Natural hazards in mountain regions of Uzbekistan: A review of mass movement processes in Tashkent province

Mukhiddin Juliev, Alim Pulatov, Johannes Hübl

Abstract— this paper represents a short review from different scientific sources on mass movement processes in Tashkent Province. We can see that Tashkent Province is one of the most areas, which is prone to all of the natural disasters (earthquakes, landslides, debris flows, rockfalls, and avalanches). The considered region located in high mountainous area and presence of a considerable quantity of precipitation leads sectors covered with loess rocks to be more vulnerable to mass movements. Most effective triggering factors of mass movement processes in this area mainly rainfall and seismic activities. Sometimes the synchronous development of these two factors can create the huge losses. The presence of a big water reservoir, settlements and recreational zones in this area increase the efficiency of the region in terms of prevention of natural hazards. Nowadays the main attention paid to Mingchukur landslide and its impact to a water reservoir. Therefore, for obtaining accurate data for inaccessible areas and for analyzing datasets reasonable is the using of Remote Sensing technology.

Index Terms— Landslides, triggering factors, earthquakes, remote sensing, climate, Tashkent Province, Uzbekistan.

1 INTRODUCTION

Central Asia countries have a long history of disasters that have brought out economic and human losses. In this territory, we can observe all types of natural and technological hazards, including earthquakes, floods, landslides, mudslides, debris flows, avalanches, droughts [5].

Earthquakes are the prevailing hazard in Uzbekistan. It lies in a region with low to very high seismic hazard zone [5]. Since 1955, Uzbekistan has experienced 81 earthquakes above five in magnitude, of which 11 were above six. An earthquake struck Tashkent on 26 April 1966 that killed 10 people, affected 100,000 others and caused economic losses of $300 million [30], [18].

Landslides are the second natural hazard in terms of a number of victims and damages. However, most of the earlier publications were in Russian and, thus, remained practically unknown in the Western World [13].

In Central Asia, landslides often occur in the loess zone of contact with other rocks, on clay interlayers of the Mesozoic and Cenozoic age, reaching a volume from tens of thousands up to 15-40 million m3, characterized by the duration of preparedness and relatively rapid and catastrophic displacement of the masses [24].

During the last years, a large number of projects and studies conducted in the mountainous regions of Uzbekistan to prevent landslide processes. In Uzbekistan, 90000 km^2 area covered by mountains, where about 3.0 million people are living, 17% mountainous area vulnerable to landslides, 10-12% of the total damage caused by natural disasters falls on landslides. Formation of landslide processes is a natural relief forming processes which, due to changes in climatic conditions and the development of mountain slopes increasing year by year. Mountain region of Uzbekistan is most prone to geohazards in Central Asia region. Landslide processes are often associated with the impact of three factors: climatic, seismic and man-made or technogenic.

Landslides triggered by snow melting, precipitation, and underground waters consist 65-70%, by old and recent earthquakes - 25-20% and by technogenic factors - 15-20%. Last years the great attention paid to building new and reconstruction of old transport communication and transport movement on mountain highways has increased in ten times that can trigger the formation of new landslide sites. In mountain zones still operating existing economic constructions and mines where throughout 30-40 years large landslides developed. Their main feature is that, despite the long period of development, they continue to move year after year and become less predictable [25].

Remote sensing technologies became a powerful tool in natural sciences. During the last decades that this technology has also extended to landslides [3],[15],[32],[17],[31]. Nowadays, new techniques of Remote sensing finding their application more effective for landslide detection, mapping, monitoring and hazard analysis. Landslide detection and mapping can be done by optical and radar imagery. A new generation of high-resolution satellites, such as World-View, Geo-eye can be very useful for creating inventory maps of landslides in regional and local scales [4],[16].

- *Mukhiddin Juliev, Researcher of the Institute of Mountain Risk Engineering, University of Natural Resources and Life Sciences, Austria E-mail: mukhiddinjuliev@gmail.com*
- *Alim Pulatov, Head of EcoGIS Center, Tashkent Institute of Irrigation and Melioration, Uzbekistan, E-mail: alimpulatov@mail.ru*
- *Johannes Hub1, Head of the Institute of Mountain Risk Engineering, University of Natural Resources and Life Sciences, Austria E-mail: johannes.huebl@boku.ac.at*

2 CLIMATIC CONDITION OF UZBEKISTAN

Uzbekistan extends from the foothills of the Tian Shan and Pamir mountains in the east. The natural environment of Uzbekistan is very wide from the sand and gypsum deserts of Kyzylkum to the eternal snows and glaciers of the Pamir-Alai mountains. Water is coming from glaciers in the Tian Shan and Pamir-Alai mountains. Rivers Syr Darya and the Amu Darya, flow from the Tian Shan and Pamir-Alai mountain ranges to the Aral Sea [4]. Ugam, Pskem, Chatkal, Kurama ranges belong to Western Tian Shan system and Turkestan, Zerafshan and Gissar ranges with their continuous on southwestern - Babatag and Kugintangtau ranges, belong to Gissar-Alai system [19] (Figure 1). The observed global climate changes can have a serious influence on the different blocks of the environment and their individual characteristics and on a socio-economic sector [7]. Climate Change evaluation processes on the territory of Uzbekistan on day-to-day observation has started since 1951, as well as on the longer-term monthly and seasonal data. By the analysis of average changes in seasonal temperatures by districts, we can see the trend of intensive warming throughout the Republic [19]. Climate change conditions for Central Asia propose that temperature will increase from 1° to 3°C by 2030-50 [9] (Figure 2). Relationship of water invasion of mountain regions of the Central Asian region, first of all, are connected with sharply expressed continentality and aridity of the climate and with the character of evidence of the basic climatic factors - an atmospheric precipitation, temperature, evaporation, and an air moisture. Precipitations brought mostly with the air masses formed over the Atlantic Ocean. Distribution of precipitation on the territory of Uzbekistan extremely irregular and it closely related to exposure height, the location of ranges and an exposition of slopes.

Fig.1 Mountain ranges and deserts in Central Asia (from Climate Change in Central Asia, 2009)

The minimum quantity of an atmospheric precipitation (<100 mm/year) drops out in the western part of the country (Ustyurt, lower reaches of Amu Darya, Kyzylkum). To the southeast and the east from the flat area as approaching mountains it increases and reaches, and in places exceeds 800-900 mm/year. Therefore, all territory of Uzbekistan divided into eight zones - from 800 to 100 mm [1]. Plentiful humidifying by an atmospheric precipitation occurs, when the mainstream of the air masses bearing a moisture directed to the hillsides of the Ugam, Pskem, Chatkal, Kurama and a northeast part Gissar ridges. The snow cover in mountains at height of 1200-2000 m can reach up to 90-100 cm, reaching in some years up to 1.5-2 m, the amount of precipitation in the wet year comes up to 1070-1250 mm. As for plain, piedmonts, and mountains of Uzbekistan, we can see the precipitation characteristics in autumn (15-20 % from the sum of annual), winter (30 %), spring (40 %) and summer (5-10 %). March, April - the rainiest months. It is important to notice that

the quantity of precipitation in a mountain zone in different years changes from 600 to 1400 mm. Last years in a climate of Uzbekistan observed the process of aridization, i.e. big contrast has marked in quantity of an atmospheric precipitation between years. Periodicity time of landslide activation in the mountain region of Uzbekistan related to the transition of dry years with wet years. In dry years, we can observe the processes, which can change the stability of slopes, rocks dry up, fracture, and new conditions created for the subsequent saturation during the wet period [1]. Soil and air heat increases, daily and annual fluctuations of the air temperature rise. As a result, the discharge of springs decreases in ten times, many of them temporarily dry up. Ground water level decreases from 3-4 to 10-12 m. Hence, the volume of the pores unfilled by water increases, the susceptibility of soils to fast soaking increases, i.e. the dry period prepares change of structure and a condition of soils for failure in a wet year. Large mass movements can occur during the period of thawing of snow and falling off high quantity of precipitation. Discharge of springs will increase in the mountain region of Uzbekistan [25]. Tashkent region in the area of distribution of landslides heads the list (50-67%).

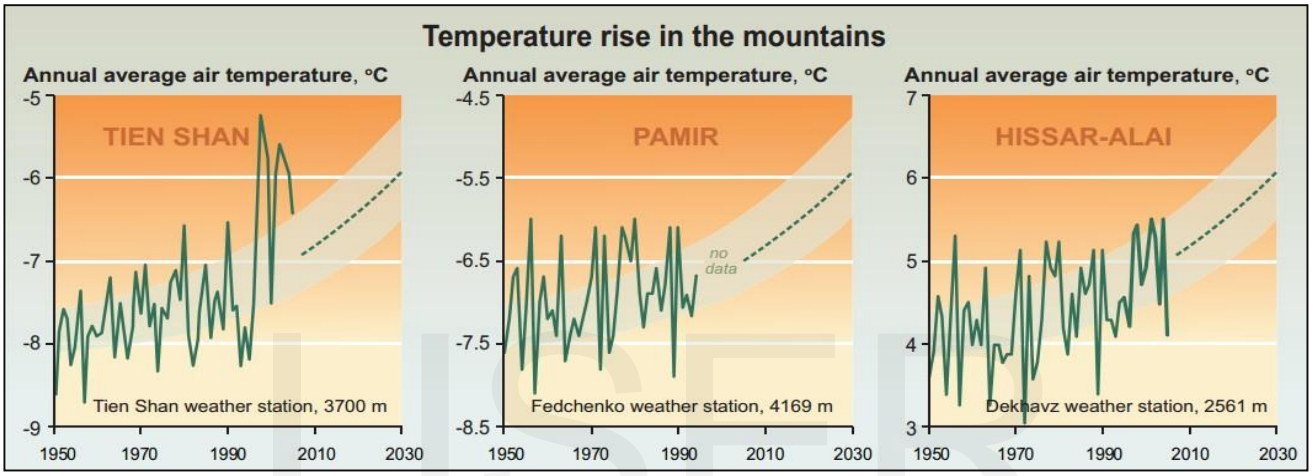

Fig. 2 Temperature rises in the mountains (from Climate Change in Central Asia, 2009)

3 GEOMPORPHOLOGICAL CHARACTERSITICS

Relief of Bostanlik district relatively monotonous and mainly represented by hills, mountains and highlands. The lowlands are common in the western and southern part of the district. Mountains occupied almost all of the territory, where the highest mountain ranges: eastern Tianshan, Karzhantau ridge Pskem Mountains, Ugam and Chatkal Ridges. The heights of the district respectively, increasing from west to east and from south to north. The southern and western parts of the area are on average at an altitude of 1000 meters above sea level. The rest of the district where the highlands prevails located at an altitude of 1200 to 4000 meters above sea level [21]. The hills are formed mainly sandstones and loess. Foot of many mountains consists mainly of shale and granite. The region is icluduд in a seismic zone, and annually in the district occur from 5 to 8 or more earthquakes of different strength. Almost all mountain ranges have down streams, some of which turn into rivers. The bulk of the streams and watercourses in the district are tributaries of the Chirchik River. The largest of them, Beldersay Pskem, Ugam, Koksu, Chimgansay and others [20]. Through the district flows the river Chatkal, which is sometimes considered the left part of the Chirchik River. Almost all rivers flow into the Charvak reservoir (Figure 3). All rivers and their inflows characterized by instability of a water balance in a various season. The largest settlements - cities of Gazalkent, Charvak, Humsan, Saylik, Nanay, etc., only 40 mountain settlements [25]. Water reservoirs on rivers are crucial for societies for hydropower generating, irrigation purpose and for controlling river flow [29],[26]. In Central Asia available more than 290 water reservoirs and the total volume of them over 163 km^3 that regulate more than 50% of the monthly regions river flow and the area occupied by reservoirs constitutes roughly 6% of the CA countries irrigated areas [9]. In mountain regions of Uzbekistan on the rivers Chirchik, Akhangaran, Narin, Kashkadarya, Surkhandarya operate 6 water reservoirs with capacity from 170 million m^3 to 2.0 billion m^3. Coastal zones are located on high downslopes characterized by a complex geologic structure and formed by weak and easily eroding rocks.In 1970, construction of the Charvak dam with the height of 167 m has ended and started flowage of Brichmulla depression and filling of the Charvak reservoir in the area around 40 km^2 and with the volume of 2 billion m^3. Coastal zone of the Charvak water reservoir has the extent of 80 km. The

most hazardous area is landslide Mingchukur, located in the center of Brichmulla depression, on the northern coast of a water reservoir in 3,5 km from dam site.

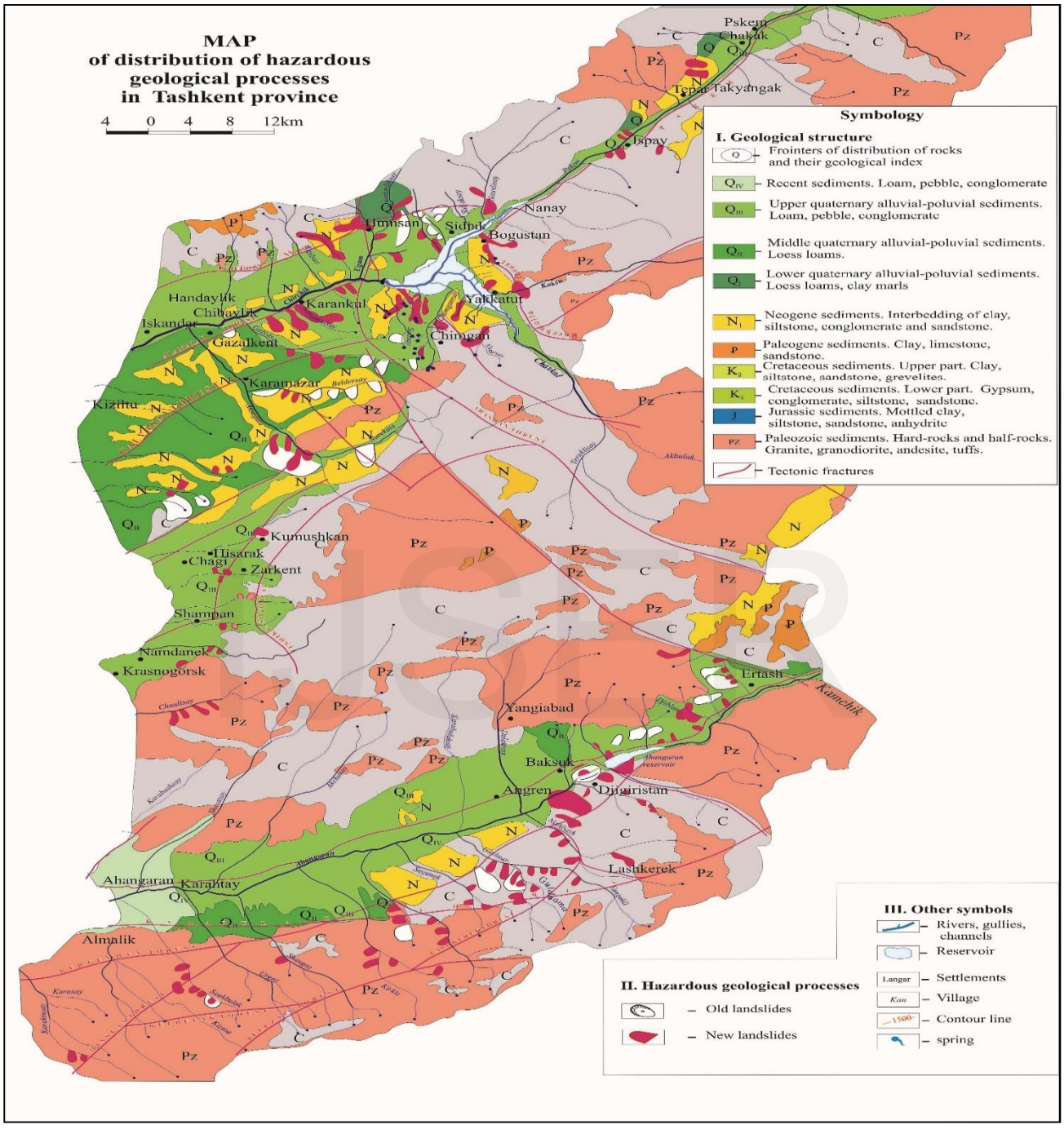

Fig. 3 Map of distribution of hazardous geological processes in Tashkent Province (from Niyazov, 2009)

The general width of a landslide is 3,0 km, depth of a surface of sliding of 50-20 m, the volume of the landslide is 70,0 million volume м3. Most mobile is the right western board of a landslide. Now it has the width in the top zone of 450 m, in the bottom 940 m, at the average width of 700 m and length of 700 m to depth of offset of 50 m the landslide volume makes 24,5 million m^3. Slope formed from the surface by conglomerate and gravels covered with loamy soil. The thickness of conglomerate and gravels 5-20 m, loams 5-10 m. After coming formation of continental lies down thick strata continental molasses of Neogene formed by siltstone, sandstone, clay and gravelites. The geologic and tectonic structure of a landslide caused by the

flexural-rupture zone of the Pskem fault. Main rupture pass through the base of a wall of failure of landslide and has the depth of 10-12 m (Fig 4). In intervals of heights of 1000-1200 m wedge out more than 10 springs that testifies to the distribution of horizon of ground waters in Middle Quaternary conglomerate-gravels. Slope steepness on the average changes from 17-200. Activation of Mingchukur landslide has begun since the first year of operating water reservoir [25].

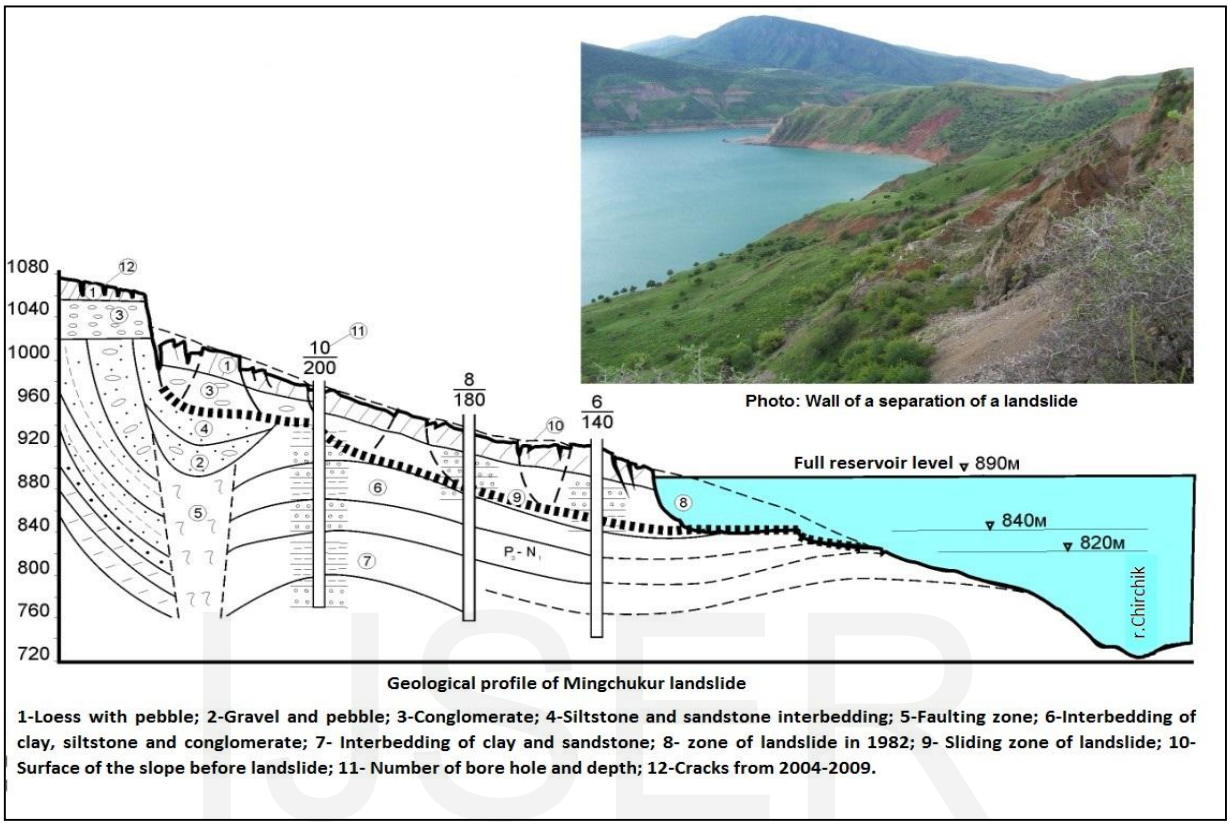

Fig. 4 Geological profile of Mingchukur landslide (from Niyazov, 2009)

The current study was formulate based on the Resolution of the Cabinet of Ministers (RCM) of the Republic of Uzbekistan № 585-dated 19.02.2007 "On the activities on prevention and recovery of emergency situations related to floods, mudflows, avalanches and landslides" and the national program for forecast and prevention of emergency situations. From the aforementioned Tashkent region is the most landslide prone area and attention should be paid to Mingchukur landslide because the further development can bring negative consequences.

3 LANDSLIDES TRIGGERED BY EARTHQUAKES

Earthquake-triggered landslides in mountain area are the main geological hazard in Central Asia [28]. Seismically triggered landslides are very common in tectonically active mountain regions. Tien Shan is one of the most active regions of the Central Asia. By the history, strong earthquakes in the Tien Shan and Pamir have been come along by the number of landslides [14]. In last decades, a huge number of investigations focused on the seismic-tectonic activity of the Tien Shan. This area can be ranked among the most seismically hazardous regions of the world [13]. By the analyses of Keefer (1984) and Rodriguez et al. (1999), we can see that landslides can be triggered if earthquakes have a magnitude equal or larger than 4 [12]. In Central Asia, more than 70% of new landslides formed in a zone of ancient and old landslide circuses. The reason of formation of secondary landslides are the changes of the basis of erosion and depth of a surface of sliding at additional seismic or technogenic influence. On extension scale seismically triggered landslides have the massive formation of various types of deformations, cover the large areas, their distribution defined by earthquake magnitude, its intensity and frequency, duration of fluctuation, speedup size, depth of the center, distance from epicenter etc. [25]. The problem of analysis of the influence of the seismic phenomena on the stability of slopes prone to landslides in seismically hazardous areas is extremely important. For investigation of the influence of the seismic phenomena in Uzbekistan, the special attention involves to Pamir-Hindu Kush zone deep-earthquakes. In this region

located, the most intensive zone of continental sub crustal seismicity on depth to 320 km. Earthquakes of this zone differ with the high degree of stability. The strongest seismic movement occurs on the depth of 200-250 km. Some of them can reach M = 7 and more, and intensity of shakes in the territory of Afghanistan reaches 9 points. In Uzbekistan, intensity of earthquakes does nor not exceed 4-5 points, but they differ in duration and a low-frequency spectrum of fluctuations.

From 1991 to 2006 there are fixed 56 perceptible earthquakes and 18-20 (30-32 %) of them have occurred during spring time. These earthquakes in mountain zones of Uzbekistan cause low-frequency long fluctuations that during spring time in wet slopes can develop crack formations, debris flows and landslides [25]. The territory of Central Asia is highly active area and application of up to date technologies very necessary for predicting earthquakes, monitoring of mass movement processes.

4 VULNERABILITY OF BOSTANLIK DISTRICT

Currently in various countries conducted intensive development of vulnerability and risk assessment methodology of the regional and local mass movement processes. The vulnerability is a very important component for mass movement processes. It can give us lose rate for the particular area disturbed by landslides [10], [11], [27]. Assessment of landslide vulnerability and risk mostly focused on determining the effectiveness of protective structures, countermeasures or organization of monitoring system. It mainly consists of two parameters (A) and (B), where A - geological factors (relief, geological structure, the composition of rocks and source of rocks humidification) and B - information about the history of deformation and displacement of rocks. The sum of these factors (A + B) determines the nature of the landslide hazard area. Bostanlik district of Tashkent Province has specific geological, hydrogeological, engineering geological characteristics and is high seismicity (from 1957 to 1977 were marked seven earthquakes by the intensity of 6-8), the quantity of an atmospheric precipitation, in various years changes from 600 to 1600 mm / year. In recreational complexes on the slopes built five cableway lines. In addition, in the foothills on 70-s of the last century were built and are now operating: Bostanlik canal length of 20 km, and Pskem and Keles canals - 30 km with the consumption of 28-32 m^3 / s. Around the Charvak reservoir in the last 20-25 years, a number of major health recreation areas developed, which determined the social orientation of its infrastructure. Here constructed wellness, sports facilities for simultaneous rest more than 100 thousand people. On the coast of Charvak reservoir operating 74-recreation area, in the southeast and east coast - a year-round international tourist complexes. Thus, Bostanlik district characterized by such indicators: total area of region is 4,2 thousand км^2 and 1,33 thousand км^2 of this area covered by loess; the possible development of an area of landslide processes - 220 km^2; area affected by landslide processes - 90-95 km^2; in the mountainous area inhabited by 612000 people; 140 mountain villages; households, located in the foothill and mountain areas more than 10000; large recreation areas, resorts and children's camps - 180; mountain reservoir - 1; channels in the foothill zone - 3; rivers - 4; large gullies - 33; mining enterprises - 3; water pipelines - 3; cableway lines - 5; mountain road - 240 km; mountain lakes - 3. Bostanlik district characterized by a wide extension of landslides, mudflows and debris flows. Landslide processes represent the greatest hazard to Bostanlik region. The largest areas of possible development of landslides observed in Ugam, Charvak and Aksagata zones. In these zones are widely developed both ancient and modern landslides. The greatest quantity of landslides has occurred in wet years [25]. From aforementioned, it is very important to have different studies in the field of landslide monitoring and mitigation of the consequences. Remote sensing as a tool can be very useful in the areas with very high altitude.

5 CONCLUSION

As mentioned before in mountain regions of Uzbekistan number of investigations carried out by different researchers in different years. Most of the projects done by State Committee of Republic of Uzbekistan for Geology and Mineral Resources, Ministry of Emergency Situations, State Committee of the Republic of Uzbekistan for Nature Protection, Centre of Hydrometeorological Service, Institutes of Academy of Sciences and United Nations Development Programme In Uzbekistan. Different triggering factors can cause different consequences in this study area. Climate change in Uzbekistan is also affecting in a prevention of natural hazards. Analysis of different sources shows that Tashkent Province has a big history of mass movement events triggered by different activities. Application of Remote Sensing techniques is becoming the very effective tool in case of mass movement analysis in Uzbekistan. Nowadays it is necessary to create centralized accurate input data of historical events for time series analysis of big and catastrophic landslides. Remote Sensing technology with accurate input data from field analyses and monitoring results can help to see the further behavior of mass movement processes. Tashkent Province is a good platform for new investigations and all given information

encourage us that the studies in this area should be continued and it is necessary to look for new modern approaches of prevention of natural hazards.

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