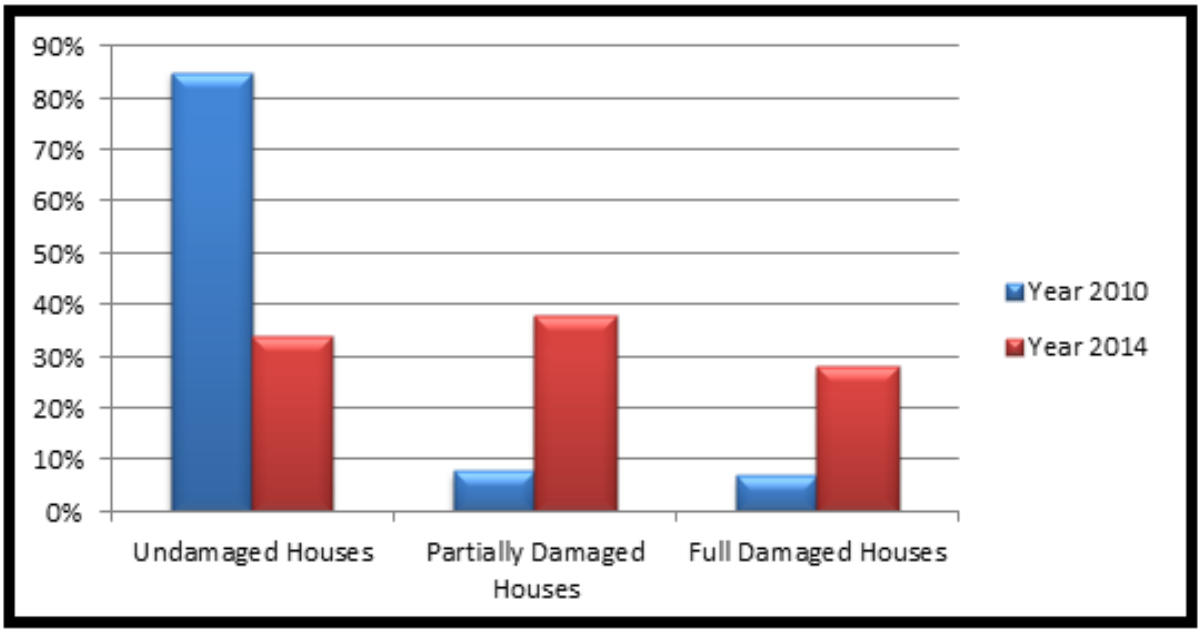

Fig. 10. Houses damaged due to 2010 & 2014 flood.

Houses Damaged due to Floods

Based on the field survey it was found that the study area had three types of houses in which 34% of the respondents had semi-pucca house, 4% have katcha while 62% have pucca house type. According to this survey almost 38% of the houses that made with katcha and semi-pucca materials were more vulnerable to damage caused by floods.

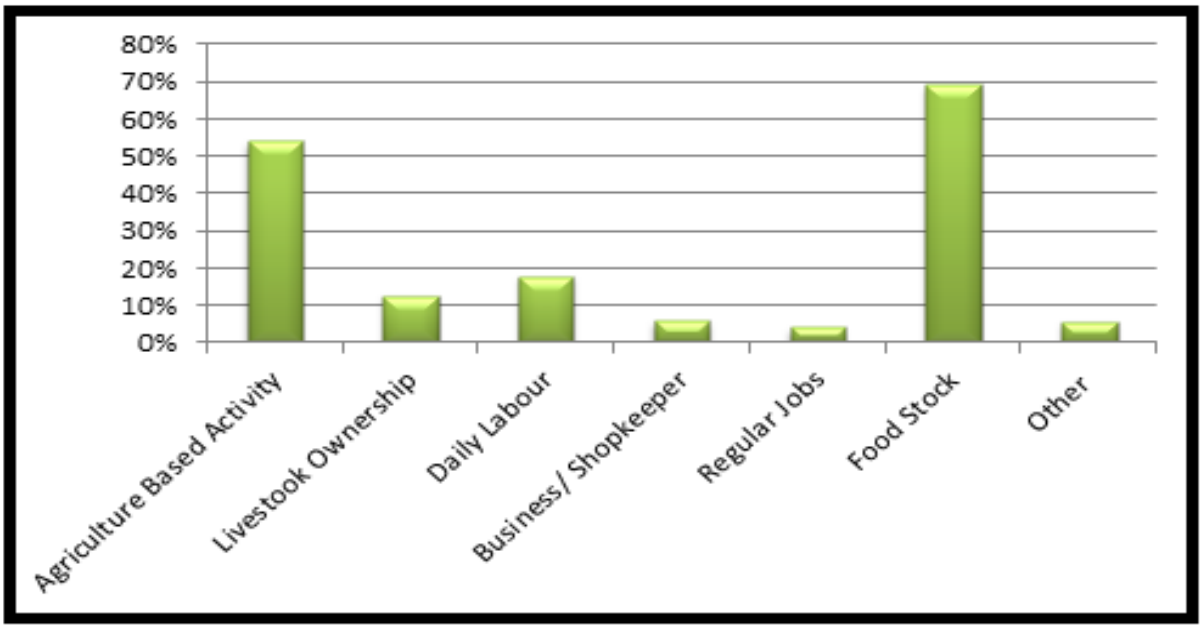

Fig. 11. Losses to livelihood sources after flood.

According to Figure 10, the percentage of damage houses in District Mandi Bahauddin due to 2010 flood was analyzed that 7% houses were fully damaged, 8% were partially damaged while 85% were undamaged. While on the other hand 2014 flood caused a large number of house damage than 2010 flood. 34% houses were completely damaged while 38% were partially destroyed. Residents of these houses i.e. about 7809 people were evacuated from flood affected area.

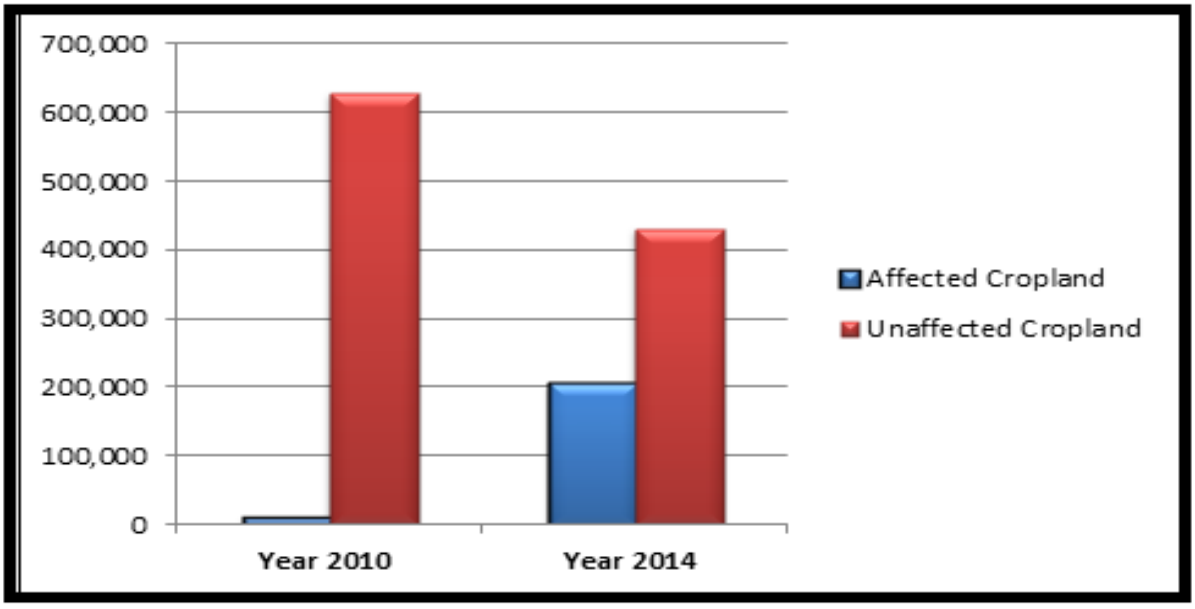

Fig. 12. Comparison of Cropland affected due to 2010 and 2014 flood.

Chi-square results showed a statistically significant relationship between flood causes and houses damaged. It is non-parametric test of independence. The P value was .002 which was less than α (alpha), i.e. 0.05 thus p< α, thus H_i will be accepted. Therefore, we conclude that floods were a reason for the house damage.

Village Affected due to 2010 and 2014 Floods

Like house damages, flood in the study area also affected many villages. 46% villages were affected due to 2010 flood. People in these villages faced many problems. Unaffected villages in 2010 were 54%. While in 2014 flood cause more bad impact than 2010 flood in this area and affected 57% villages of the district and unaffected villages were 43%. People in these villages were socially and economically badly affected by floods.

Affected population in the flood affected areas

Large number of population has been affected in Mandi Bahauddin affected areas due to flood in 2010 and 2014. Total number of population in flood affected areas was 1,384,000 and 1,611,360 while the affected population is 161, 5139(11.67%) and 226,645(14.06%) in 2010 and 2014 respectively.

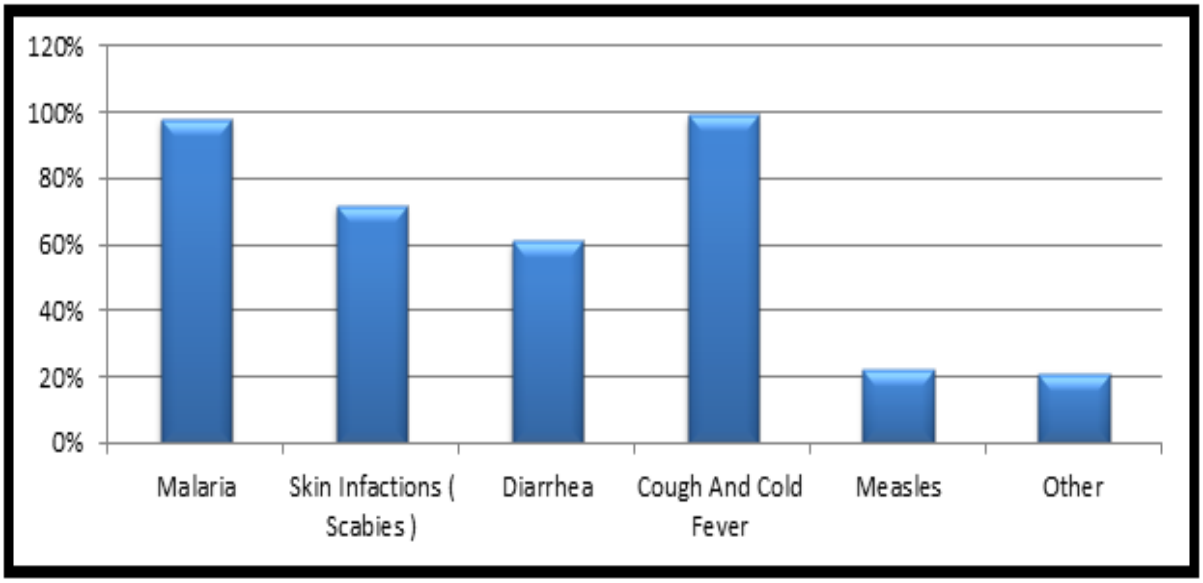

Fig. 13. Main health problems reported in the community (Percentage).

Flood Impact on Livelihood

In the study area primary source of income not only for flood victims but also for entire population was agriculture. After survey, it was examined that 63% of the households earned their living through agriculture. Besides agriculture, daily laborer (16.3%), livestock herding (8%), business/shop keeping (4.5%), daily-wages jobs (6.1%), home-based workers (0.4%) and others (1.7%) were reported as influential livelihoods.

According to the result of study figure 11, 12.5 % income of those houses that earned from livestock rearing, was lost due to flood, 54% agriculture based income was affected, about 17.8% of the day laborers were affected, 69 % food stock was affected from which 5.8% of those who were related with business/shop as a source of income, came under flood influence while those households that gave information about the loss of livelihood were 5.7% of the total population. 4.2 % of the respondents were having Government or private jobs at regular base and reported that they were much stable in their income.

In the meanwhile, animal diseases which were recorded during survey were foot and mouth disease, external and internal parasites, Hemorrhagic

Septicemia and Black Quarter appeared high due to flood. Maximum loss was reported in Tehsil Phalia of District Mandi Bahauddin because it is flood plain of river Chenab.

Comparison of Cropland affected due to 2010 and 2014 flood

Along with above mentioned affects flood also destroyed the cultivated land. In 2010, flood destroyed less cropped area than 2014 flood which was almost 10, 211 acres of agricultural land as shown in figure 12. On the other hand 2014 flood damaged a large area of agricultural land i.e. 2, 06,000 acres.

Flood impacts on health

Figure 13 show the details of prominent health crisis in the flood affected area. The main disease that affected the population was Malaria along with the cold and cough, and fever that stood at second rank, while measles infection was least to be reported. Skin infections were also prominent in Mandi Bahauddin. Diarrhea was also the most common health issue.

Impact of Flood on Education

The immediate evaluation about the flood in District Mandi Bahauddin revealed that this district has bad school infrastructure. 161 schools were functioning in affected areas of Mandi Bahauddin form which only 15 schools were partially or completely damaged while 6 schools were used as temporary settlement. 9% schools were damaged in relation to the total percentage of schools which are shown in Table 1.

The situation of school going children was also examined in the district Mandi Bahauddin. It was noted that 23.3% children were absent from school in the area of Mandi Bahauddin that were affected due to floods. Wadhwani *et al.*, 2012 also proved the same facts which are illustrated above that human daily life and services along with their lives are disturbed when flood decimate all sectors of economy and society.

Conclusion

Mandi Bahauddin experiences high flood from Chenab river than Jhelum river, during flood season. That is the reason Tehsil Phalia of district Mandi bahauddin was more affected due to flood of 2010 and 2014, as compared to other areas. During field survey villages of Tehsil Phalia were selected that are near to Chenab River or on the embankment of the Chenab River.

This study concludes that according to field survey and PMD, causes of 2010 and 2014 floods in Mandi Bahauddin were abnormal rainfall and bad structural measures. The mean annual rainfall in 2014 was 2.63mm which was higher than the mean annual rainfall of 2010 i.e. 2.12mm and also above the monthly normal rainfall. Water level reached 329,483 cusecs in Qadirabad barrage which is situated on River Chenab, on 27th August 2010 at initial phase of flood while in 2014 water level reached 947,000 cusecs on 7th September, while on 8th September it was 904,000 cusecs which also indicated that 2014 flood was more hazardous than 2010.

Great damages in many villages happened as a result of largest and hazardous floods. Houses have been severely affected by the floods which were situated along river side.

The houses have almost no withstanding ability especially those that are constructed with mud have very little resistance to flood events. 2010 flood affected 55 villages and almost 20 houses were damaged while in 2014 flood, 103 villages and 568 houses were affected. Mandi Bahauddin is an agricultural district and flood destroyed the large area that came under the agriculture land which was more than 300 acres of land in that area. While the figure that was given by secondary data source i.e. PDMA report, that 2010 flood destroyed 10, 211 acres of crops area while 206, 000 acres crop areas were affected due to2014 flood in whole district. In the same way, flood also affected the livelihood of people, their health and also had negative impacts on

education sector, since many schools were damaged due to flood. People suffered from many diseases like malaria, diarrhea, etc. Mitigation measures are very necessary for the prevention of future flood hazard. According to the flood victims two factors are important for the prevention of flood and to lessen the intensity of flood impacts.

One is structural measures, like walls built along banks, construction of dams and use of flood resistant material for the houses and second one is non-structural measures include training of how to evacuate from flood affected areas, or the policy of the government must be changed from disaster response to disaster mitigation.

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