An Overview of the Impacts of Geological Hazards on Production

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INTRODUCTION

Natural disasters are events that occur constantly in the lives of people in almost every region of the world, their origin, continuity, effects and damages differ from region to region. Throughout the history of humanity, the level of people affected by these natural disasters has been proportional to the size of the disaster as well as the type. It has been seen that the natural events experienced with the passing time are generally in an order, and in order to minimize the negative consequences of each natural events, measures have been tried to be taken in every period as required by the conditions. Studies on this subject continue to the extent permitted by the technical and scientific infrastructure. Scientific studies on natural disasters have shown that revealing the originary classification and characteristics of each natural disaster is helpful in predicting the behavior and possible consequences of natural disasters at a realistic rate (Montz et al., 2017). Geological hazards, which differ in their origins and mechanisms, are divided in four main groups such as seismic, hydro-meteorological, terrain instability and volcanic hazards. Evaluation of all aspects of natural disasters that have occurred from the past to the present has shown how each geological hazard will be effective in which part of the earth. In this context, geological risk areas from global to local scale have been determined and risk management stages, which are the most important among all risk parameters, have been revealed. In terms of preventing geological hazards and/or minimizing their damage, the things to be done before, during and after the realization of the risk in all hazard groups are within the scope of risk management.

The continuation of production processes in every field is very important for human survival. There are countless examples of the effects of geological hazards on production from various regions of the world, and it is necessary to keep the negative impact of production from these hazards as low as possible. In this review article, geological hazards will be introduced by giving various examples from Turkey and the world, the negative effects of geological hazards

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on production and the importance of geological risks in production will be mentioned.

BASIC CONCEPTS IN GEOLOGICAL HAZARDS

The terms to be used when describing the effects of a natural hazard on humanity consist of four main concepts such as hazard, risk, vulnerability and disaster. These concepts are related to each other in terms of the realization of existing geological hazards and their consequences.

Hazard

Any element sourced from the natural phenomena that poses a threat to people and their property is known as a natural hazard. Natural hazards can cause significant changes in people's lives and activities by threatening their lives. A natural hazard becomes a natural disaster when it damages people's property or causes injury and/or death. Not all of the geological hazards are natural, some of them have human influence or are created by humans Bell (2003). Geological hazards are divided into four groups as seismic, hydro-meteorological, volcanic and terrain instability hazards (Table 1).

Table 1 Types of geological hazards

VOLCANIC HAZARDS	SEISMIC HAZARDS	TERRAIN INSTABILITY HAZARDS	HYDRO-METEOROLOGICAL HAZARDS
Explosion Ash fall Lava flow Pyroclastic flow Lahar Debris avalanche Toxic gases	Earthquakes *Volcanic origin* *Tectonic origin* Ground motion *Human-induced*	Landslide Rockfall Topple Earthflow Mudflow Debris flow Creep Solifluction Subsidence Collapse	Flood Storms Drought Snow avalanche Tornado Hurricane Hail Thunderbolt Fog

Risk

Risk is defined as the possibility of harmful consequences or expected loss (death, injury, environmental or economic damage) from natural or man-made hazards. The presence of a natural hazard does not imply that the risk exists. The probability of a natural hazard to pose a risk, or in other words to result in damage to people's property or lives, increases or decreases in direct proportion to the concept of vulnerability.

Vulnerability

Vulnerability is the possibility of injury to life, property, or both, due to any natural phenomena. For any natural hazard, the level of vulnerability can be minimized by applying disaster management rules before the hazard takes action. There is a mathematical formula between the concepts of Risk, Vulnerability and Hazard and it is expressed as Risk = Hazard x Vulnerability (Figure 1).

Fig. 1 The formula of the concepts of hazard, vulnerability and risk

Disaster

The realization of the risk according to the level of vulnerability as a result of the action of any natural hazard is defined as a disaster. The magnitude of damage to people's property and/or lives in disasters increases the degree (severity) of the disaster. In addition to this general definition of natural disaster, there are different definitions according to the situation considered, and Akar (2013) summarized the definitions of natural disasters made by different researchers. Accordingly, natural disaster is defined by Kim (2011) as a situation or event that requires national or international assistance and limits local capacity, and Moe and Pathranarakul (2006) defines natural disaster as floods, earthquakes, hurricanes, extreme weather conditions, drought and volcanic eruptions. They stated it as a situation that brought distress to the society. While Pindyck and Wang (2011) define disasters as events that lead to a decrease in consumption and wealth by reducing the capital stock and/or the efficiency of capital on a national or global scale, according to Otero and Marti, (1994); Natural disasters are sudden, dramatic, unplanned events that cause great losses. Akar (2013) stated that Benson and Clay (2004) define natural disasters from an economic perspective, and in this definition, natural disasters cause human, physical and financial capital losses, reduce economic activities, and seriously affect the expenditures and incomes of public and private sector organizations.

GEOLOGICAL HAZARD TYPES

Geological hazards are divided into four subgroups depending on their origin. Although each of these four groups of geological hazards has different formation conditions in itself, there are situations where they are related to each other in the heterogeneous and dynamic structure of the earth.

Volcanic Hazard

The formations of volcanoes in different parts of the earth generally develop depending on plate movements. Volcanic activities are observed in different areas such as subduction zones at the converging plate boundaries, diverging plate boundaries and intracontinental hot spots. During volcanic activities, the explosiveness index changes depending on the chemical composition of the magma. While basic magmas are more fluid, acidic magma is more viscous and more prone to explosive volcanism (Figure 2 a,b). The hazads originated from a volcano are explosion ash fall, lava flow, pyroclastic flow, lahar, debris avalanche and toxic gases (Figure 2a-e).

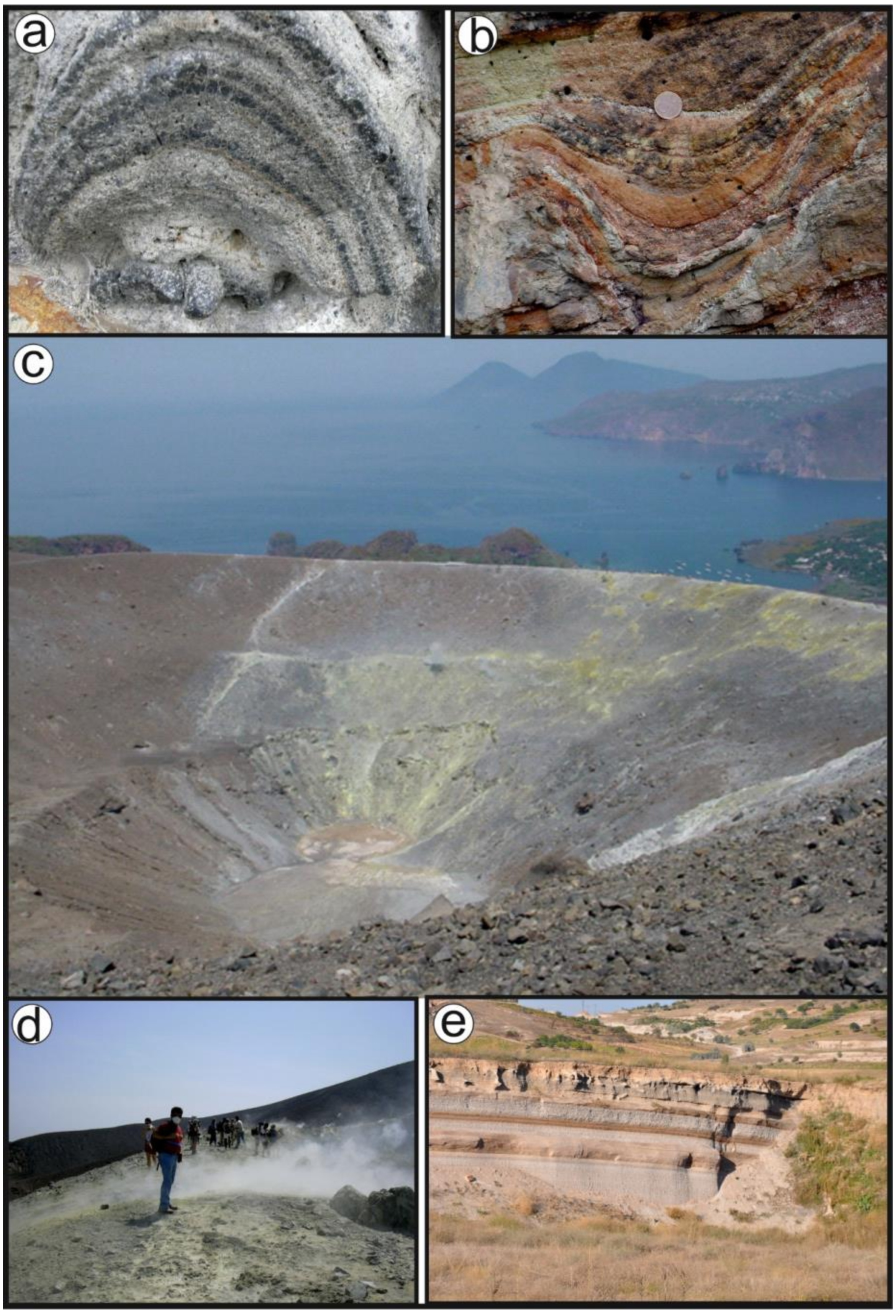

Fig. 2 a) Basic lava b) acidic lava c) crater d) gas ejection from Vulcano-Italy e) pyroclastic deposits from Capadoccian region Nevşehir-Turkey

Most of these hazards are effective in the crater of the volcano and its surroundings. Volcano crater is a circular shaped depression formed as a result of the collapse of the uppermost part of the volcanic chimney due to the cavity formed by the material coming out from the depths of the earth (Figure 2c). Since volcanic hazards are predictable, their activities can be monitored by making continuous observations on them. Therefore, it is possible to minimize the level of vulnerability by using the possibilities of current technology and implementing applicable evacuation plans for the personnel involved in all kinds of activities to be carried out in the vicinity of active volcanism.

Seismic Hazard

Earthquake is the phenomenon of sudden vibrations that occur due to fractures in the earth's crust, spreading in waves, shaking the environment and the earth's surface. Earthquakes are originally divided into two subgroups as volcanic and tectonic earthquakes. Tectonic earthquakes, which occur with the discharge of energy accumulated along the fault lines in the earth's crust, are more destructive than earthquakes, which are named after the ground movements that occur during volcanic activities. Faults occur when two pieces of earth move relative to each other. The faults that form the source of tectonic earthquakes are named as normal, reverse, strike-slip, and oblique-slip faults according to the direction of this relative motion (Figure 3). Local ground motions caused by people during various activities such as mining, construction, etc. are also included in the seismic hazard group.

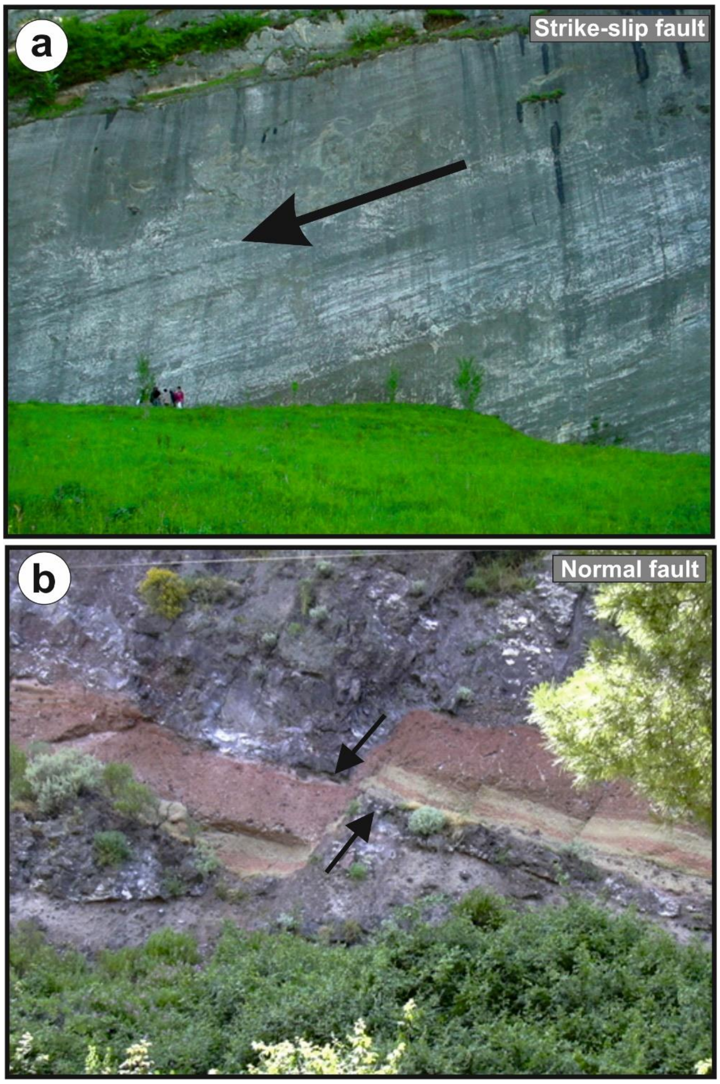

Fig. 3 a) Strike-slip Vuache fault in France b) Normal fault in Vulcano-Italy

In order to be affected by the seismic hazard as little as possible, it would be appropriate to make the construction plans considering this situation. Earthquake hazard maps have been prepared to assist in planning in this sense, and it is necessary to show sensitivity in the use of these maps on both regional and local scales (Figure 4). Building plans should be implemented by making microzone maps on a local scale and also by conducting paleoseismology studies to control the activity status of the faults in the region.

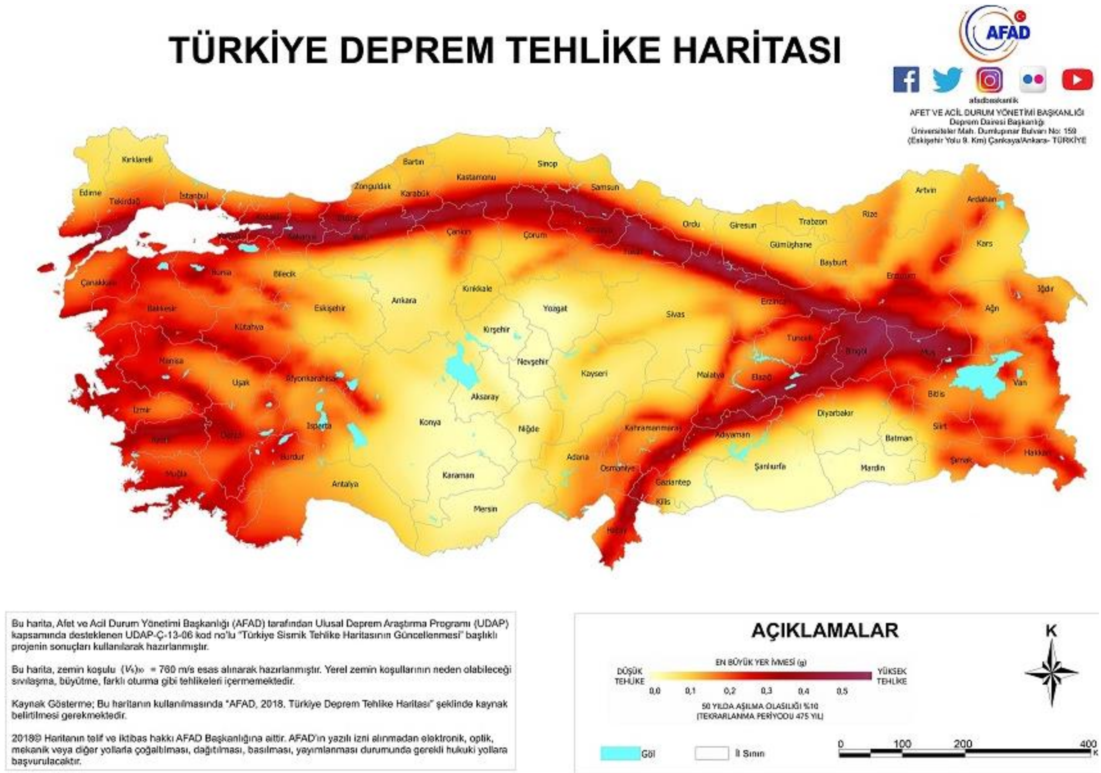

Fig. 4 Earthquake Hazard map of Turkey
Source: https://deprem.afad.gov.tr/deprem-tehlike-haritasi [Accessed 31 Mar. 2015]

Terrain Instability Hazard

Mass movements are generally defined as the downward movement of geological material on a slope under the direct influence of gravity. There are various mass movements ranging from slow to very fast with the effect of many factors such as the type of geological material, weathering and climate, slope angle, water content, vegetation and natural and human-induced loads on the slope. The hazard of terrain instability is mostly in the group of foreseeable hazards, and the level of vulnerability can be reduced by taking special precautions and making applications for each of the above-mentioned factors, which have a primary effect on terrain instability. Especially in slow mass movements such as creeps, it is possible to follow the traces of the movement through superficial elements such as trees, roads, geological layers, fences, poles of electricity and telephone overhead lines. Further detailed investigation can be made by using modern techniques such as Global Positioning System (GPS), Triangulation and Trilateration, Borehole and Surface Extensometers, Inclinometers, Piezometers, Tiltmeters etc. Among the ways to reduce the risk of land instability, or at least to keep the damage to a minimum, the top priority is to reveal the geology of the potentially unstable area. First of all, potential land instability risk areas are determined locally and their maps are made. For this risk assessment, if there are mass movements that have occurred in the relevant area before, they are primarily evaluated and studies are continued in this direction. Regional terrain instability density maps can help in this regard (Figure 5).

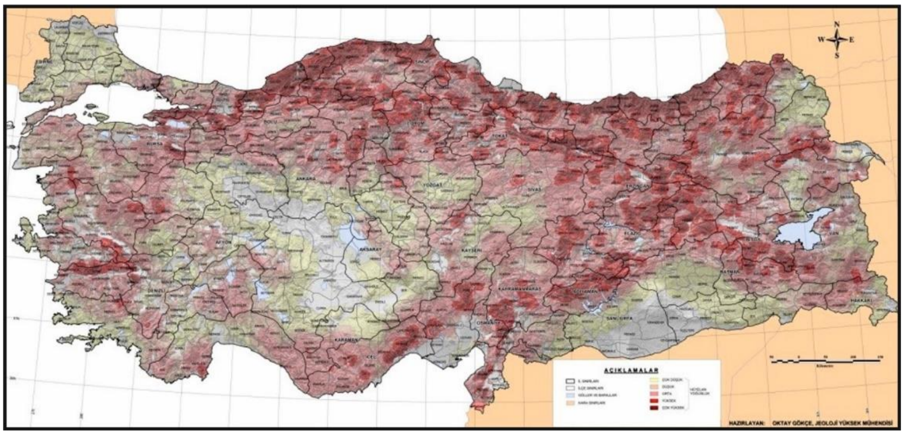

Fig. 5 Landslide density map of Turkey

Source: https://www.afad.gov.tr/afet-haritalari [Accessed 31 Mar. 2015]

To prevent land instability, reducing slope, terracing, drainage of ground and surface waters, protection and retaining walls, making rock bolts and studs, covering rocky sections with wire nets and similar applications are modern approaches for a residential area. One of the examples where some of them are applied professionally is the Lafrasse landslide area in Switzerland-Sion (Figure 6).

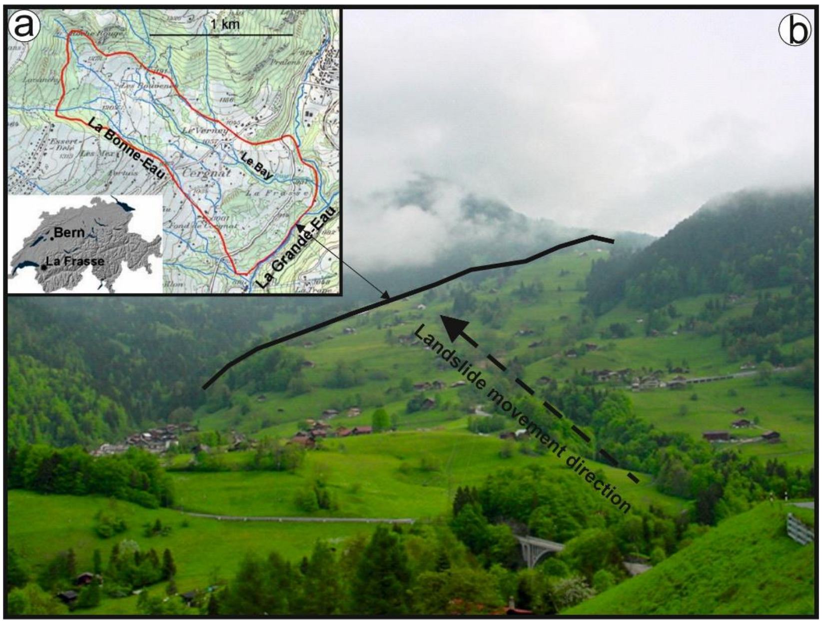

Fig. 6 a) The location (Tacher et al., 2005) b) general view of Lafrasse Landslide Sion-Switzerland

Hydro-meteorological Hazard

Continuous urban development causes significant changes in ecosystems, leading to intense convection processes and an increase in precipitation. This causes significant interruptions in the water cycle, resulting in hydrographic changes in urban areas. Such interdependent climatic and hydrological changes stand as a serious problem in the face of ongoing climate change (Żmudzka et al., 2019). Especially in recent years, with the effect of global warming and climate change, floods caused by precipitation above seasonal averages are frequently encountered. With the changing climate, human beings are faced with many hydrometeorological hazards such as flood, storm, drought, snow avalanche, tornado, hurricane, hail, thunderbolt and fog more and more frequently. Floods are the most common hydro-meteorological hazards, and the precautions to be taken before the occurrence of this hazard are very important. Figure 7 includes a post-flood view of a river north of Turin in northern Italy, illustrating what size material a river can carry during a flood.

Fig. 7 A flooded riverbed from North of Turin-Italy

Before a region can be resettled as a residential area, the natural drainage network must not be changed as much as possible and a discharge system must be arranged to ensure discharge at the highest precipitation level. In order for the existing drainage network to discharge in a healthy way, periodic maintenance should be done and the necessary cleaning works should be done regularly. In addition, in order to ensure that the life and property of people in production and living areas are minimally damaged, necessary direction walls should be built to protect them from heavy rains and potential hydrometeorological risks should be taken into account in the construction planning.

DISCUSSION

The Earth has been the scene of many geological events during its 4.6 billion-year life, and all kinds of materials it contains are in a continuous cycle with the effect of environmental conditions. Geological disasters occur less frequently among all disasters, they cause twice as many loss of life and damage for each event that occurs, but on the other hand, the rate of insurance coverage is low-indicating that the sufferes are affected more seriously (Blong,1992). When the human factor enters the events that continue in the inner order of the earth, some disruptions occur in the above-mentioned cycle. Since the geological events, both created by the internal dynamics of the earth and induced by man, occur within certain rules, it will be possible to deal with events from both origins by applying scientific rules.

Panwar and Sen (2019) investigated the effects of four types of natural disasters, namely flood, drought, storm and earthquake, on growth, and their macroeconomic consequences, using panel data from 102 countries in the 1981-2015 period. Researchers have found that natural disasters have different effects on macroeconomics and vary between economic sectors according to disaster types and intensities. For example, they observed a positive effect of normal floods on agricultural growth and even the growth of other sectors of the economy, while the effect of floods was stronger in developing countries. While the negative effects of drought were observed on agricultural growth, it did not have a significant effect on any other economic sector. MacKenzie et al., 2009, stated that the earthquake that caused great loss of life and property in Japan on March 11, 2011, and the tsunami that followed it, also disrupted the global supply chains, which was shown as the reason for the slow growth in the global economy. They stated that they have international effects on production. Hayakawa et al., 2015 investigated the firm-level impact of the 2011 Thailand flood, particularly its impact on production.They concluded that while both directly and indirectly affected firms, on average, did not change their local purchasing share, directly affected small firms increased their local purchasing share, especially they are more likely to reduce their share of purchases from other companies. Krebibich et al.,2014 stated that the Thailand flood disaster caused the closure of many factories, damaging the global automobile production and electronics industries, and the economic damages of natural disasters increase exponentially every year. Aktürk and Albeni., 2002 pointed out the effects of two major earthquakes that occurred in Marmara and Düzce on 17 August and 12 November 1999, respectively, on economic performance in Turkey, considering that these earthquakes had macroeconomic consequences. Considering that natural disasters will bring some opportunities,

it is necessary to minimize the socio-economic costs of the production sector, especially by considering the faults in the selection of the establishment location (Aktürk and Albeni., 2002). The very recent hydro-meteorological disaster that occurred in August 2021 continues to affect Turkey and once again reveals the extent of the damages of the flood geological hazards that cause serious loss of life and property in the Kastamonu-Sinop-Bartın cities of the Black Sea region.
If we give an example from Turkey, where the geological hazards that harm production and the economy take action under the influence of people:On February 6 and 10, 2011, two landslides with a volume of about 50 Mm^3 occurred in the Afşin-Elbistan Lignite Enterprise Çöllolar Open Pit operation with short intervals. In the first landslide, one worker lost his life, and in the second landslide, a total of 10 mining workers, two of whom were engineers, lost their lives (Özbay and Cabalar, 2015). The landslides caused by these mining activities also caused significant production losses, and there were significant disruptions in the supply of coal to the two thermal power plants located in the region. Closson and Karaki (2008) drew attention to man-induced geological hazards such as sinkhole formation, subsidences, landslides and reactivated salt karsts caused by the diagonal interface between Dead Sea saltwater and fresh groundwater being pushed down and into the sea. There are a lot of human-induced landslides in China (Runqiu and Lungsang., 2004). Many examples of human-induced geological hazards can also be cited (Youssef et al., 2016; Cecioni and Pinada., 2009; Wang et al., 2002; Jian-bin., 2009)
The concept of Disaster Management, which can be defined as a management process that requires the use of all institutions and organizations, opportunities and resources of the society in line with the determined strategic goals and priorities, in order to prevent and reduce disasters, to plan, direct, coordinate, support and effectively implement the measures to be taken. It consists of main stages such as mitigation, preparedness, response and recovery, which must be done during and after the disaster (Coppola, 2006). It is of vital importance that disaster management processes are implemented on time and in place for both natural disasters that we encounter as a result of both human-induced and geological processes.

CONCLUSIONS

As conclusions:

- The negative effects of geological hazards on production is constant, and it is necessary to explain the geological risks from individual to global scale very well to people and to evaluate each geological hazard separately in the activities to be carried out in each field.
- Risk, vulnerability and hazard relationship should be considered very well for almost every geological hazard and it should be tried to overcome with minimum damage without interrupting human life in terms of production and economy. For each geological hazard, the criteria for reducing vulnerability

should be tried to be applied, and previous analyzes on the relevant hazard should also be used.

- In the evaluation of investments to be made in the production area by the local authorities in a certain region, geological risks must be kept in the foreground.
- The low insurance coverage of disasters caused by geological hazards further increases the victimization of individuals and institutions damaged by these hazards. Therefore, expanding and strengthening the coverage of the insurance sector will close an important gap.

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Abstract: Throughout history, human beings have been affected by the ongoing events in their environment. While some of the events take place in the sphere they live on, some of them are in the way that events outside the earth affect the world. Necessary measures should be taken on time and in place so that people are not adversely affected or at least minimally affected by the aforementioned events. Geological hazards are the most important risks that occur in the environment of human beings and have a high probability of damaging people's life and property. In terms of risk management of geological hazards, which are divided into four main groups as seismic, hydro-meteorological, terrain instability and volcanic hazard and have their own characteristics, the efforts to prevent and reduce losses for each of them also differ within themselves. In this review article, geological hazards were introduced in general by giving various examples from the world, the effects of geological disasters on the economy and production were discussed, and the points to be considered for each risk were tried to be emphasized.

Keywords: production and geological hazards, seismic hazard, hydro-meteorological hazards, terrain instability, volcanic hazard