# MASS MOVEMENT HAZARD MAP GUIDELINES FOR LAND USE AT TURKEY

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**ABSTRACT:** It is a fact that Turkey has all conditions required for natural disasters due to its geologic, geomorphologic and climate characteristics. Landslides are the disaster type having the most damaging effect after the earthquake for Turkey. Mass movement guidelines prepared by AFAD for the production of landslide, rock-fall and avalanche disaster hazard maps. Guideline have been provided together with basic literature information on mass movement in general and technical information. Details are provided on the concept of mass movement and its characteristics in the guideline and then stages of mass movement inventory development have been focused on. Mass movement inventories are the foundation of mitigation efforts. Stages of technical analysis in such mapping efforts of mass movement and parameters that especially need to be taken into consideration have been analyzed subsequently. Methods employed in such studies follow parameter assessments and then the concepts of mass movement susceptibility, hazard and risk have been emphasized.

When the literature on mass movement is examined, it can be said that the number of mass movement assessments increases every year. It is known that improvements in computer, GIS (Geographical Information System) and RS (Remote Sensing) technologies played an important role in the increase, particularly in the last 15-20 years. Mass movement inventory, susceptibility, hazard and risk assessments are performed by taking advantage of mentioned computer, GIS and RS technologies nowadays and presented to the users. At this study; GIS using all phase for preparing mass movement hazard maps. After producing these hazard map, decision maker and politicians can be used for preliminary land use planning, hazard mitigation and DRR studies.

**KEY WORDS:** Mass movement, land use planning, hazard map, DRR

## 1. Introduction

As is known, excessive casualties and damages are experienced in many parts of the world due to disasters. Extremely high economic losses are suffered. Furthermore, besides these direct losses, loss of markets, production, and labor, unemployment, and environmental damage should also be taken into consideration. Thus, it is evident that the actual losses are far beyond the estimated ones. Turkey is one of the most vulnerable countries for natural disasters due to its geologic, geomorphologic, and climate characteristics. Furthermore, unplanned urbanization and uncontrolled population increase are important factors triggering the increase of losses. Many citizens have lost their lives, and immense economic losses have been incurred to date in Turkey due to natural disasters.

According to Table 1, earthquakes, landslides, rock fall, floods and avalanche are disasters causing the most damage in Turkey. This data summarizes the overall disaster profile of Turkey for the past 58 years and consists of evaluations of the database of AFAD (Disaster and Emergency Management Presidency). Furthermore, when the distribution of disaster types affecting settlements (province, district, township, and village) based on the said database is examined (Table 2), earthquakes, floods, and landslides once again appear to be the disaster types causing the most damage, and it can be observed that 43.75% of settlements in Turkey have experienced a disaster type at least once.

**Table 1.** Number of disasters and disaster victims according to disaster type (Gökçe et al., 2008).

| Disaster Type | Disaster Number | Number of Total Affected Disaster Victims |
|---|---|---|
| *Landslide* | 13494 | 59345 |
| *Rock-Fall* | 2956 | 19422 |
| *Flood* | 4067 | 22157 |
| *Earthquake* | 5318 | 158241 |
| *Other Disasters* | 1175 | 9237 |
| *Avalanche* | 731 | 4384 |
| *Multiple Disasters* | 2024 | 12210 |
| ***Total*** | **29765** | **284996** |

**Table 2.** Number of settlements affected by disasters according to disaster type (Gökçe et al., 2008).

| Disaster Type | Number of Settlements Experiencing a Disaster | Rate in the Total Number of Settlements |
|---|---|---|
| **Landslide** | 5472 | 15.31 |
| **Rock-Fall** | 1703 | 4.76 |
| **Flood** | 2924 | 8.18 |
| **Earthquake** | 3942 | 11.03 |
| **Other** | 992 | 2.78 |
| **Avalanche** | 605 | 1.69 |

AFAD has taken a leading role in raising disaster awareness in Turkey and in putting this awareness into practice. Within the framework of this aim AFAD prepared guidelines about mass movement hazard map standard. This guideline analyzes the current status of knowledge and practice in the world and Turkey concerning mass movement It also elucidates the technical terminology concerning these issues. Additionally, it also detail the stages of preparation for a landslide inventory and their significance. GIS and applications for RS are also discussed.

At this article, given detail information about most important mass movement type landslide disaster and how can we prepare landslide inventory, susceptibility, hazard and risk map for following AFAD's mass movement guidelines.

## 2. The Landslide Concept

The landslide concept is defined by Cruden and Varnes (1996) as the downward movement of rock, debris, and earth material or a mixture of them with the effect of gravity (Figure 1). Landslides are fundamentally included under mass movements. For the sake of AFAD's guideline, landslides must be regarded as downward movements of the abovementioned natural materials with the effect of any triggering element or preparative parameter. Furthermore, it must be noted that movements such as subsidence or lateral spreading are excluded, and that identifications and evaluations are made considering rock-fall, slide, flow and other mass movements as a combination of them, which are frequently observed in Turkey.

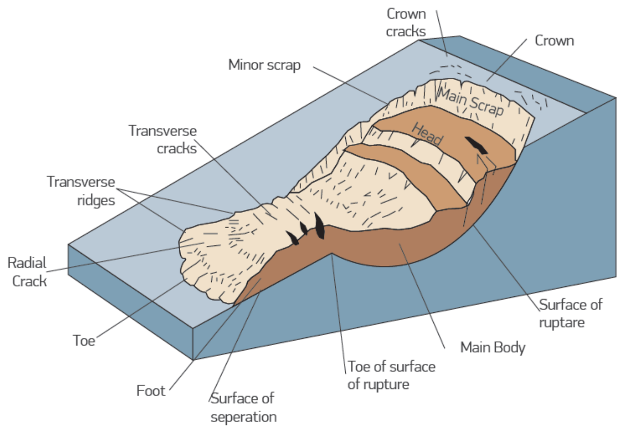



**Figure 1.** A rotational landslide and elements (http://pubs.usgs.gov).

Landslides may be triggered both by geological, geomorphologic, climatic factors and processes and several human activity factors and also by processes related to nature and human effect. Furthermore, a mass movement occurs in a certain manner due to geomorphologic properties resulting from many factors and a successive chain of events determining the velocity of the movement on the slope and increasing and/or decreasing the mass slide rate. Landslides not only cause loss of life and property in settlement areas affected by them but also can lead to damage and losses in areas having an economic value such as highways and railways, agricultural and forest lands. Moreover, landslides which may cause a negative effect on the quality of streams are also likely to lead to some problems in socio-economical terms such as urbanization and protection of natural habitat and life quality of society (Schuster and Fleming, 1986). On the other hand, landslide damages are mostly misevaluated within excessive precipitation processes and earthquakes, which are one of the most important factors triggering a landslide, and thus the extents of landslide damage are considered to be lower than expected and/or what they really are (Schuster, 1996).

## 3. Major Landslides in Turkey

Considering geological and geomorphologic properties, the Black Sea Region (at north part of Turkey), in particular, as well as the Eastern Anatolian and Central Anatolian Regions include areas where landslides frequently occur İn Turkey. Another concern emphasized in the mentioned study is the observation of a landslide incident in 5472 settlements (% 15.31) out of 35.741 kept in the concerned database (province, district, township, municipality and villages) (Figure 2).

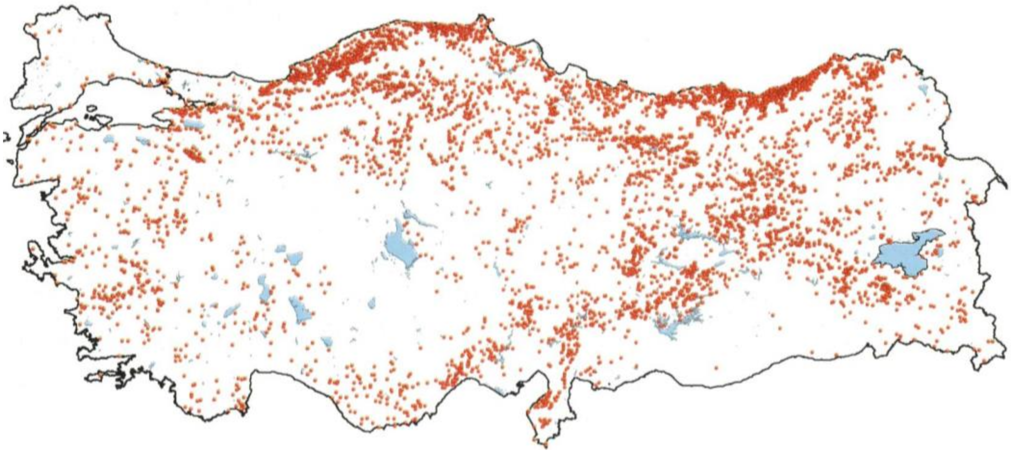


**Figure 2.** Locational distribution of landslides in Turkey between 1950 and 2008 (Gökçe et al., 2008).

The landslides of 1929, 1950, 1952, 1985, 1988, and 1990 in Turkey, caused loss of life and property to a great extent, particularly in the Black Sea Region. The Tortum, Geyve, Ayancık, Sinop, Of, Sürmene, Sera/Trabzon and Maçka/Çatak landslides are some of them. For example, 65 people lost their lives and substantial damage arouse due to the landslide on 21.06.1990 in the Maçka/Çatak region following heavy rainfall (Öztürk, 2002). Another debris/mud flow type landslide on 13 July 1995 in Senirkent (Isparta) caused 74 casualties and buried thousands of houses under the earth. 15 people died and the village mosque and 21 houses were buried under the earth after a landslide on 17.03.2005 in the Kuzulu neighborhood of the Sugözü village of the Koyulhisar district of Sivas province. The volume of the material moving at the time of the landslide was approximately 12.5 million $m^3$ and the landslide occurred in the form of rotational instability. As a result of the landslide on 26.08.2010 in the Gündoğdu town of the Rize province, 13 citizens lost their lives and substantial damage was suffered. These landslides records are reflected in the press and it can be said that the problem of landslide in Turkey is of much more critical extents considering thousands of other landslides, which could not be kept in records and occurred away from settlements.

## 4. Landslide Analysis Stages

Landslides are likely to progress depending on several parameters such as hydrological, climatologic parameters and vegetation/land use as well as geological and/or morphological processes; and may be triggered by some factors such as earthquake, rain and human effect on nature. Furthermore, landslides also play an effective role in the development of the land surface (Brabb and Harrod, 1989; Harmon and Doe, 2001). Carrying out a detailed landslide inventory and mapping on landslides, which is a kind of major natural disaster affecting human life, is an important issue required to be taken into consideration as the first step of all kinds of studies regarding landslides. In addition, spatio-temporal landslide analysis is the basis of every stage of mitigation efforts and of finding out the development of the land surface (Soeters and Van Westen, 1996; Guzzetti et al., 2000; Galli et al., 2008; Booth et al., 2009; Guzzetti et al., 2012).

### 4.1. Landslide Inventory Map

Landslide inventory maps include extremely important information for decision makers, planners and local authorities in terms of practice. Therefore, landslide inventory maps are generated at various scales from a local scale to greater scales at many different locations around the world by using various methods; and landslide characteristics are kept in databases. When considered in general terms, it is necessary to specify landslide location, sort, size and effects as well as time of occurrence and features, if any, such as triggering parameters regarding the generation of landslide inventory maps (Guzzetti et al., 2000; Guzzetti et al., 2012). There are many methods in generating landslide inventory maps, which are accepted in the literature. Those which are frequently used are summarized below (Soeters and Van Westen, 1996; Guzzetti et al., 2000; Metternicht et al., 2005; Lee and Lee, 2006; Nichol et al., 2006; Weirich and Blesius, 2007; Booth et al., 2009; Marcelino et al., 2009; Alkevli and Ercanoglu, 2011; Guzzetti et al., 2012).

1) Topographical map and Digital Elevation Model (DEM) analysis
2) Aerial photo interpretations
3) Field surveys/onsite geomorphologic analysis.
4) Printed or digital map archives
5) LIDAR (Light Detection and Ranging) implementations
6) Utilization of satellite images

Constituting the basis of landslide practices, creating landslide inventory efforts are based on the studies composed and published by WP/WLI (1991) for the first time. Despite other studies carried out afterwards regarding landslide inventories to be created for recording the landslide characteristics (Soeters and Van Westen, 1996; Cruden and Varnes 1996; Fell et al., 2008a and b; Van Westen et al., 2008), it is still hard to refer to a standard landslide inventory form which is universally valid. Furthermore, both in Turkey and around the world, the forms and data are used, which are recommended in abovementioned practices and mostly updated by the researchers according to their objectives considering areal conditions on which they carry out their studies.

### 4.2. Parameters Utilized in Landslide Assessments

Parameters of various origins are utilized in landslide susceptibility, hazard and risk assessments in addition to landslide inventories and databases by observing the purposes of mapping. The basic purpose here is establishing direct and/or indirect relations between the landslide characteristics in the field and the parameters taken into consideration, and it is based on the production of susceptibility, hazard or risk maps. In the process starting after the early 1980s, extraordinary developments in GIS and computer technologies provided an opportunity for digital based landslide assessment activities. Such activities increased each day and have become an essential assessment and application instrument today. In such studies, the researchers used data sources with radically different types and structures and performed landslide susceptibility, hazard and risk assessments. It should be noted that the purpose of the study, access to data, time, and financial conditions have an effect on the parameter to be used and the mapping technique to be selected. As it can be observed in the Table below, while preparative parameters constitute the basis of landslide susceptibility mapping, it is necessary to take triggering parameters into consideration in landslide hazard mapping (Table 3).

**Table 3.** Parameters utilized in landslide assessments (Aleotti and Chowdhury, 1999).

| Parameter Group | Sub-Group | Purpose |
|---|---|---|
| Preparative | - Geologic<br>- Topographic<br>- Environmental | Susceptibility |
| Triggering | - Earthquake<br>- Precipitation<br>- Human-effect | Hazard |

At this study all parameter classified like;

- Geologic parameters: lithology, material characteristics, weathering, seismicity, distance to tectonic elements.
- Topographic parameters: topographic elevation, slope gradient, aspect, curvature, slope characteristics, drainage characteristics, distance to ridge, stream power index, sediment transport index, topographic wetness index.
- Environmental parameters: vegetation characteristics (NDVI), precipitation, land use, distance to roads, annual solar radiation.

### 4.3. Landslide Susceptibility and Assessment Methods

When the literature on landslides is examined, the number of landslide assessments increases every year. The concept of landslide susceptibility is defined as relatively a classification of locations where landslide may occur in the future regarding preparative parameters such as geological, topographic and environmental parameters, which are considered as to be effective on landslide occurrence (Varnes, 1984; Aleotti and Chowdhury, 1999; Fell et al. 2008a; Van Westen et al., 2008). The definition also involves determination of location, areal distribution or size and spatial dispersion of landslides that have occurred or may occur in the future.

When assessed in general, a landslide susceptibility study should answer the questions of where, and under which conditions will landslides occur and what kinds of landslides will occur in the future (Aleotti and Chowdhury, 1999). There are many methods in landslide susceptibility assessments ranging from simple statistical analyses to methods involving extremely complicated mathematical modeling (e.g. bivariate statistical analyses, logistic regression, soft computing methods, etc.) (Van Westen et al., 2008).

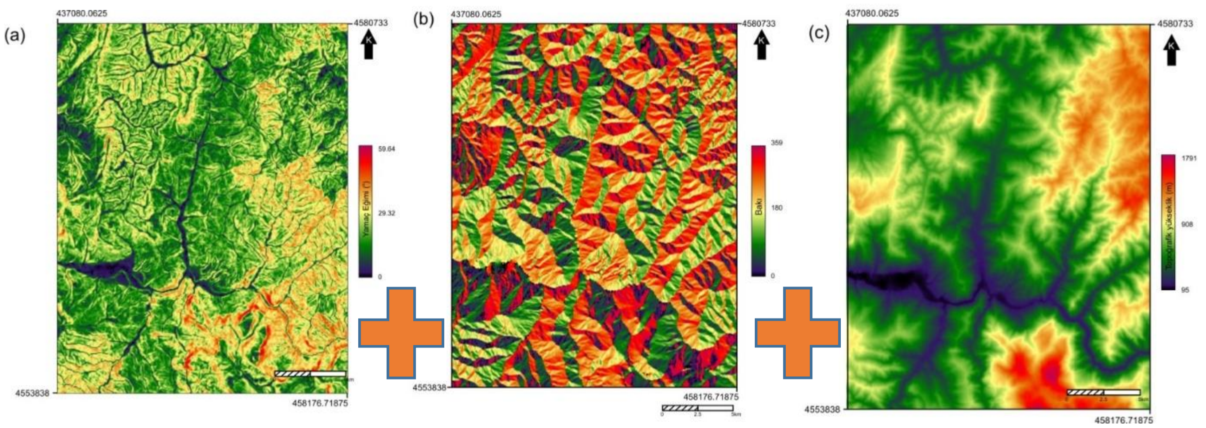
When considered in general, methods used in landslide susceptibility assessments are examined in two groups so as to be qualitative and quantitative methods (Guzzetti et al., 1999; Fell et al., 2008a). Quantitative methods are conducted in a computer aided and data-based manner by using mostly GIS based data groups while qualitative methods include methods depending on directly field observations and experiences/information. In this respect, it can be said that qualitative methods generally include subjective applications based on personal information and experience while quantitative methods comprise more objective methods depending on data (Van Den Eeckhaut et al., 2012). Besides, there is no conventionally accepted landslide susceptibility assessment method. All methods (except for geomorphological analyses) are GIS based medium and regional scaled analysis methods, and it is necessary to select a mapping unit convenient in terms of mapping method. Mapping method is defined as homogenous land units that have definable borders on land surface and distinguishable from neighbor units by specific local features. Mapping units such as grid cells (pixels), topographic/geomorphological units, and areal units like basin/sub-basin are used in landslide susceptibility assessments (Guzzetti et al., 1999). Although mentioned mapping units change according to study purpose and used methods, the most preferred mapping unit in the literature is pixel based grid cells; and this mapping unit will be selected as the base in the studies conducted.

### 4.4. Model Practice

In this section of the guideline, ways of assessing landslide susceptibility in an area are focused based on the Frequency Rate (FR) method, one of the aforementioned methods. The reason of selecting the method is the fact that it is simpler than other methods in terms of application, used in the literature frequently, and provides sound results (Ercanoğlu et al., 2008; Yılmaz, 2009). Moreover, another reason of preference is the fact that it can be applied in every field with basic statistic and GIS knowledge. The Yenice district and its vicinity in the Karabük province, one of the settlements where landslides occur most frequently in Turkey, have been selected as the pilot application area in the application for assessing landslide susceptibility through the frequency rate method.

Accordingly, first of all, inventory studies related to the occurred landslides were conducted in the selected area. Air photographs taken from the General Command of Mapping (HGK) and archives of Natural Disaster Database of the Former General Directorate of Natural Disasters were made use of for pre-assessments in landslide inventory mapping. Then, landslide locations were mapped by performing detailed fieldwork in the region. Landslide locations that were mapped on topographic maps with a scale of 1/25000 in the field were transferred to the GIS platform by digitizing (Figure 3).

Parameters that are considered to be effective in landslide occurrence were produced under present conditions for assessing landslide susceptibility in the GIS for the mentioned area. Among the considered parameters, slope gradient, aspect, and topographic elevation were directly associated with the DEM, and produced from the DEM obtained in line with the topographic map information received from the HGK. The land utilization map was converted into the raster format with the help of coding in the database within the vector data. The drainage proximity map was realized benefiting from the DEM and via converting features obtained by digitizing streams in topographic maps into the raster format and buffer procedure.



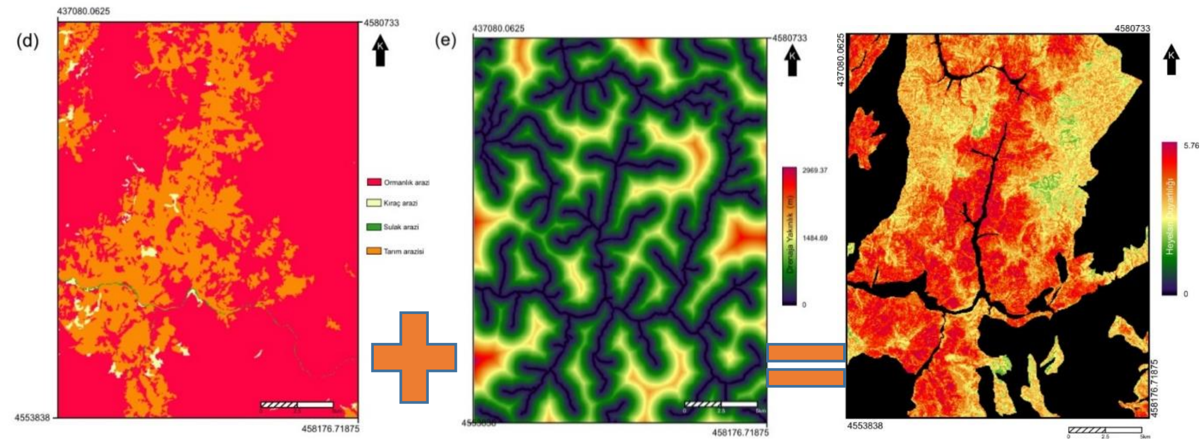



**Figure 3.** Parameters used in the application site and their features: a) slope gradient; b) aspect, c) topographic height; d) land use, and e) proximity to drainage f) Landslide susceptibility map produced according to FR values for the application area.

As mentioned before, landslide susceptibility analyses are based on establishing a relationship between the landslide inventory map given in the previous section and considered parameters. With the help of established relationships, landslide susceptibility maps of areas to be regarded can be produced on a pixel basis in the GIS.

Distribution of parameters in landslide and non-landslide areas was examined on a pixel basis depending on landslide location in Yenice and its vicinity that were designated as the application area. Although there is no standard regarding pixel dimension, the general tendency in the literature is selecting the pixel dimension between 15 and 30 m for medium and regional studies. Since the value was 20 m in the study on which the application was based, the assessments were made for pixels at the dimensions of 20 m x 20 m. Using Frekans Ratio method, FR values were calculated in the GIS, and assigned to related parameter subgroups. In the next stage, the total FR values were calculated for each pixel and the landslide susceptibility map was produced in the GIS (Figure 3).

**4.5. Landslide Hazard Assessment**

A natural hazard in a region is a probability of occurrence of an event (e.g. landslide) which has a potentially detrimental effect on a certain area and in a certain period according to Varnes (1984). The definition involves a trigger factor (e.g. earthquake, precipitation, etc.) having a return feature in the environment different from landslide susceptibility and factors such as location, time and size. In order to produce landslide hazard maps, there is a need for landslide susceptibility mapping, which digitally express landslide susceptibility (probability) and are modeled utilizing landslide inventory maps and preparative parameters. Locational, temporal and dimensional probabilities of landslides in the working area should be predicted while making a transition from landslide susceptibility to landslide hazard (Guzzetti et al., 1999; Fell et al., 2008a; Corominas and Moya, 2008; Van Westen et al., 2008).

There are generally two approaches in the literature for producing landslide hazard maps. The first one depends on calculation of landslide occurrence frequencies per mapping unit (basin, sub-basin, etc.) in the area to be studied through the production of landslide inventory maps related to different times (Cascini et al., 2008). In this approach, landslide location information related to previous periods is mostly realized by making use of air photographs.

The second approach is used if there is information particularly related to landslide occurrence dates and reliable information on whether these landslides occur because of any trigger factor (Martha et al., 2013). In the approach, information related to landslides to occur in the study area can be enhanced by information to be obtained from archives, locals and the press. If the information is obtained, precipitation and earthquake records related to the study area should be obtained. If there is landslide information triggered by precipitation, regional precipitation data should be compiled at first, then, primary precipitation analyses and threshold precipitation values are determined, and they are associated with landslide occurrence. The threshold precipitation value that can be critical is determined by the Gumbel Distribution approach, and precipitation is associated with trigger landslide times in areas where landslides possibly occur. After this stage, landslide hazard maps can be produced for different future temporal transition periods.

### 4.6. Landslide Risk Assessment

When considered in general, producing landslide risk maps requires interdisciplinary study and planning much more than landslide susceptibility and hazard maps. In order to produce such maps in a sound manner, making use of knowledge of experts in different disciplines other than geologists such as social sciences, urban and regional planners, etc. ensures obtaining successful results. At the end of risk maps, loss and damage predictions are modeled with the help of considered conditions (different scenarios); detailed information on subjects such as population, settlement, critical facility, economic activity in the study area is required. Thus, the number of risk maps in the literature is less than susceptibility and hazard maps.

According to Varnes (1984), landslide risk is interpreted as a prediction of loss of life and property and economic loss as a result of a landslide in a certain region at a certain time. In other words, risk mathematically equals to the multiplication of the damage/loss amount that can occur in all elements under risk by landslide hazard (Van Westen et al., 2006).

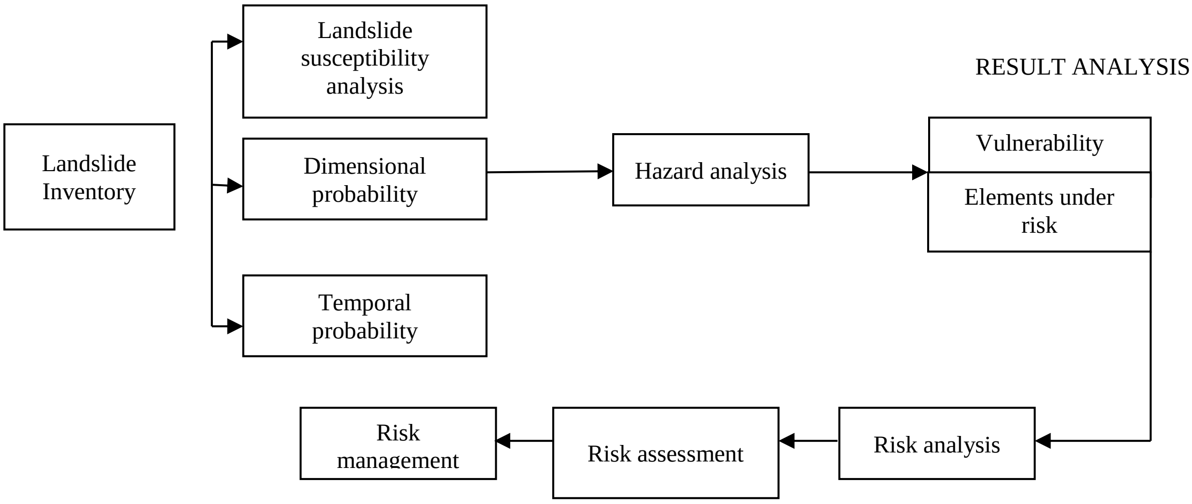



**Figure 4.** Landslide risk calculation and risk method stages (Van Westen et al., 2006).

When Figure 4 is examined, it can be observed that the landslide inventory is the basis of all assessments, and it is necessary to shift to hazard analysis (landslide locational probability, dimensional probability, and temporal probability). After that, a result analysis (considering vulnerability and elements under risk) should be conducted by landslide hazard scenarios. Following different analyses for different types of landslides, landslide risk maps are produced by risk analysis and calculations; and risk management plans can be made for considered regions.

### 5.Conclusion

Turkey, like many other parts of the world, has suffered many casualties, the loss of property, and damage to its economy due to natural disasters. A vital tool to minimize damage caused by disasters is the development of an integrated disaster hazard and risk map at a country, regional, and provincial level. Utilizing such maps enables decision-makers and local administrations to carry out robust planning and provides important guidelines to ensure that sites selected for development purposes are safe from the risks. The preparation of the disaster hazard maps is one of the most important products of AFAD's efforts (Figure 5). Turkey has invested in developing a comprehensive system of guidelines and methodologies for disaster hazard maps. The methodologies are in line with international standards. There is cooperation between different sectors. There is also cooperation between different levels of government primarily between the national and regional/county level. Risk assessments are carried out at provincial or county level and are limited by the scarcity of quantitative data on the vulnerability of elements at risk (buildings, key infrastructure, roads).

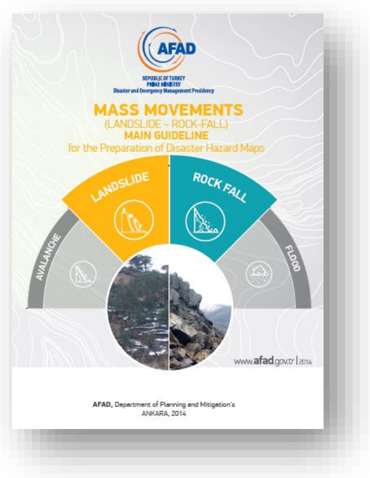



**Figure 5.** AFAD's Guidelines.

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