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ORIGINAL PAPER

Analysis of landslide causes and associated damages in the Kashmir Himalayas of Pakistan

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Abstract This article deals with the analysis of landslide causes and associated damages in the Kashmir Himalayas of Pakistan. The present study is based on Muzaffarabad, which lies in the lesser Himalayas. Geologically, the Kashmir Himalaya is the young and most dynamic system in the world. In Muzaffarabad, mostly, people live on the fragile mountain slopes, and therefore, they are highly vulnerable to the risk of landslides. To achieve the objectives of the study, data were collected both from primary and secondary sources. Primary data were obtained through intensive field work and human perception survey, while secondary data were obtained from the related line agencies. The analysis reveals that in the study area, immature geology, active seismic zone, wide range of temperature and seasonal rain are the major physical factors, whereas human interventions on the fragile slopes are intensifying factors which in effect contribute to the landslide incidence. As a result, the adverse impacts on housing, sources of livelihood earnings and human casualties are escalating day-by-day. There are several implementing agencies which are responsible for reducing the risk of landsliding. So far, these agencies have not reduced the landslide damages rather their intensity and frequency have been increased especially after 2005 Kashmir earthquake.

Keywords Landslide · Causes · Effects · Evaluation · Management

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1 Introduction

Landslide hazard is a wide spread and recurrent phenomenon all over the fragile Himalayan systems (Niederer et al. 1989; Malik and Farooq 1996; Abbasi et al. 2002; Dahal et al. 2008). Geologically, the Himalayan Mountain range is the youngest and most dynamic system in the world (Dahal and Hasegawa 2008). The Pakistani Himalaya is specifically famous for the recurrent seismic activities, landsliding and flash floods (Khan et al. 1994; MonaLisa et al. 2009). Here, landsliding is a frequently occurring geomorphic process and interrupting day-to-day human activities (Crozier 1986; Kamp et al. 2009). Similarly, researchers have also estimated that one-third of the total world landslides occur in the Himalayan region (GOP 1987; Khan 2000). In this region, the problem of landsliding varies from small scale slope failure to heavy landsliding. It depends on several interrelated factors including lithology, slope gradient, climate, land cover and drainage that bring landslide susceptibility (Gabet et al. 2004; Lin et al. 2006; Gattinoni 2009; Kanungo et al. 2009; Groneng et al. 2011). The extent of landslide damages varies from area to area. Various studies indicate that Kashmir Himalaya is the world's most terrible slide-affected area (Khan 1992; Khan and Rahman 2006; Khattak et al. 2010).

This paper deals with the analysis of landslide causes and associated damages in the Kashmir Himalayas of Pakistan. The present study is focussed on Muzaffarabad, which falls in the lesser Himalayas of Pakistan (Fig. 1). Geologically, Muzaffarabad region is enclosed by Hazara–Kashmir Syntax. It is dissected by the main boundary thrust (MBT) and Bagh-Balakot Fault, which is known for crustal deformation and tectonic uplift (Kazmi and Jan 1997; Saba et al. 2010). The 2005 earthquake has destabilized numerous slopes and triggered 158 landslides in and around Muzaffarabad city (Kamp et al. 2008; Rahman et al. 2011). Historically, the region has experienced several earthquakes of various magnitudes (Rossetto and Peiris 2009), and a high-magnitude earthquake is expected in the future (Bilham and Wallace 2005; Raghukanth 2008). Hence, earthquakes and rain are the two key mechanisms for triggering landslides in the area (Zhou et al. 2002; Khan and Rahman 2006; Owen et al. 2008).

The study area is deeply dissected by small and large river valleys and exposed the fragile slopes for mass wasting. In the study area, climate is predominantly monsoonal and usually heavy rainfall led to rain-induced landslides. Beside climate and geo-tectonics, human factors are also contributing to the landslide hazard. In addition to this, lack of land-use planning and regulations, degradation of natural resource base, improper drainage, road construction on steep slopes and rapid increase in the built-up environment are some of the human-intensifying factors. Usually, roads are constructed along the fragile steep slopes and destabilize the thick bed of conglomerates, which in turn trigger slope failures. Therefore, during rainy months, landslides mostly occur along the spine roads in the Muzaffarabad region. Similarly, clearing of forest cover and overgrazing have further accelerated the problem of landsliding. As a result, the intensity and recurrence of landslides are increasing in the Muzaffarabad area.

In the study area, severity of landsliding varies from place to place depending on climate, geology, environmental settings and human factors. These deteriorating processes have seriously affected the local communities from time to time. In the study area, landslides have caused damages to housing, transportation and communication lines and sources of livelihood earnings.

To cope with the landslide problem, there are several organizations responsible for landslide risk management, but mostly they lack sufficient skills of integrated landslide risk management strategies. They mostly focus on the structural measures, which are adopted

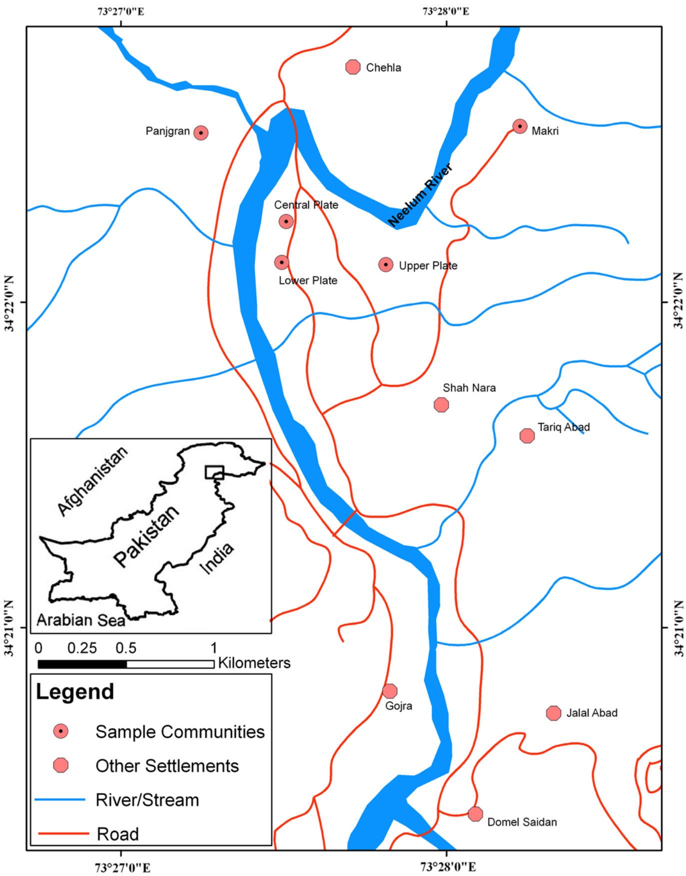

Fig. 1 Location map of the study area (Muzaffarabad)

by almost all the landslide-related implementing agencies. This is one of the costly landslide reduction strategies and beyond the reach of a developing country like Pakistan and hence led to the wastage of scarce financial resources.

This article is divided into five major sections; section one describes the detailed introduction of the study. Second section describes the environmental settings of the study area. Section three deals with the methods and materials applied for carrying out the analysis. Section four includes analysis, results and discussions, whereas summary and findings are elaborated in the final section.

2 Environmental setting of the study area

Muzaffarabad lies within the lesser Himalayas and falls in the monsoon region (Khwaja 1980; Chalise and Kark 1995; Saba et al. 2010). The test area Muzaffarabad is the state capital of Azad Jammu and Kashmir. It is located at the confluence of Neelum and Jhelum rivers. Geographically, the study area stretches between $34^{\circ}20'$–$34^{\circ}23'$ North latitude and $73^{\circ}26'45''$–$73^{\circ}28'40''$ East longitude (see Fig. 1). The terrain is predominantly mountainous, and the altitudinal variation ranges from 700 m to 4,200 m above sea level. Similarly, Neelum and Jhelum are the main river systems, which confluence at *Domel*.

In Muzaffarabad, the drainage pattern largely varies from dendritic to parallel. Jhelum is the main river flowing through the Jhelum valley, while Neelum river in the Neelum valley. These two rivers are draining the area and also receive several perennial streams throughout the course. They are mostly recharged by springs, rain and snow melts. In the study area, flash flood is a recurrent hazard during monsoon (GoP 1999; Rahman 2010). The climate of Muzaffarabad is subtropical highland type. January is the coldest month, while June is the hottest month. A wide annual and diurnal range of temperatures exist. The average annual rainfall is >1,500 mm (GoAJK 2000). January, October and November are the dry months. The rainfall is unevenly distributed and mostly received in the summer months. However, in winter, the precipitation is largely received in the form of snow.

The population of Muzaffarabad district was 746,000 in 1998, which increased to 833,000 in 2009 (GoP 1999; World Gazetteer 2009). During 1998–2009, the average annual growth was 2.8 %. In the capital city, the population density varied from 300 to 800 persons/km^2 in 2009, whereas, in the district, the density is 136. Population is mostly concentrated on gentle slopes, piedmont plains and terraces of the Jhelum and Neelum rivers. Natural vegetation spreads over an elevation of 700–4,200 m. Small patches of terraced farming are also practiced in the area. The dominant crops are rice, maize, wheat and potatoes. Only one crop is grown at the higher altitude due to the long cold winter season. Muzaffarabad is a beautiful scenic place and attracts tourists from all over the world.

3 Methods and materials

For this study, both primary and secondary sources were consulted. Prior to intensive field survey, reconnaissance visits have been made to grasp the environmental setting of the area as shown in the web of research frame (Fig. 2). Thorough reviews of literature and discussion with the key stakeholders have also been made, which enabled us to get clear picture about the extent of causes, damage loss assessment and how to potentially minimize the landslide hazards.

Similarly, drainage and surface terrain was extracted from the SRTM image. The Digital Elevation Model (DEM) is a digital representation of the earth's terrain. DEM has large applications in disaster risk management. Nevertheless, numerous derivative information including slope angles, elevations and slope aspect were obtained from SRTM image. The contours of Muzaffarabad area were interpolated and a digital elevation map was developed. The terrain of Muzaffarabad is predominantly mountainous and varies from 700 to 4,200 m above sea level (Fig. 3). Most of the peaks exceed 4,000 m elevations. In Muzaffarabad area, the slopes are moderate to steep. Steep slopes and unconsolidated loose material decreases the shear strength of the material that triggers landslide (Rahman et al. 2011).

Primary data were also obtained through questionnaire surveys, filed observation and structured interviews with the officials and environmentally aware people of the area. The questionnaires were developed to collect human responses and perceptions about the causes, effects and management of landslide hazards. These questionnaires were supplemented by intensive field observations. Ideally, the entire population of the area should

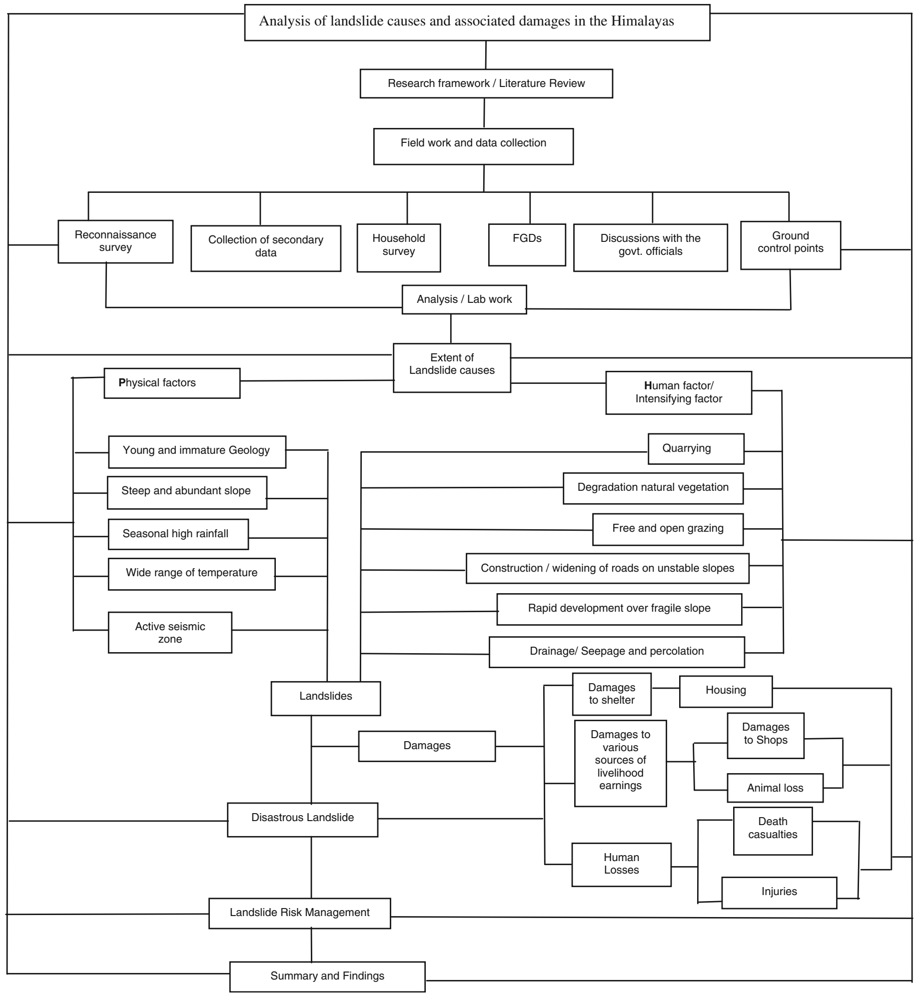

Fig. 2 Research model

have been surveyed. However, due to limited time and scarce resources, a sample household survey was conducted. To achieve the objectives of the study, five sample sites namely: Upper Plate, Lower Plate, Central Plate, Makri and Panjgran were selected by random means (see Fig. 1). During field survey, three types of questionnaires for individual households and focus group discussions (FGDs) were used (Rahman et al. 2011), and for the officials of the line agencies. For the individual household questionnaire, 150 questionnaires were administered using simple random sampling techniques representing 10 % of the households. The sample of the respondent for interview was largely random in its composition. In the sample sites, a total of thirteen FGD's were administered. The participants in each FGD's vary from minimum 5 in Panjgran to maximum 16 in Central Plate. In every sample site, two to three questionnaires were filled in during FGD's. Group discussions with the community leaders, local organizations, farmers and other residents

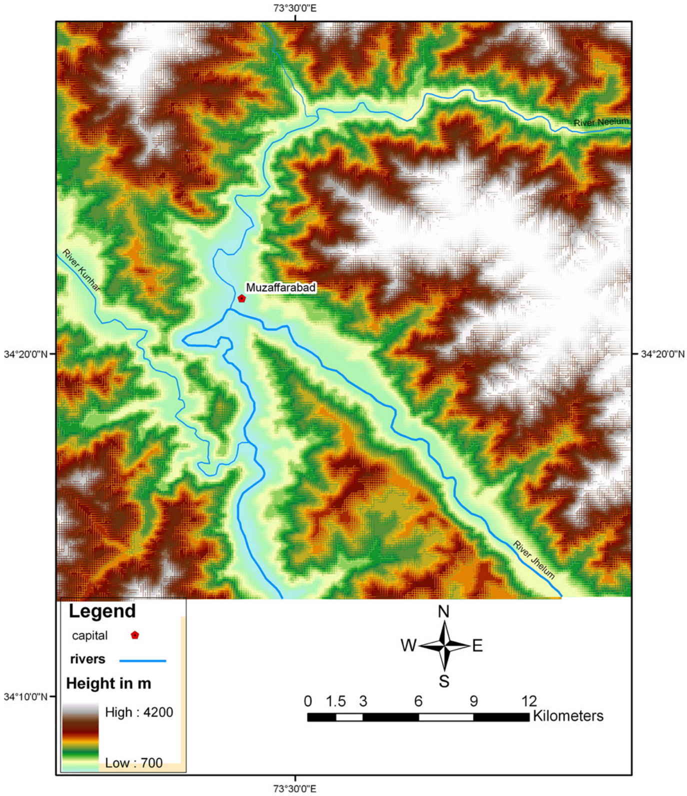

Fig. 3 Muzaffarabad, map showing surface terrain, capital city and drainage system

were the landmark feature for cross-checking the data obtained during household questionnaire survey and officials of the line departments. Questionnaires from the officials of the concerned government department were also filled in. This data helped in understanding the extent of causes, effects and landslide hazard management. In this paper, the average loss assessment has been calculated for the past 20 years (1984–2004) irrespective of the number of recorded disasters that occurred.

Secondary data were obtained from government line agencies, namely the Forest Department, Pakistan Meteorology Department, Geological survey of Pakistan, Revenue Department, District Coordination Officer (DCO), Muzaffarabad Development Authority (MDA), and Building and Works Department. Data were also obtained from reports, documents, books and research articles. GIS was used for preparing the spatial database and analysis. Geology and tectonic maps were prepared from the latest geological maps of the study area. The potential landslide hazard map has also been developed from the available datasets. Muzaffarabad land-use map has been developed from the Muzaffarabad guide map R.F 1:10,000 of survey of Pakistan. Rainfall data of Muzaffarabad meteorological station were obtained from the office of the Director General, Pakistan Meteorology Department, Islamabad. Finally, the collected data were analysed and presented in the form of statistical diagrams, tables and maps.

4 Analysis, results and discussions

Landslide is a frequently occurring phenomenon throughout the lesser Himalayas of Pakistan. In Muzaffarabad, landslide is caused by both physical and human factors. In the following discussion, analysis of landslide causes and related damages in the Muzaffarabad area has been made.

4.1 Factors of causing landslides in Muzaffarabad

The available literature, intensive field work, secondary data and human perception survey reveals that several physical and human factors are responsible for causing landslides in the Muzaffarabad area. Unconsolidated loose material, soft rock, the active seismic zone, steep and irregular fragile slopes, seasonally heavy rainfall, active freeze and thawing are the major physical factors, whereas deforestation, quarrying, building and road construction over the fragile slopes are the key human-induced landslide factors. These causative factors have been analysed in the following lines:

4.1.1 Surface geology

Geologically, the study area is susceptible to complex change. Murree, Muzaffarabad and Hazara are the prominent Formations (Fm) reported from the test area (Fig. 4; Pearce 1987; Hussain et al. 2009). Lithologically, Murree Formation (MF) is of Oligocene–Miocene age and consists of siltstone, hard grey-to-red sandstone and red calcareous shale (Shah 1977; Rahman et al. 2011). It also contains subordinate conglomerate and lenses of limestone. Stratigraphically, Muzaffarabad Formation (MzF) is located at the top of the elevated parts (Shah 1977; Kazmi and Jan 1997). This Formation is Precambrian in age. It mainly consists of dolomites and limestone. However, in certain areas, it contains shale and limestone. Figure 4 indicates potentially active landslide area which is reported from Muzaffarabad formation and lies close to the Bagh-Balakot and Jhelum strike slip fault. This high concentration of potentially active landslide is attributed to surface geology and seismo-tectonics. The Hazara Formation (HzF) is comprised of Precambrian argillite, phyllite and slate (Saba et al. 2010). Similarly, in Muzaffarabad, the surface material belongs to Holocene period and mainly consists of alluvium. The slopes are mainly composed of unconsolidated loose material, holding a weak cohesion. At lower altitudes, the earth stratum mainly consists of alluvium, which is deposited by running water in several phases and residual soil. Therefore, such material has maximum probability of slope failure (Dunning et al. 2007). Field survey reveals that river valleys are mostly covered by thick colluviums, which has potentially a weak contact with the underlying bedrock. In Muzaffarabad area, several landslides have been activated in this weak contact of colluviums and bedrock, and therefore, it has high tendency towards the slope failure.

4.1.2 Seismo-tectonics

Tectonically, the region is enclosed by Hazara–Kashmir Syntax, which is cross-cut by the MBT and Bagh-Balakot Fault line (Fig. 5; Searle and Khan 1996; MonaLisa et al. 2009). The study area is also represented by a region of considerable crustal shortening and tectonic uplift (Kazmi and Jan 1997; Saba et al. 2010). Muzaffarabad is located close to the active Bagh-Balakot fault line, which ruptured recently during 2005 Kashmir earthquake.

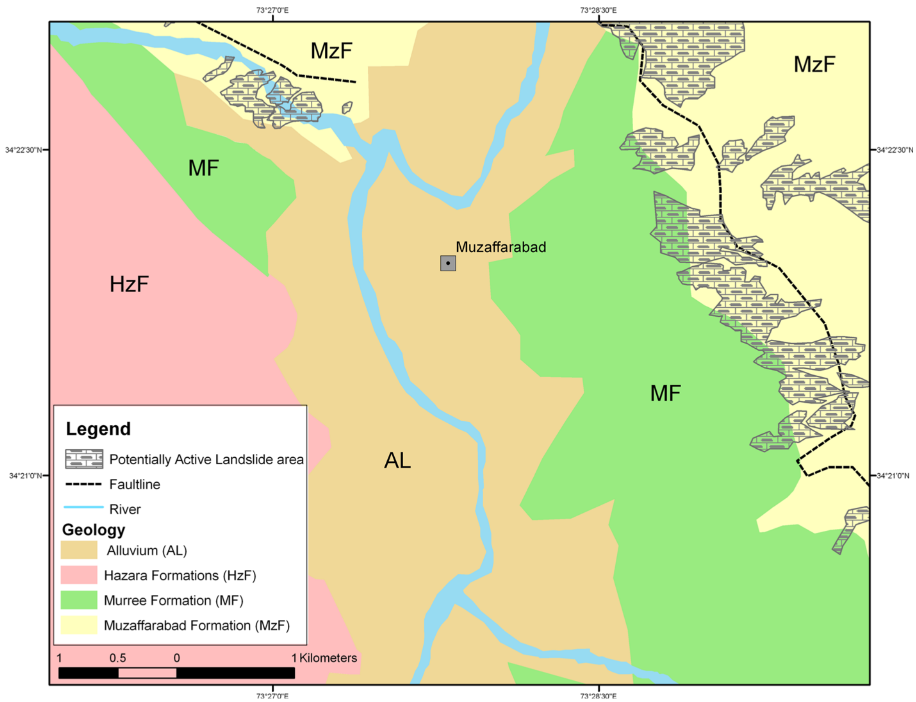

Fig. 4 Geology of Muzaffarabad and surroundings (modified after Searle and Khan 1996; Saba et al. 2010)

Usually, earthquakes create cracks, which after rain, trigger and accelerate the process of slope failure (Kazuo et al. 2009; Schneider 2009; Rossetto and Peiris 2009; Miyagi et al. 2011). This phenomenon has been observed in the field and also reported by the local residents during responses and perception survey. The analysis found that prior to 2005 Kashmir earthquake, rain was the major causative factor of landslide in the study area.

According to Zaré et al. 2009, Muzaffarabad is located on the highest earthquake-affected area (meizo-seismal region) and placed on high seismic hazard zone particularly after 2005 Kashmir earthquake. In this context, a Muzaffarabad city map was especially prepared to show the fault lines that passes through the study area (Fig. 6). The map also shows the potential landslide hazard zones, Bagh-Balakot fault line and the concentration of denuded hill slopes which has multiplied the risk of landslides in the area. Based on the field work, the landslide hazard zone is further classified into high landslide hazard zone, moderate landslide hazard zone and low landslide hazard zone. The analysis further reveals that almost all the potentially active landslide area is reported from the eastern and northern section of the study area. They mostly lie on both sides of the fault lines, which clearly indicate the relationship of landslide phenomenon and seismo-tectonics. Keeping in view the scenario, during field work, most of the slope cracks were found in the vicinity of fault lines which in turn triggered landslides. Similarly, Khattak et al. 2010 also concluded that the recent seismic activity of 2005 stimulated numerous tension cracks in and around Muzaffarabad, which in effect activate landslides. Based on the filed survey, there has been constant increase in the frequency and magnitude of landslides after 2005 Kashmir earthquakes. Therefore, seismo-tectonics is an important factor of triggering landslides in the Muzaffarabad area.

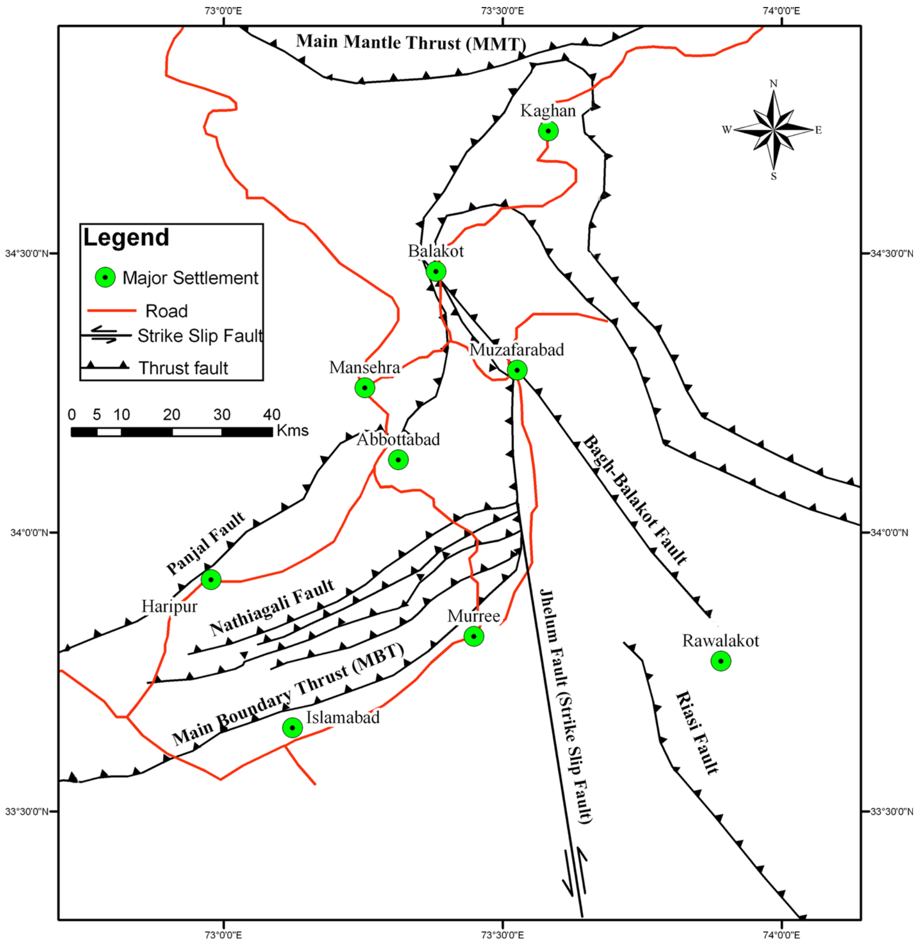

Fig. 5 Tectonic map of Muzaffarabad and surroundings (modified from Monalisa et al. 2009; Rahman et al. 2010)

4.1.3 Climate

Beside seismo-tectonics and geology, climate is another physical factor causing landslides in the area. According to Pakistan Meteorological Department, the climate of Muzaffarabad is subtropical highland type. In the study area, January is the coldest month with mean minimum temperature of 3.2 °C and June is the hottest month with mean maximum temperature of 37.6 °C (Fig. 7; GoAJK 2000). The temperature of Muzaffarabad rises rapidly from February to August with a break of monsoon, and then it steadily decreases. There is wide range of diurnal and annual temperature as well. Therefore, the surface material expands and contract at a different rate, which ultimately led to the slope failure. The problem is further aggravated by alternate freeze and thaw during extreme low winter temperature and hot and moist monsoon period.

In Muzaffarabad, the annual rainfall is unevenly distributed. According to Pakistan Meteorological Department, the average annual rainfall of Muzaffarabad is approximately

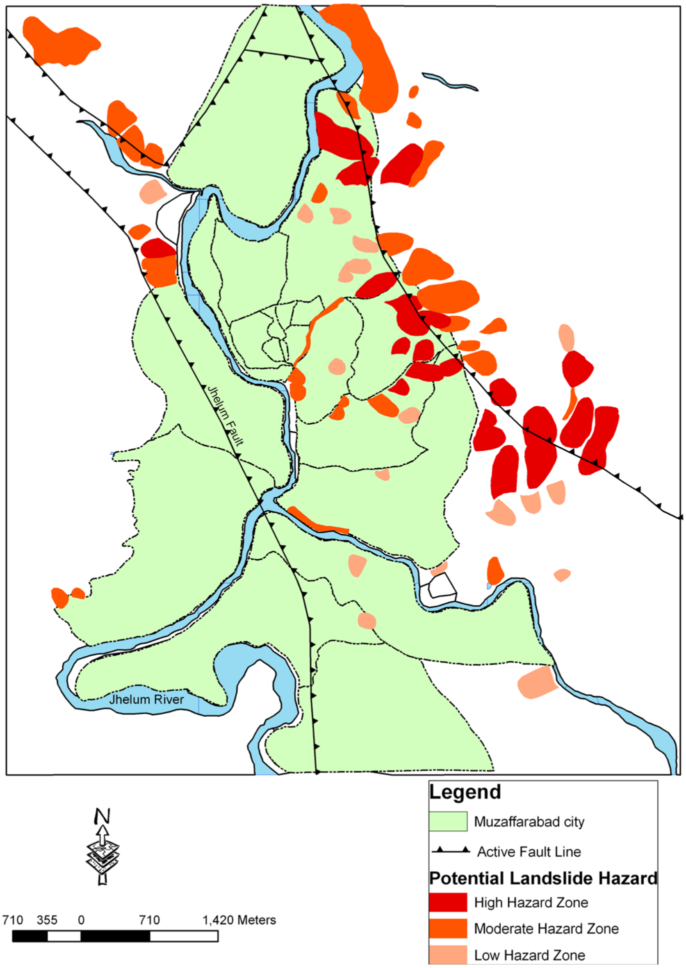

Fig. 6 Map showing fault lines of the study area. The map also shows the potential landslide hazard zones (modified from Kamp et al. 2009; Khattak et al. 2010; Saba et al. 2010)

1,500 mm (GoAJK 2000). Usually, January, October and November are the dry months, whereas in rest of the year, rainfall is fairly good. Precipitation is received in two well-marked seasons, monsoon (summer) and western disturbances (winter). July and August are the wettest months and receive comparatively high rain due to the monsoon period. This wet spells increase the soil infiltration and surface runoff over the vulnerable slopes, which encourage rain-induced landslides. During field work, this phenomenon has been commonly observed in the Neelum and Jhelum valley especially where bare and unconsolidated slope dominate the scene. The analysis further revealed that the 2005 earthquake activated several tension cracks, which after rain, stimulated and triggered rain-induced landslides. According to the field survey, the frequency and intensity of rain-induced landslides have been increased after 2005 earthquakes. It was also found from the analysis that prior to 2005 earthquake, seasonally heavy rainfall was the dominant factor behind the landslide incidence. In addition to this, during winter, the higher elevations receive

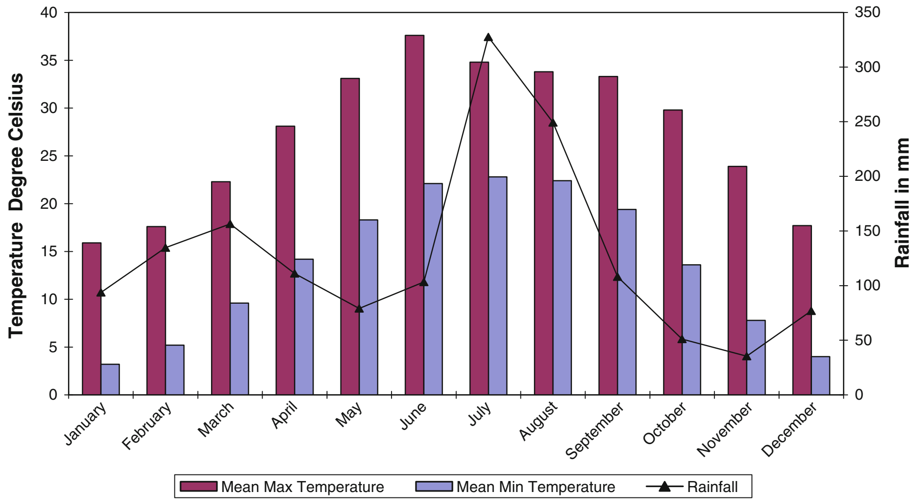

Fig. 7 Muzaffarabad, mean monthly maximum and minimum temperature and monthly rainfall, 1961–2009

precipitation in the form of snow. The analysis reveals that slow but steady snow water seep and percolate in the soft rock which have weak contact with the bed rock and as a result causes slope failure. Similarly, when snow is accumulated on the hill slope, it exerts pressure on the underlying area and trigger slow movements, among which snow avalanches and soil creeping was very obvious in this fragile ecosystem.

4.1.4 Human factors

Degradation of vulnerable slopes by population pressure, overgrazing, construction of roads and houses are the major human-intensifying factors causing landslides in the area. In the study area, plain and level lands are scarce. The residents have limited choice for construction of houses and are compelled to live on the fragile slopes. Contrary to this, the population of Muzaffarabad is increasing at a rate of 1.7 % per annum (GoAJK, 2000). Due to excessive population growth, the built-up area has been expanding rapidly. In effect, it has put tremendous pressure on susceptible slopes and consequently increased the risk of landslide.

Muzaffarabad city map shows the denuded and barren hill slopes in the lower reaches and pastures above the tree-line (see Fig. 6). According to FGD's and officials of the Forest Department, the degradation of fragile slopes has been further aggravated by overgrazing especially in summer. Almost every year, such open grazing for 3–4 months has been causing a high loss of vegetation cover on landslide-vulnerable slopes, as the vegetation cover binds the loose material and prevents it from slope failure. Therefore, in Muzaffarabad, conservation and plantation would be a long-term bioengineering solution to the recurrent problem of landsliding.

In the study area, thick beds of conglomerate have been exposed by running water, road cuttings and excavation. In Muzaffarabad, most of the development has been carried out over these vulnerable slopes, and the urban authority is hard press to extend urban infrastructure services to the growing population. During field work, it was found that majority of the houses lack proper sanitation, drainage and water supply system. The seepage and percolation from unpaved open drains and pipes have been identified as one of the major landslide-triggering factor in the area.

Similarly, roads are constructed on unstable steep slopes by cutting beds of conglomerates and unconsolidated loose material. The record of the Communication & Works Department revealed that the road density was increased almost twenty times since 1950. As a result, frequent slope failure is reported from the road networks according to the officials of MDA's and FGD's (Fig. 8). The analysis further reveals that increase in the road density over the vulnerable slopes has positive relationship with the incidence of landslides. So, it clearly indicates that construction of roads over the fragile slope is also a landslide intensifying factor. It was also found during field survey that after rainfall, roads have been often blocked by the landslides. It is because roads are constructed along the vulnerable steep slopes, which destabilize the thick beds of conglomerate, and in turn, it triggers slope failures. Similarly, ruthless blasting and excavations using heavy machinery have further aggravated the problem of slope instability. Ironically, buildings and roads are constructed without detail environmental impact assessments (EIA), which is a glaring example of ignoring and violating the Environmental Protection Act 1997.

4.1.5 Human perception and responses

There are various causes of landslides; however, based on the individual household survey and FGD's with the community, following were identified as important factors in accelerating the landslide problem in the area. Community members in the five sample sites were asked about the causes of landslides in the area. Out of total 150 respondents, 30 % prioritized intense rainfall as the major cause of landsliding in the area, whereas 25 % said physical development over the fragile slopes including building roads, houses, apartments and improper drainage (Table 1). In addition to this, 10 % of the total respondents replied that wide range of diurnal and annual temperature is a major contributing factor in triggering the landslides in the area, while 15 % were of the opinion that the presence of loose material and soft rocks on the slopes are the major causes of landslides. However, 20 % of the total respondents were of the view that earthquake is a major cause of landslide occurrence (Table 1). Based on their indigenous knowledge, the respondents prioritized intense rainfall, physical growth on the fragile slopes; seismic activities and soft lithology have been blamed as the prime triggering forces behind the landslide problems.

In the study area, major causative factors include the ecological and environmental imbalances that have been caused by consistent human interventions. It was found that the careless and unwise exploitation of land, forest, mineral and other resources has led to increase in the landslide incidence. The population and potential landslide area have been expanded, in addition to a significant increase in the human capacity to change the hill slopes (Fig. 6). The analysis reveals that during the past 20–30 years, there has been a sharp increase in the extent of landslide occurrence. Ironically, all this had happened in spite of the fact that neither the climate nor the rock structure appears to have changed significantly. However, the earthquake of 2005 triggered several landslides in and around Muzaffarabad.

Field studies together with the available data revealed that the destabilization of susceptible slopes by slide-intensifying factors has led to the increasing frequency of landslide occurrence. During field survey, all the key stakeholders were asked about the frequency of landslide occurrence. In almost all the sample communities, majority of the respondents favoured that the frequency of landslide has been increasing from the past two decades.

Fig. 8 Heavy landsliding on Chakothi Road

Table 1 Household response regarding causes of landslides

Factors	Response to various factors	Frequency (%)
Physical factors	Intense rainfall	30
	Earthquake	20
	Loose material	15
	Wide range of temperature	10
Human factors	Anthropogenic activities	25
Respondents (n) 150		

Source Field survey, 2004

However, few respondents were of the opinion that in Muzaffarabad, the landslide frequency is uncertain and mainly depends on physical and human factors.

4.2 Impact of landslides on the study area

Disaster experts have applied different criteria for damage assessment (Liu et al. 2009; Rahman et al. 2011). In addition to this, in the landslide incidence, the economic and psycho-social cost is also borne by the victims. This indicates that assessing the actual cost is not possible; however, scholars have applied various weighting and scaling approaches to measure the complex costs of landslide disasters. In Muzaffarabad, the average loss assessment was computed for the past 20 years irrespective of number of landslide occurrence. In the present article, the landslide-related damages have been classified into housing, sources of livelihood earnings and human casualties. The data pertaining to landslide damages were not available fully in the concerned government departments. Therefore, these data were obtained through individual household field survey.

Damages to shelter were found the severely affected sector, while assessing the adverse physical impacts of landslides in the area. The analysis revealed that several houses have been badly damaged by the landslides during the past 20 years (1984–2004) irrespective of number of disasters occurred. In the test area, a question was asked from the individual household heads that "*Has the landslide affected your house*?" a predominant majority (67 %) of the household heads replied "yes", while 33 % said "no". In addition to house structure damages, there were losses to furniture and other domestic gadgets too. Though, these losses were comparatively less than the extent of damages to house structure. Similarly, a total of 49 houses were damaged by landslides in the past 20 years. However, all landslides were not (or not perceived) of a sudden nature according to the household survey. According to the residents, the first sign of slide impact on housing appears in the form of small cracks and bulges on the walls and floor of the houses. With passage of time, these cracks expand and ultimately lead to either full or partial collapse of house. Consequently, in the sample communities, 19 concrete, 15 semi-concrete and 14 adobe houses were damaged partially, whereas one semi-concrete house was also fully damaged. According to the respondent's estimates, total economic loss to the housing sector was worth 630,000 Pak rupees[1] in the past 20 years (Table 2).

Besides damages to housing sector, various sources of livelihood earnings have also been seriously affected. In the study area, shops and livestock are the two major sources of livelihood earnings. The analysis reveals that several shops have been fully damaged with available goods inside the shops. According to household field survey, in the five sample areas, a total of nine shops were damaged in the past 20 years, out of which three were in Lower Plate, one each in Upper Plate, Central Plate and Panjgran that were damaged partially and in Makri, one shop was fully damaged and two partially. Total estimated economic losses to the shops were 100,000 Pak rupees in the past 20 years. The analysis further reveals that in all the five sample communities, landslide has also adversely affected the livestock, which is considered as an integral part of the agricultural economy. It was reported that a total of 13 livestock perished and 15 injured as a result of landsliding during the past twenty year. The total loss to the livestock sector as per the respondents' estimates was worth 66,000 Pak rupees. In addition to this, several times landslides have blocked and damaged large track of roads.

The literature revealed that there is no standard formula to measure the human sufferings in monetary terms. Therefore, majority of the scholars have referred human lives as precious and priceless (Liu et al. 2009). If severe injury occurs instead of death, the corresponding loss is usually considered less. This is again difficult to conclude, as an injured person may carry psychological impact, which can last for years and can affect other family members. The related loss may be homogeneous and hard to evaluate. Nevertheless, human sufferings, coping and resilience are part and parcel of the outcomes of disaster impacts. Therefore, in this survey, a simple and symbolic number was used to quantify the degree of landslide severity. In the study area, several casualties have been reported. Two persons died, and three injured as a result of landsliding in the past 20 years.

[1] Rs = Pakistani rupees (48 Rupees = 1 US$, price level, 2004).

Table 2 Number of houses damaged by landslides, 1984–2004

S No	Type		Number	Average cost per damaged house in Pak rupees[a]	Total cost in Pak rupees
1	Adobe house	Partially	14	5,000	70,000
		Fully	0	0	0
2	Concrete	Partially	19	15,000	380,000
		Fully	0	0	0
3	Semi-concrete	Partially	15	10,000	150,000
		Fully	1	30,000	30,000
Total			49	–	630,000

Source Field survey, 2004

[a] 48 Pak Rupees = 1 US$ (Price level, 2004)

4.3 Evaluation of landslide risk-reduction policies

Based on FGD's, field survey and consulting officials of the related line agencies, the following landslide hazard-reduction policies were found: modifying landslide hazard by engineering measures, compensation policy, bioengineering measures, land-use zoning and regulations. The engineering protection policy includes various structures to prevent the flow of sliding mass and debris from housing and other infrastructure. This policy is widely adopted by all the government agencies dealing with the landslide problems. The most dominant measures in this category so far adopted are the construction of check dams, retaining walls, buttresses, gabion structures, surface and sub-surface drainage. Similarly, forest department is responsible for bioengineering measures over the fragile slopes, which is a very effective measure while dealing with the landslide hazard. The other non-structure policy adopted by the local planning authorities is the compensation, which is usually implemented after the landslide occurrence. The compensation was largely given to those households, whose houses and other properties have been damaged by the landslides. Similarly, the relief compensation was also extended to those households, where human casualties occurred as a result of landslides. It was also found that relief compensation was not frequently distributed after each and every case of landslide disaster. The analysis revealed that relief compensation was extended by the government agencies exclusively.

It is evident from the data that landslide is a recurrent extreme natural event in the area. Whenever any severe landslide occurred in any part of Muzaffarabad, the government officials, political leaders and non-government organizations have visited the landslide areas to extend relief and other emergency services. During filed survey, a question "*has the landslide area being visited by any agency?*" was asked from the community members. A predominant majority of the respondents favoured that after the landslide incidence, the affected area had been visited either by government or member of NGO's.

The process of relief compensation was also assessed during field survey. It was found that only in a few cases, some food items and cash were distributed after the landslide incident. However, there were some complaints from the respondents that the relief was not properly distributed amongst the landslide victims. According to filed survey, favouritism by politicians and influential people was the major factor behind the improper distribution of relief. Therefore, the relief compensation did not reach the affected population.

In the five sample communities, household heads were asked about the role of implementing agencies in extending the structural mitigation. Majority of the community members (70–100 % in each community) replied "No" to the question "*has the government agency extended any landslide structural mitigation measures in your area*?" Contrary to this, respondents who favoured that line agencies extended structural mitigation was further asked, "*Whether these engineering measures were helpful*?" It was found that only 30 % in the Upper Plate and 20 % in Lower Plate households were satisfied with the structural measures extended by the government. These gabion structures were constructed by the Works Department, and the same was useful in protecting infrastructures from landslides. However, the field observation revealed that engineering measures were not a successful story.

Field survey and FGD's with the key stakeholders revealed that so far, the landslide risk-reduction strategies were found less effective in minimizing the adverse impacts of landslides. However, in certain areas, landslide-dealing agencies have successfully devised mitigation measures, but lack of finance was the major hurdle in implementation. This is a serious issue in almost all the developing world where outstanding policies are planned but fails to implement due to lack of resources. Similarly, lack of implementation of landslide risk-reduction measures, according to the households, is one of the main reasons behind the increasing frequency and magnitudes of landslides. Therefore, it is utmost important to explore and allocate finances for mainstreaming the regulations about construction, drainage and sewerage over the slopes and conservation of slopes through bioengineering strategies.

5 Summary and findings

Landsliding is a widespread and recurrent phenomenon all over the fragile Himalayan systems. However, the Pakistani Himalayan part is specifically notorious for it. In the study area, variety of mass movement ranging from slow to rapid has been reported. The analysis revealed that in Muzaffarabad, landslides had been caused by both physical and human factors. Loose material and soft rock, seismic activity, steep and irregular slopes, seasonal heavy rainfall, active freeze and thaw have been identified as major physical causative factors, while overgrazing, improper drainage and sewerage lines, building and road construction have been referred as the key human-intensifying factors. However, the role of seismo-tectonics and rain has been identified predominant mechanisms for triggering landslides in the area. The study area is located close to the active Bagh-Balakot fault line, which ruptured during the 2005 Kashmir earthquake. Slope cracks are mostly concentrated in the vicinity of fault lines which in turn trigger landslides. Therefore, potentially active landslides area is located on either sides of the fault lines.

Geologically, the slopes are composed of unconsolidated loose material, holding a weak cohesion with the bedrock and high tendency towards the slope failure. Beside this, there is a wide range of diurnal and annual temperature. Therefore, the minerals and rocks expand and contract at different rates, which lead to slope failure. Almost every year, the problem is further aggravated by monsoon rain and triggered rain-induced landslides. Besides climate and geo-tectonics, human factors range from lack of land-use planning and regulations, degradation of natural resource base, improper drainage, road construction and rapid increase in the built-up environment. The field studies confirmed that the increasing development over the fragile slopes has been expanding rapidly. Therefore, the conservation and regeneration of vegetation would be a long-term bioengineering solution to the recurrent problem of landsliding. In the study area, majority of the landslides have been reported from the road networks and streams or the built-up areas. It has been observed during field work that the increasing development over the hilly terrain has further aggravated the problem of landsliding. To reduce the risk of landslides, it is pertinent that prior to the construction of buildings and roads on unstable slopes, capability and soil analysis of the target area need to be carried out. Usually, buildings and roads are constructed without detailed EIA. The recommendations of EIA study should be implemented in letter and spirit which in turn will reduce the reoccurrence of landslides.

The analysis revealed that the destabilization of slopes by human interventions has escalated the frequency and magnitude of landslides. In the study area, the severity of landsliding varies from place to place depending on natural and human factors. Landslides occur more frequently during monsoon, which in effect triggers loss of lives, damage to housing and sources of livelihood earnings. It was found from the analysis that a total of 49 houses were damaged in the past 20 years. Similarly, two lives were also lost due to landsliding.

In the study area, structural measures, compensation policy and bioengineering measures were found as a landslide risk-reduction strategies. The analysis revealed that limited structural measures were found including check dams, retaining walls, buttresses and gabion structures. However, regulating surface and sub-surface drainage would be another landslide risk-reduction measure. In the study area, the engineering solution is widely adopted by all the landslide-related line agencies. The analysis further revealed that there are several organizations responsible for landslide risk management, but they lack integrated risk management strategies.

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