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Geo-Spatial Analysis: Multi-Hazards' Exposure Assessment of the Balakot Town - Pakistan

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ABSTRACT

The town of Balakot is exposed to number of natural hazards i.e. earthquake, flash flood, landslide, drought, fire, hailstorm, snowfall and windstorm. Each hazard has their own causes, nature and consequences. The elements at risks are houses, public buildings, infrastructure of utilities and services, agriculture, commercial, manufacturing etc. which has different exposure to these multi-hazards. This exposure is highly increased after Earthquake- 2005. The exposure of the elements at risk is changed with location and hazard. The interrelationship is explored through Geo-spatial analysis. Geographic Information System (GIS) platform is used for Geo-spatial analysis. The Balakot Town is highly exposed to earthquake hazard and the large portion of the bazaar is exposed to flash flood. The landslide, drought, fire hailstorm, snowfall and windstorm exposure are increased due to poor infrastructure and fabricated shelters. The geo-spatial analysis results of earthquake, floods and landslides are described through maps.

Keywords: Multi-hazards, Exposure, Elements at Risk, Earthquake, Flash Flood, Landslide, Geo-spatial

INTRODUCTION

The town of Balakot located in the Lesser Himalayan region at the right bank of Kunhar river. The tehsil Balakot is spread over 34°31′26.2″ - 34°33′42.6″ North Latitude and 73°20′26.8″ - 73°22′7.9″ East Longitude (Geological Survey of Pakistan [GSP], 1961). In the 2017 census, the population of Balakot town was 2,73,089 with the annual growth rate of 1.3 % which was 2.2 % in the 1998 census (Government of Pakistan [GOP], 2000; GOP, 2017). The town of Balakot located in the centre of valley Kunhar River and used as a gateway to Kaghan Valley. The Balakot town is not only the tehsil headquarter but also centre of political, social and cultural activities in this region. The administrative, tourism and commercial centre play a vital role for the economic opportunities in this region. Consequently, the residents of this region enjoy a well-off status in their living standard (Collins, 2009; GOP, 2005).

The earthquake of 7.6 magnitude on October 8, 2005 almost totally destroyed the physical infrastructure of housing, commercial and public buildings in this region with heavy death tolls and causality (Baig, 2006; GOP, 2006). The Earthquake Reconstruction and Rehabilitation Authority (ERRA) carried out seismic risk assessment in this region. The Balakot town and its surroundings were declared as red zone for residential purposes (GOP, 2007). However, people are still residing there and all their administrative, political, social and culture functions are restored with the passage of time. This region is not only exposed to seismic activities but also to number of other natural hazards including flood, landslides, drought, fire, snowfall, hail and windstorms etc. The adaptive capacity was dramatically changed after Earthquake – 2005. The use of fabricated shelters for residents, commercial and public buildings usage increase the vulnerability and exposure to these hazards.

In the present study, the elements at risk are identified i.e. household, public buildings, utilities and services, agriculture, commercial, manufacturing etc. and their physical conditions and/or vulnerability are assessed through transit walk by a rapid appraisal method. The historical records of disasters and their types causes and nature of hazards in the study area are studied to establish relationship between element at risk and specific hazard. The location-based interrelationship leads towards exposure analysis. The exposure of each hazard is different from other one because of different causes and nature of hazard along with the response of different elements at risk (Figure 01).

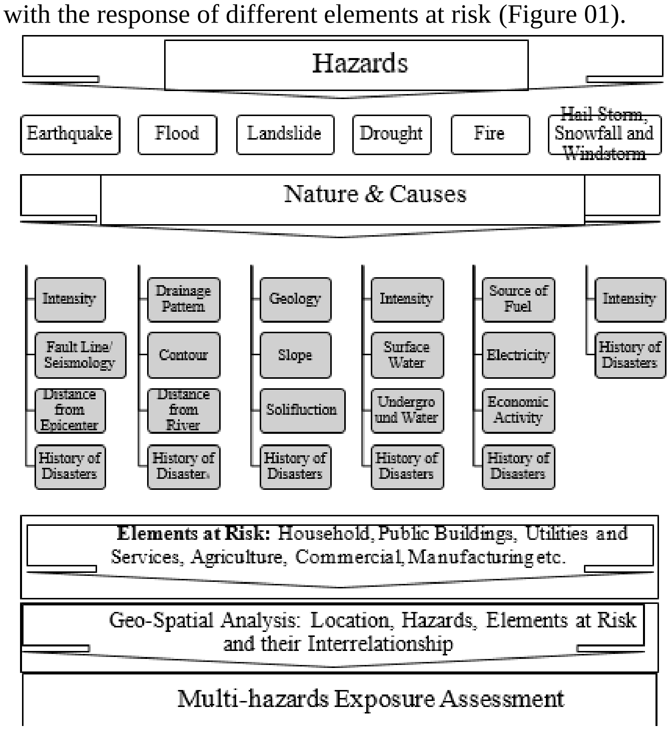

Figure 1: *Theoretical Framework of the Study*

DATA AND METHODS

The town of Balakot and its surroundings' areas which were included in the red zone are Union Councils (UCs) i.e. Balakot,

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Garlat, and Ghoonal. The two UCs of Balakot and Garlat had line share by population and area. In 2017 census, their population are 14,681 and 19,513 with 5.59 and 5.58 households' sizes. The annual percentage growth rate in these two major areas of red zone of Balakot are 1.35 and 2.58. The exposure assessment of multi-hazards through geo-spatial analysis is the methodology based on multi variables assessment in the Geographic Information System (GIS) platform. The essentials of this methodology are linking the elements at risk with the hazards. All hazards are unique with their causes, consequences and impacts. So, there exposure assessment is totally different from each other.

The inventory of elements at risk is compiled in a land uses survey. The Google Erath images are used as a base map for this study. The details of each elements at risk are recorded on the map which were converted to attributes data in GIS. The land use map work as base for elements at risk in the GIS and attributes details are used in geo-spatial analysis. In the earthquake exposure assessment, the history of hazard, distance from major and minor fault lines and critical slopes are considered. The landslide exposure assessment is based on part of earthquake variables with geology. Most importantly, considering each geomorphological unit as whole not in parts for their impacts on the elements at risk. The exposure of flood is geo-spatially dynamic all along around the banks of river Kunhar. The distance from the stream, slope and height are important parameters for the flood exposure assessment. Drought, fire and storms assessment are based on field observations and questionnaire survey. The inventory of elements at risk in the GIS is updated for these surveys and analysed for each hazard exposure assessment. Most of the results are described in the form of maps.

Elements at Risk

In the year 2017, the total number of households was more than 4500 in red zone region of the Balakot and its surroundings. In survey, four types of houses in the study area are identified: fabricated, *pakka* (cemented), Semi- *Pakka* (partially cemented), and *Katcha* (adobe). More than 80% of the housing structures are still fabricated shelters (Table 01). Besides fabricated shelters, reinforced cement concrete (RCC) and adobe structures had major share in the shelters of the area. Most of the public buildings e.g. office of Tehsil Municipal Administration, Electricity Supply, offices of judicial complex, security offices, banks etc. were also in fabricated shelters. More than 1500 units shops in the commercial areas of Balakot town provided services to local and regional customers. Most of these shops are rehabilitated in the fabricated shelters. With the passage of time, newly shopping plazas are constructed with RCC structures. The overall proportions of fabricated and RCC in commercial were 80% and 15 %, respectively. The type of commercial buildings and nature of commercial activities are described in Table 02. Likewise, any modern town, the utilities and services in the town of Balakot and its surroundings are at higher standards from the rest of Kunhar valley. These services and utilities included health, education, telecommunication, electricity, gas, streets, roads, bridges, and water and sanitation for health (WASH) facilities. 41 educational institutions provided the services to local as well as surroundings valley residents. The fabricated shelters were used in tehsil headquarter hospital and two dispensaries of the Balakot town. The physical infrastructure of the WASH facilities and transportation services were far behind the standards due to red zone limitations.

Table 1: *Types of Houses and Location Based Percentage Share*

Union Council	Resident/ Location	Fabricated	*Pacca*	*Semi Pacca*	Adobe	Other	Total
Ghanool	Ghanool	4.3	0.1	0	0	0	4.4
Balakot	Upper Pori	0.2	0	0	0	0	0.2
	Upper Bampora	1.6	0	0	0	0	1.6
	Titwal	1.6	0.1	0.1	0	0	1.8
	Takkia Lehari	0.3	0	0	0	0	0.3
	Single Poi	1.3	0	0	0	0	1.3
	Shah Ismailabad	1.1	0	0	0	0	1.1
	Rehmat Abad	0.3	0.1	0	0	0	0.4
	Pori	1.3	0	0	0	0	1.3
	Podina Baila	1.3	0	0	0	0	1.3
	Nawaz Abad	0.5	0	0	0	0	0.5
	Mangli	6.3	0.3	0	0	0	6.6
	Lughmani	1.6	0.3	0	0	0	1.9
	Lower Pori	0.6	0	0	0	0	0.6
	Lower Bampura	1.9	0	0	0	0	1.9
	Lehari	1.2	0	0	0	0	1.2
	Kohistan More	0.9	0.1	0	0	0	1
	Khwaja Khaili	4.1	0	0	0	0	4.1
	Khairan	1.2	0	0	0	0	1.2
	Kali Mitti	0.9	0	0	0	0	0.9
	Kach Bali	0.3	0	0	0	0	0.3
	Jalora	1.1	0.4	0	0	0	1.5
	Grid Baliani	0.5	0	0	0	0	0.5
	Dhodhiari	1.2	0	0	0	0	1.2
	Bazaar Baliani	0.7	0	0	0	0	0.7
	Baliani	2.7	0.1	0	0	0	2.8
	Bajori	1.8	0	0	0	0	1.8
	Bagh Baliani	0.5	0	0	0	0	0.5
Garlat	Upper Narah	7.5	0.1	0	0	0	7.6
	Upper Garlat	3.8	0	0.2	0	0	4
	Qadarabad	3.3	0	0.2	0.1	0.1	3.7
	Pandi	5.6	0	0	0	0	5.6
	Narah	3.9	0.3	0	0	0	4.2
	Mandi	1.7	0	0	0	0	1.7
	Lower Narah	5.7	0	0	0	0	5.7
	Kawas	3.4	0	0	0	0	3.4
	Habibabad	2.6	0	0.3	0	0	2.9
	Gribabad	3.2	0	0	0	0	3.2
	Ganjkal	3	0	0	0	0	3
	Deri Narah	6.2	0.1	0	0	0	6.3
	Deri	3	0	0	0	0	3
	Bailla Garlat	2.8	0	0	0	0	2.8
Total		97.1	1.9	0.8	0.1	0.1	100

Source: *Field Data, 2017*

Table 2: *Types of Commercial Activities and their Construction (%age Share)*

Type of Activity	Fabricated	*Pacca*	Semi *Pacca*	Adobe	Other	Total
Hoteling	0.7	0.0	0.0	0.0	0.0	**0.7**
Restaurant	2.7	2.0	0.0	0.0	0.0	**4.7**
Jewelry	0.3	0.3	0.0	0.0	0.0	**0.7**
Barber	2.0	2.7	0.0	0.0	0.0	**4.7**
Cloths	6.0	0.0	0.3	0.0	0.7	**7.0**
Electronics	3.3	0.3	0.0	0.0	1.0	**4.7**
General store	21.3	8.7	0.0	0.0	0.3	**30.3**
Shoes	2.0	1.3	0.0	0.0	1.3	**4.7**
Toys	2.3	2.3	0.0	0.0	0.0	**4.7**
Sweets & Bakers	0.7	0.3	0.0	0.0	0.0	**1.0**
Butchers	0.7	0.3	0.0	0.3	0.0	**1.3**
Bank	0.0	0.0	0.0	0.0	0.7	**0.7**
Tailors	4.3	0.0	0.0	0.0	0.0	**4.3**
Gifts	1.0	0.3	0.0	0.0	0.0	**1.3**
Furniture	0.7	0.0	0.0	0.0	0.0	**0.7**
Hardware	0.7	0.3	0.0	0.0	0.0	**1.0**
LPG	1.7	0.7	0.0	0.0	0.0	**2.3**
Medical Stores	1.0	0.3	0.0	0.0	0.0	**1.3**
Hawkers	1.7	0.3	0.7	0.0	0.3	**3.0**
Vegetables	1.0	0.3	1.7	1.0	0.3	**4.3**
Miscellaneous Activity	8.7	6.0	0.3	0.0	1.7	**16.7**
Total	**62.7**	**26.7**	**3.0**	**1.3**	**6.3**	**100.0**

Source: *Field Data, 2017*

Earthquake

The town of Balakot and its surrounding region located on active fault lines, which is clearly visible after Earthquake – 2005. Two fault systems of Karakoram Thrust (MKT) and Main Mantle Thrust (MMT) merged at the vicinity of Balakot town. This merging formed a triangular shape of fault lines, which look a wedge-shaped in 3D view. This structure was identified by Armbruster et al. (1978) during 1973–1974 in their micro-seismic study, which was named as Indus Kohistan Seismic Zone (IKSZ). The town of Balakot located in northern top of the IKSZ, which lies in the MMT and Hazara Kashmir Syntaxes (HKS) faults. The IKSZ has a 100 Km length and 50 Km width with south-west upper surface and lower surface towards north-east. In 1991, two seismic zones of different nature were found (Ni et al., 1991). It has a right lateral strike slip movement with a thrusting toward westside. In the north west, this lateral strike slip fault bifurcates into branches. In Earthquake – 2005, these branches were further breached which were closely associated with seismic waves and surface destruction (Aydan, 2006; Baig, 2006). The seismic micro-zonation and geotechnical survey was carried out by ERRA after Earthquake – 2005. micro-seismic hazard map of the town of Balakot and surroundings region was prepared by ERRA, which shows twenty small and four major fractures network of fault lines (GOP, 2007). Based on these findings and location on right top of this fault lines network shows very high exposure to earthquake of the Balakot town and its surroundings (Figure 02).

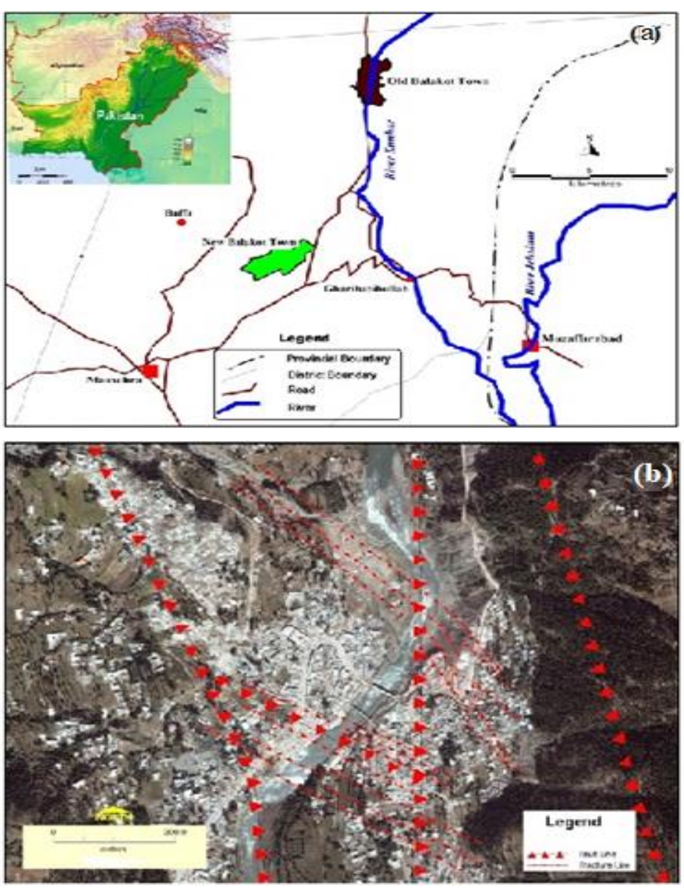

Figure 02. (a) Location Map of the Balakot Town, Source: Field Data, 2015; (b) Micro-Seismic Hazards Map of Balakot, Source: Modified after (GoP, 2006),

Floods

The town of Balakot located in the centre of valley of the river Kunhar which is passed right in the middle of red zone region. Using the hydrolysis tool of Arc GIS, the area, shape and slope were calculated for the river Kunhar. The elongated oval shape of its drainage basin with steep slope of 5075 to 632 m. The total area of the drainage basin is 2706 Sq. Km. All these are characteristics of flash flood. The slope and/or contours are very gentle in surrounding of Balakot which increase the risk and exposure of floods. Torrential rainfall in monsoon is the major cause of floods. In 1992, 1993 and 2010 episodes of torrential rainfall occurred in monsoon season which caused severe floods in the region and particularly in the Balakot (Atta-ur-Rahman & Khan, 2011; GOP, 2010). These flash floods severely damaged the bazaar, residential area on both sides of the river and Syed Ahmad Shaheed shrine (Ozaki, 2016; Correia & Matias, 1991). In surrounding of the Balakot town, the width of the river varies between 80 - 150 metres while the bridge, market and few houses are almost at 05 metre height from the stream's bed. The shrine is at 03 metre height from the stream's bed. The Government has constructed a protection wall on right side the river to protect these infrastructures. However, low to medium exposure to flood is persisted (Figure 03 & 04).

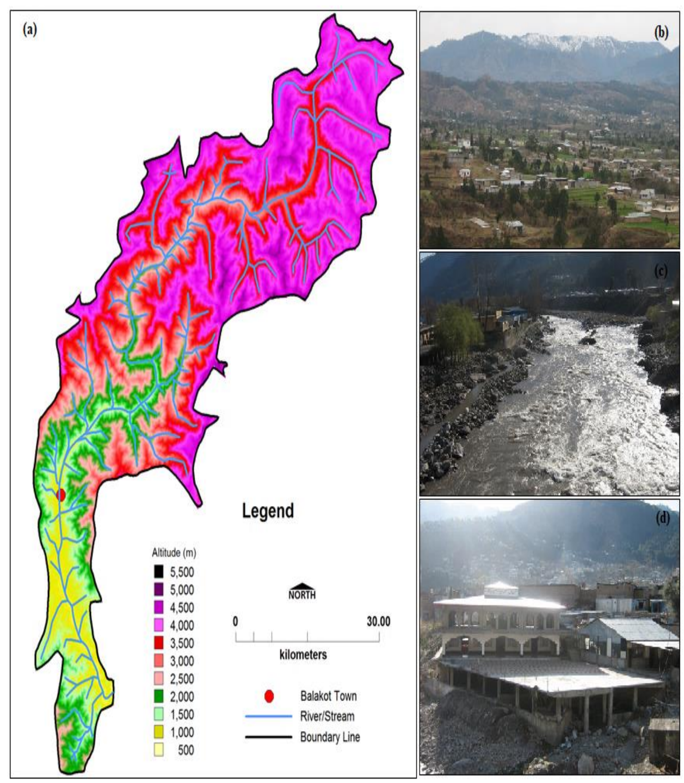

Figure 03. (a) Drainage Basin of the River Kunhar, Field Data 2017; (b) River Kunhar Valley near Balakot, Field Data 2017; (c) River Kunhar near Balakot, Field Data 2017; (d) Shrine of the Syed Ahmad Shaheed at bank of River Kunhar, Field Data 2017

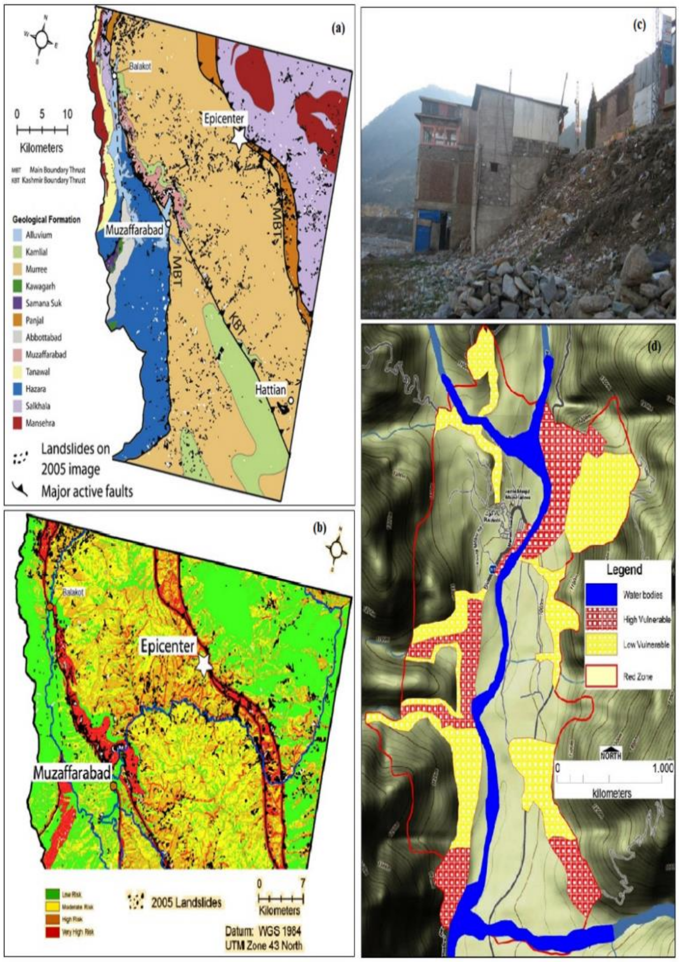

Figure 04: (a), (b) & (c) Monthly Rainfall at Balakot, 1992, 1993 & 2010, respectively, Source: GoP, 2010; (d) Flood Hazard's Exposure of the Balakot Town Drainage, Source: Field Data 2017

Landslides

The Earthquake – 2005 triggered number of landslides events in the Balakot region. Most of these landslides were associated with fault lines particularly of fault rapture in the Balakot region. The inventories of landslides were prepared after the Earthquake – 2005. Balakot located on the IKSZ and active fault lines with complex geology. All along the fault line on the eastern side is highly suspectable for landslide events (Kamp, et al., 2008; Mahmood, et al., 2015; and Sato et al, 2006). The Kunhar river passed in the centre of the red zone region of Balakot with poor tributary drainage system. In the built-up areas, the geology is based on stable parameters which decreases susceptible to landslide. The main features for landslides exposure are: vertical erosion along banks of the river, roads and streams sides cutting, and on eastern side the faults lines and their fractures. Based on these factors and historical data exposure map of the landslides is prepared (Figure 05).

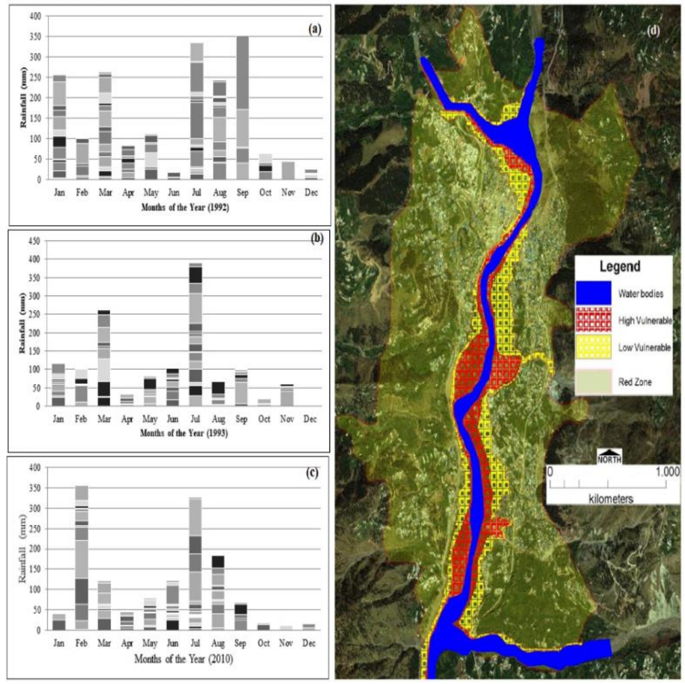

Figure 05: (a) & (b) Landslides Inventory and Risk Map of after Earthquake – 2005, Source: Kamp et al, 2008; (c) Vertical Cutting and Landslide Hazards' Exposure of the town of Balakot and its surroundings, Source: Google Earth & Field Data, 2017

Fire, Hailstorm, Snowfall, Windstorm and Drought

The exposure to fire hazard was very high in the fabricated shelters because of loose electricity network, small kitchen size and the source fuel which was volatile (Table 03). In the commercial areas of the Balakot town, shops were contagious with poor fire safety system. Recently, few cases of fire were documented with damages to properties at small scale. The residential areas are more exposed to fire hazard than commercial areas where Rescue services are easily available (United Nation International Strategy for Disaster Reduction (UNISDR), 2010; Kachenje, Kihila, & Nguluma, 2010). The windstorms, hails and snowfall had low exposure due to low frequency and intensity in the region. Mostly, agriculture sector is at risk from these hazards with negligible damages in housing, commercial and human resources are ever reported. Moderate drought was reported after Earthquake – 2005. The basic reason was not the shortage of rainfall but the shaken and fracture aquifers which was recharged with the passage of time.

Table 03: *Types of Houses and Source of Fuel (Percentage Share)*

Type of House	LPG Cylinder	Electricity	Wood	Coal	Other	Total
Fabricated	45.7	1.9	48.5	0.3	0.8	**97.1**
Pacca	1.9	0.0	0.0	0.0	0.0	**1.9**
Semi *Pacca*	0.1	0.0	0.7	0.0	0.0	**0.8**
Kacha	0.0	0.0	0.1	0.0	0.0	**0.1**
Other	0.0	0.0	0.1	0.0	0.0	**0.1**
Total	**47.7**	**1.9**	**49.3**	**0.3**	**0.8**	**100.0**

Source: *Field Data, 2017*

CONCLUSION

The town of Balakot and its surroundings were destroyed by Earthquake – 2005. After Earthquake – 2005, fabricated shelters were used extensively for residential, offices, schools and commercial activities. The damaged infrastructure of utilities & services along with fabricated shelters increase the exposure and vulnerability to all hazards, dramatically. The Earthquake – 2005 not only increases the exposure of earthquake hazards but also triggered landslides and increases the exposure of flash flood, drought, fire, hailstorm, snowfall and windstorm. The active fault line along with mini fault lines (fractures) are passing through Balakot Town. In addition, the physical vulnerability and location of physical infrastructure on unstable slope and geology (IKSZ) increases the earthquake exposure extremely high. Based on drainage pattern analysis in Arc GIS, type of flash flood hazard is identified. The contour and slope analysis from the bank of river Kunhar, it was estimated that exposure of flash flood near bazaar area was very high and down the stream it decreases where agriculture activities are practiced. For landslide hazard exposure assessment, inventory of landslide hazard and disaster of this region were studied. The location of the elements at risk and slope analysis in ArcGIS (contour slope analysis) identified the low, medium and high exposed areas to landslide hazard. Drought was a temporal phenomenon after Earthquake – 2005 which the residents are well adopted now days. The exposure of fire, hailstorm, snowfall and windstorm are very high because of fabricated shelters and not intensity of hazards. The multi-hazards' exposure assessment provide a methodological framework for detail research and a base for disaster risk reduction measures to cope with multi-disasters scenario in the Balakot Town.

Overall, the exposure of the area is high due to its geographical location, poor housing types, and inadequate mitigation measures. The physical condition of the WASH facilities such as water distribution pipelines, and drains were unhygienic, because most of them were open. The physical infrastructure of electricity and telephone i.e. poles, transformer, and meters were in inappropriate and open places. During field observation, it was found that most of the agricultural land of was in active flood plains and was highly exposed to flash floods. The irrigation infrastructure such as water channels and culverts were non-cemented. There were very few manufacturing units of cement blocks and furniture for local consumptions.

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