

# Landslides Inventory Maps in the Region of Tizi-Ouzou

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**Abstract.** Landslides are a complex natural phenomenon that constitutes a worldwide serious natural hazard. Northern Algeria, as all the Mediterranean countries, suffers by this hazard in many towns (JIJEL, Bejaia, Algiers, Constantine, Mila, Media...). Landslides constitute a significant problem for development and urban planning particularly in the city of Tizi-Ouzou, where after each pluvial season; landslides cause many damages for constructions, soils and human lives. The region of Tizi-Ouzou is situated in an area with a variable geology characterised by the presence of different loose formations, where the landslides are widespread. The inventory map of landslides was constructed by field surveys and historical phenomenon, the number of major and significant landslides considered exceeds 25, scattered all about this region. Our paper aims to present the first inventory map of the major landslides induced by different parameters as lithology, geology, slopes, precipitations, urbanization and seismic activities in this region since 1950. Each landslide will be presented and characterized with different geotechnical and geophysical parameters. The results of this study show the importance of landslides inventory in the region of Tizi-Ouzou, to preserve and reduce the hazard to build in risk region, to save human lives and provide useful tools to take decisions.

## 1. Introduction

The geomorphology of Northern Algeria is characterized mainly by steep mountains and slopes, where landslides are one of the most natural hazards widespread. This phenomenon is observed in several provinces of the country, Algiers, Bejaia, Constantine, Mila, Media, Jijel, Tizi-Ouzou, etc. The region of Kabylia knows in recent years an intense activity of this hazard; several natural slopes know ground movements more or less extensive and active. Landslides in Kabylia are widespread and differ in their type and the nature of the lands of their triggering; our study will focus on a general inventory of largest landslides cases registered in this region in recent decades.

Landslides are a complex natural phenomenon that constitutes a serious natural hazard in many countries. Landslides also play a major role in the evolution of landforms. The term 'landslide' includes a wide variety of slope movements, such as soil slips, deep-seated slides, mud flows, debris flows, rockfalls, etc., [1,2].

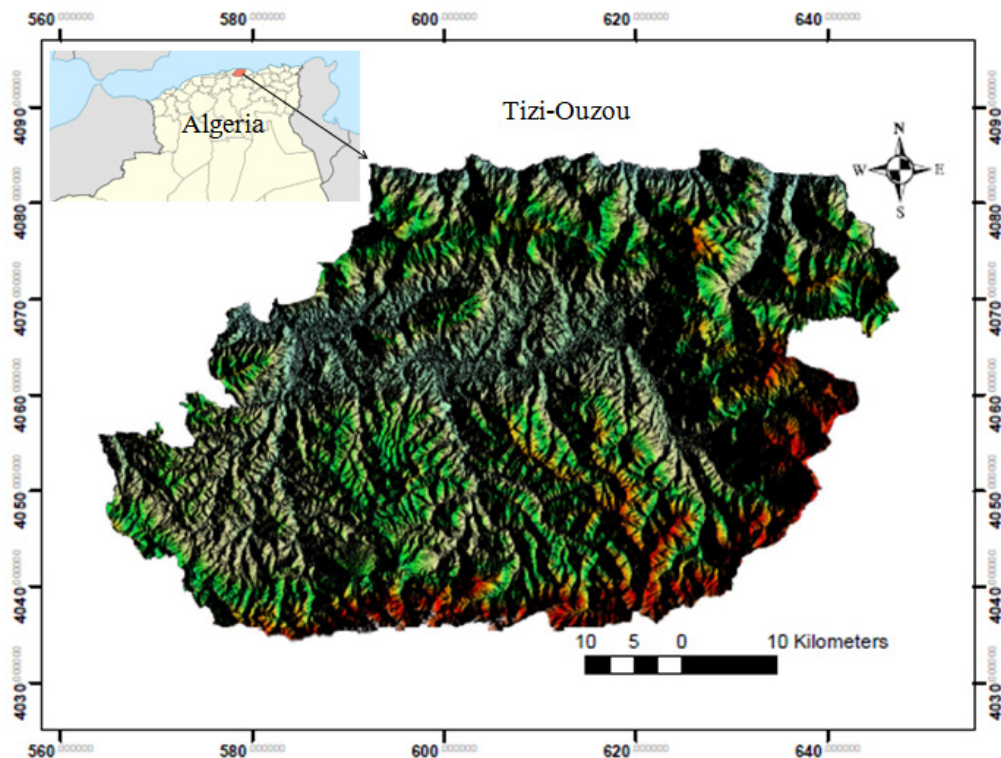
Landslide inventories generally fall into two classes: (1) landslide-event inventories that are associated with a trigger; and (2) historical (geomorphologic) landslide inventories, which are the sum of one or many landslide events over time in a region [3].



## 2. Study area

### 2.1. Geographical position of the study area

Tizi-Ouzou is located 100 km east of the capital Algiers, in the region of Kabylia. It covers an area of 3568 km<sup>2</sup>. The resident population as estimated in the 2008 census is 1'127'607 inhabitants. The density is 381.21 inhabitants per km<sup>2</sup>. Landslide is a natural hazard that affects humans and their constructions especially in the mountainous area as Tizi-Ouzou (Figure 1).



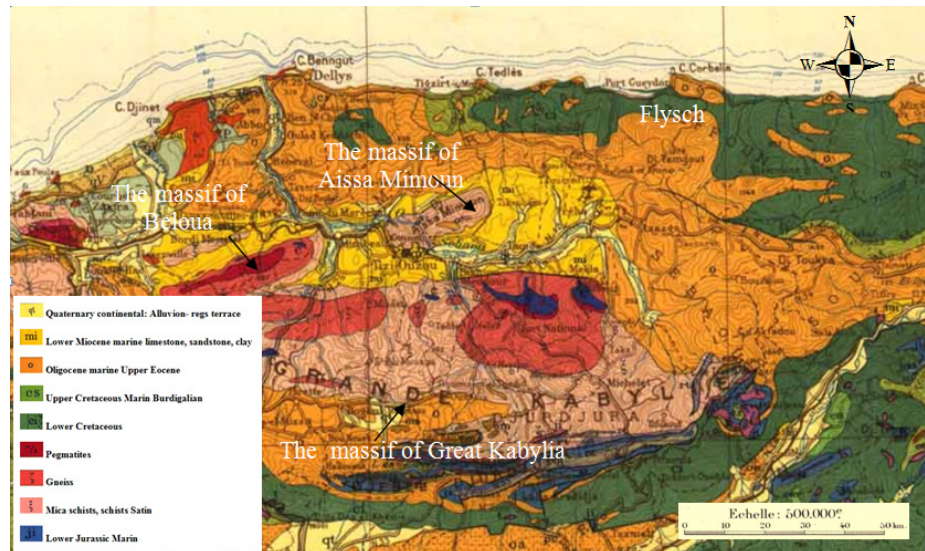
**Figure 1.** The location of the landslides study area

### 2.2. Geological and geotechnical context

The altitude of this area ranges between 10 and 2308 meters above the mean sea level, while the relief is dominated by hilly and mountainous areas. The average annual rainfall varies from 1200 to 1600 mm/yr, many rivers from Djurdjura (Oued Aissi, Oued Ksari, Rabta) have eroded the massif and the slopes are almost always high (above 12%). The lithology as shown in (Figure 2) is variable, characterized by the presence of different loose formations, where the landslides are widespread. The region of Kabylia, which contains our study area is located in the interne areas of the Maghrebideschain, the geology of study area is constituted by: (1) the metamorphic formations of Great Kabylia in the south that form three main groups (the massif of Beloua and Aissa Mimoun, massif of Sidi Ali BOUNAB and the massif of great Kabylia essentially calcareous [4]), (2) the sedimentary rocks formed by the Miocene lower oligomiocene marine followed by marine Lower Cretaceous and Upper Cretaceous in the North, (3) the quartzite sandstone of Numidian in the East and the North-East and (4) the large depressed area that corresponds to the Synclinal of Tizi-Ouzou in the Centre.

The region of Kabylia is also subject to the action of local and regional earthquakes (Boumerdes 2003 M = 6.8; Algiers 2014, M = 4.3, etc.). These earthquakes, of which the effect is certainly amplified because of the particular geological structure of Tizi-Ouzou, may play a triggering or aggravating role on landslides.

The landslides in the region of Tizi-Ouzou are situated in different formations commonly with loose geotechnical characteristics, [5,6].



**Figure 2.** Geological map of Tizi-Ouzou, 1/ 500 000 edition 1951/ 1952 M. G. Bétier

### 3. Landslide inventory map

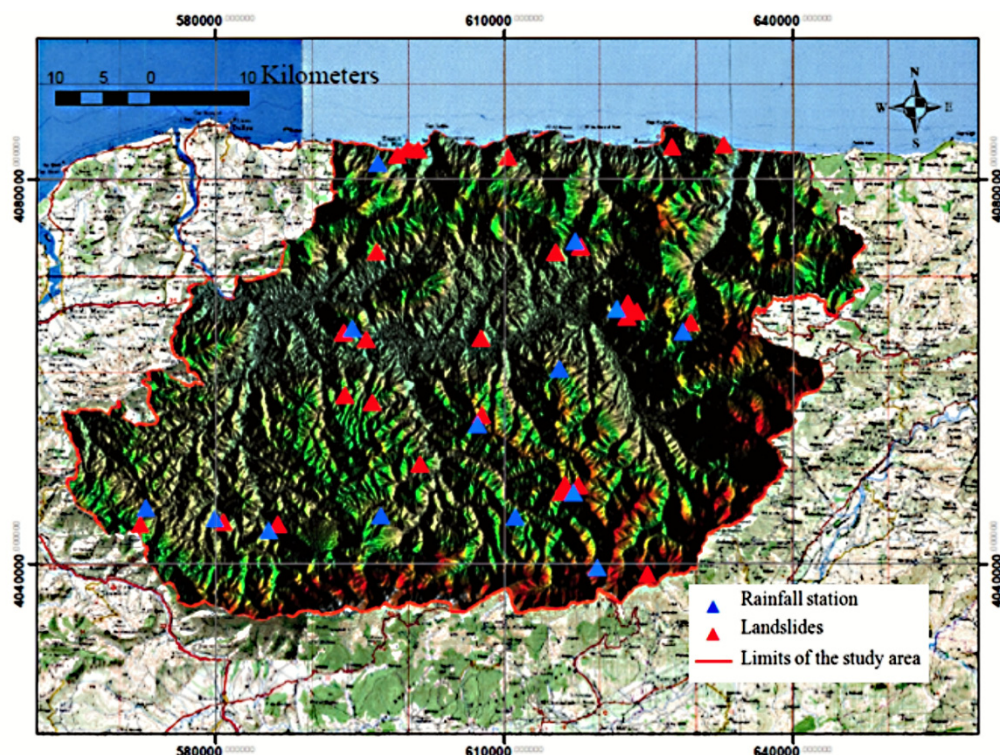
The landslides inventory map is the fundamental step in landslides characterization and study of their evolution; it may be used for evaluating and reducing landslides hazards in this region. In this paper, the landslide distribution is mapped using field investigations between 2010 and 2015, and analysis of available data that included: (1) archive from the local authorities and lab reports [6-8] (2) scientific publications [9,10] and the topographical and geological maps, (3) laboratory tests on undisturbed and remoulded samples, (4) field maps and interviews with local people.

DEM with 30 x 30 m<sup>2</sup> grid resolution of Tizi-Ouzou is generated from topographic map using ArcGis software, in view of the wide study area we have used a 1:500 000 topographic maps to generate geodesic information and to localise the landslides. DEMs image allowed us to extract other characteristics such as elevation, slope gradient, under ArcGis, to improve data geographic information system of the study area. Many of these sites have been the subject of studies by the localities of public or private services to better identify and quantify them. The majority of landslides in Tizi-Ouzou are due to increased urbanization and development, continued deforestation and increased regional precipitation (Figure 3).

### 4. Results and Discussions

Three main types of instabilities have been identified at Tizi-Ouzou. They are simple and translational landslides affecting the slopes of low inclination composed of flysch (marl and clay), complex landslides that often develop in metamorphic schist land with steep slope (over 25°) and earth flows affecting clay formations of the quaternary. The first type is located in the northern part of Tizi-Ouzou (Tigzirt and Azazga Ighil Bouzal (Figure 4c), Iflissen, Makouda), the second is located in the metamorphic basement formations of Great Kabylia (Ain El Hammam, Azazga, Talla Allam, Bouzeguene, Beni Douala,...) while the third develops in two types of terrain: in the soft series of Eocene (Tala Tgana, Azazga Ighzer Boulina) and in the Kabylia dorsal mainly calcareous (Illiltene Figure 4a, b). Tizi-Ouzou is characterized by the economic development and increasing urbanization, resulting from population growth recorded in recent years. About 15% of the surface of the province is in sliding, situation which poses significant problems to regional planning. In this context, local authorities are interested to the understanding of the landslides mechanisms in order to establish recommendations in the regulation of new constructions and in the restoration of old buildings.





**Figure 3.** Distribution of landslides in the study area



**Figure 4.** Examples of different disorders on soil of Tizi-Ouzou landslides: (a) mudflow of Illiltan on May 2012, (b) December 2015, (c) translational Azazga landslides (Ighil Bouzal) in May 2012

## 5. Conclusions

This work represents a first full inventory, which will help us to the understanding of types and spatial landslides distribution in the region of Tizi-Ouzou. It is also an approach for analysing site sensitivity to ground movements in this region. The effects of landslides on people and structures can be lessened by total avoidance of constructions in landslide hazard areas or by restricting, or imposing conditions in the norms constructions in hazard area. The landslides distribution can be completed, with new landslides in the future, we exclude from this inventory the road instabilities and low displacements of roadways in many emplacements although that indicates the existence of beginning of landslides, and our inventory is focalized on the largest landslides that caused by different natural and human factors. The mapping of landslide in the study area is quite difficult; it required the collection of important information and a very good knowledge of the site. Some of the trigger can be easily detained (slope, urbanization) others, such as (geology and hydrology, geotechnical characteristics) are more difficult to assess, especially regarding their recognition in depth. The result of this study is the development of a final inventory map in our study area (Tizi-Ouzou), which is a very useful tool to easily identify areas exposed to these three types of landslides.

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