Landslide Monitoring with GNSS measurements and prediction with Linear Regression Model: a case study Taşkent (Konya, Turkey) Landslide

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ABSTRACT

In 2011, study started the monitoring of the landslide in the Taşkent valley in Taurus Mountain steep-slope using Global navigation satellite systems (GNSS) observation at the Taşkent landslide. GNSS technique provided three-dimensional cartesian coordinates in the International terrestrial reference frame (ITRF) of the observation points with GNSS receivers in horizontal and vertical reference system. GNSS measurements provide two periods of data. For monitoring the landslide area mini geodetic network established on the area and covers stable and unstable areas with four stable reference points and thirty-four rover-observation points in active landslide area. To determine movements with a static model, a functional model, solved according to the least-squares method, was constituted for each observation period. The test statistic value computed from the difference vector and covariance matrix was compared with the F distribution. As a result, moving points and movements were computed.
The GPS displacement data in a month show the landslide slid horizontally 2.28m-0.31m and vertically -0.31m-0.20m, respectively maximum and minimum values.
In this paper, the movements and landslide area with river distance and rover points to roads and coordinate values had been analyzed with linear regression analysis methods and achieved the coefficient of the determination,r^2, at 93 % movements and other factors. For the predict movements in landslide regions, linear regression models can be useful for predict future displacements.

Keywords: GNSS, Konya, Landslide Monitoring, Regression analysis.

1. INTRODUCTION

''Landslide'' is a common term defined as a the movement of a mass of rock, earth or debris down a slope [1].
In previous studies, a various surveying techniques have been used to monitoring movements of unstable areas. Leveling, theodolites, electronic distance meters (EDM) and total station measurements provide both the coordinates and changes of target, control points and landslide features.
In the last few decades, the Global Navigational Satellite Systems (GNSS) has used very efficiently. For the purpose of geological mapping and geological studies which the accuracy

required investigations are need to GNSS measurement devices for give a better decision on study areas, such as landslide, mass movements, rock-falling, submarine landslides and many research area [2, 3].

The Taşkent landslide has been selected to monitor using GPS observation in Taşkent County located in the North Taurus mountain chain, one of severe landslide sensitive areas in Turkey due to the steep-slope valley with a schist formation. The study area present not only a wide variety of geology and climate characteristics, but also strong human activity such as road cut and fill, pipeline, farms and drainage channels. The Taşkent village is located on rock cut formation. So, the population and buildings are not affecting from landslide. However, Taşkent and Balcılar town roads influenced from landslide disruptive impact. The uncontrolled slope, float cutting on the road and water draining induce the reactivation of the Taşkent landslide.

The study area has the necessary conditions for landslides, including steep slopes, adequate precipitation, and weak soil and rock units. The scope of the study is to examine the short period parameters and to define their relations to landslide displacement and size in the studied area. The main goal of this study is assessment and estimate of the Linear Regression method in landslide deformation and validation of landslide direction map of study area.

2. STUDY AREA

The performance of the GNSS in measuring ground displacements has been completed in the active landslide of Taşkent. This landslide is located in the steeps of Taurus Mountain, 130 km south of Taşkent province, Turkey. The whole landslide area includes different slope values, 37%, 64%, 58%, 60% some of the area slopes, average slope of the landslide is about 54.75%

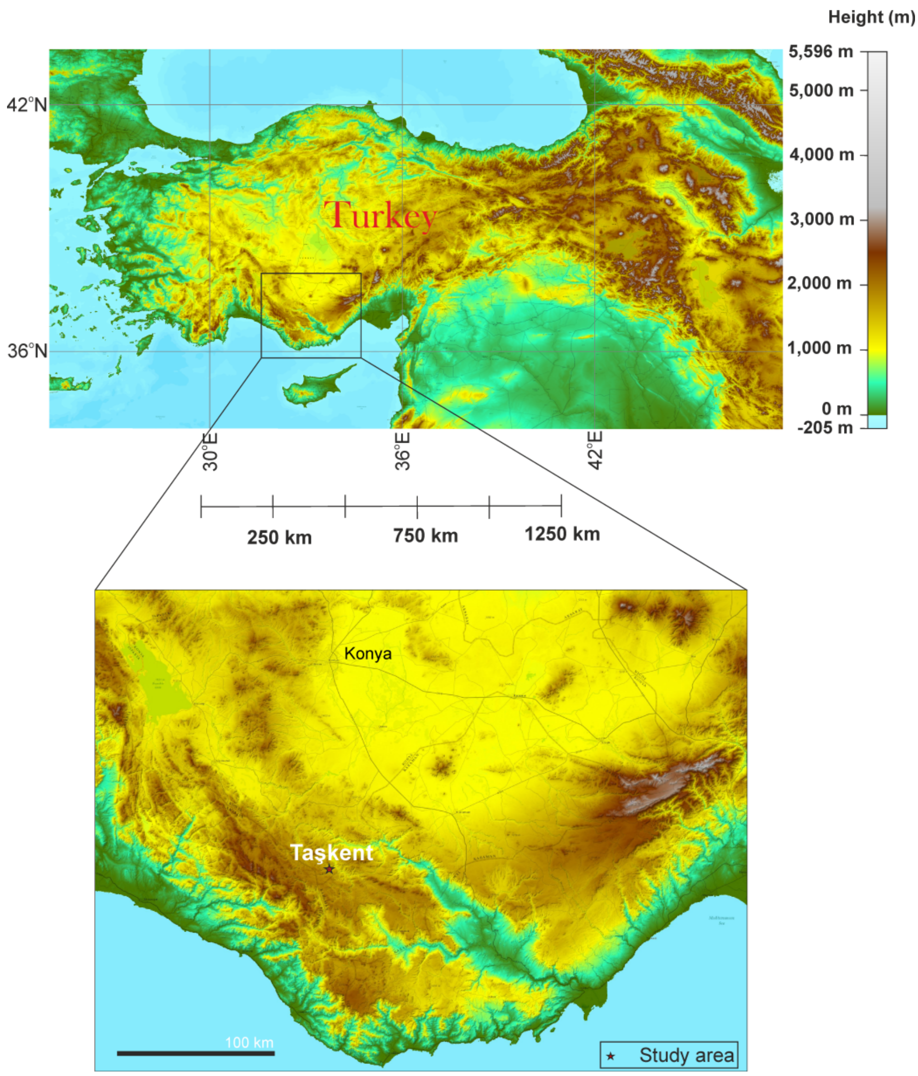

Figure 1: Study Area Location Map

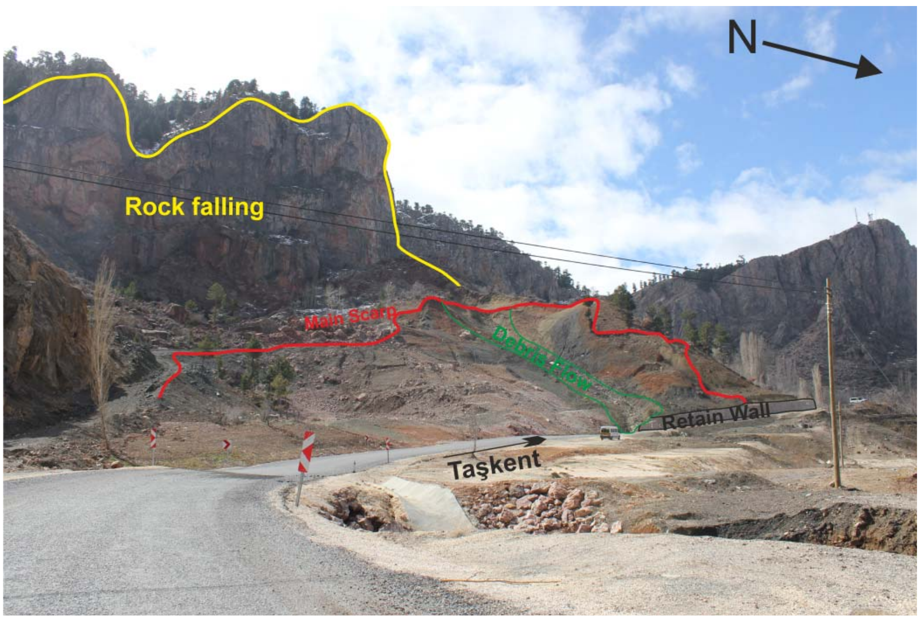

Figure 2: Landslide Region

3. MATERIAL AND METHODS

3.1. GNSS measurements

GNSS technologies have been frequently applied for the purpose of landslide monitoring [4]. Recent research showed the applicability of using the GNSS survey determine the three dimensional (3-D) coordinates of stations in the field of landslides [5].
A local deformation network frame is fundamental for accurately monitoring landslide movements derived from GNSS observations. In this study, we define a stable and unstable GNSS stations in the Konya Taşkent province.

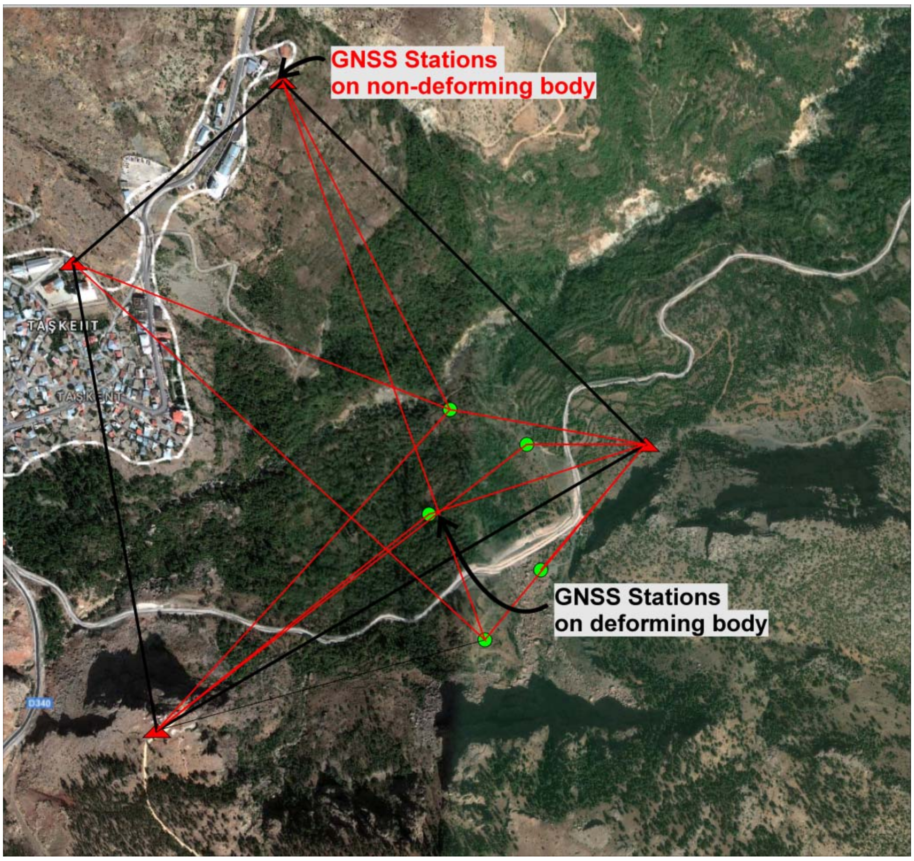

Figure 3: Monitoring of landslide using static relative positioning with GNSS stations

In Figure 3, red triangles indicate control stations on the deforming surface that provide baseline monitoring data. The green circles indicate GNSS Rover stations inside the active landslide area, which are being monitored for horizontal and vertical movement relative to red triangles.
Periodic GNSS monitoring consisted of rapid-static campaigns between November 2011 and April 2012. Surveys were performed with double-frequency receivers at the master stations and at the rovers simultaneously. Post-processing of surveys was executed with commercial software Leica GEO Office v5.
To determine movements with a static model, a functional model, solved according to the least-squares method, was constituted for each observation period [6].
For observation of active landslide area, thirty-four observation points established and four reference points established.

3.2. Regression Analysis

In this section we examined relationships between different qualitative variables. Linear regression and correlation are two commonly used methods for examining the relationship between quantitative variables and for making predictions. We review linear equations with dependent variable which is movements or displacements in landslide area, we determine the regression equation, the equation of the line that best fits a set of observation points.
Among all predicted lines, the least-squares criterion is that the line having the smallest sum of squared errors is the one that fits the data best.
Linear regression line that best fits a set of data points according to the least-square criterion.
For this purpose, the most regression equation is

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 ... \tag{1}$$

Where,
y=dependent variable (Landslide movement),
β=coefficient parameters,
X=independent variables
In general, several methods exist for evaluating the utility of a regression equation for making predictions. One method is to determine the percentage of variation in the observed values of the response variable that is explained by the regression (or predictor variable).

Using the total sum of squares and the regression sum of squares, we can determine the percentage of variation in the observed values of the response variable that is explained by the regression, namely, SSR (sum of squares)/SST (total sum of squares). This quantity called the coefficient of determination and is denoted r^2. Thus, $r^2 = SSR / SST$.

4. RESULTS AND DISCUSSION

The triggers of landslide are distance to road, distance to road, and coordinates of stations and estimated temperature differences entered the multiply linear regression model (Table 1). Before the model creation, data's need to Zscore value due to different measurement units included.

$$z = \frac{x - \mu}{\sigma} \tag{2}$$

where:

μ is the mean of the population;
σ is the standard deviation of the population.

Table 1: Descriptive statistics

Data	N	Minimum	Maximum	Mean	Std. Deviation
dx	38	-2.2886	.3169	-.220047	.5193729
dy	38	-.3057	.2043	-.057650	.1364436
dz	38	-.2485	1.1464	.156266	.2999081
Dist_River(m)	38	143.9500	601.3200	384.595000	100.5593170
Dist_Road(m)	38	1.5600	250.3900	80.865263	75.7244625

Est_Temperature	38	10.0	15.0	11.718	1.3799
Cum_Movemet	38	.0000	2.5779	.373560	.5596542
Valid N (listwise)	38				

Table 2: Model Summary

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	.966[a]	.933	.920	.28302364

a. Predictors (Constant) dx, dy, dz, dist_road, dist_river, temp

Model is dependent variable: Cum_Movement

Table 3: Anova table, Dependent variable; Cum_movement, Predictors (Constant); temp, dist_road, dist_river, dx, dy, dz

Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	10,811	6	1,802	71,818	,000[b]
1	Residual	,778	31	,025		
	Total	11,589	37			

In Figure 4 histogram of residuals suggests that the residuals (and hence the error terms) are normally distributed. But, there is one extreme outlier (with a value of 4)

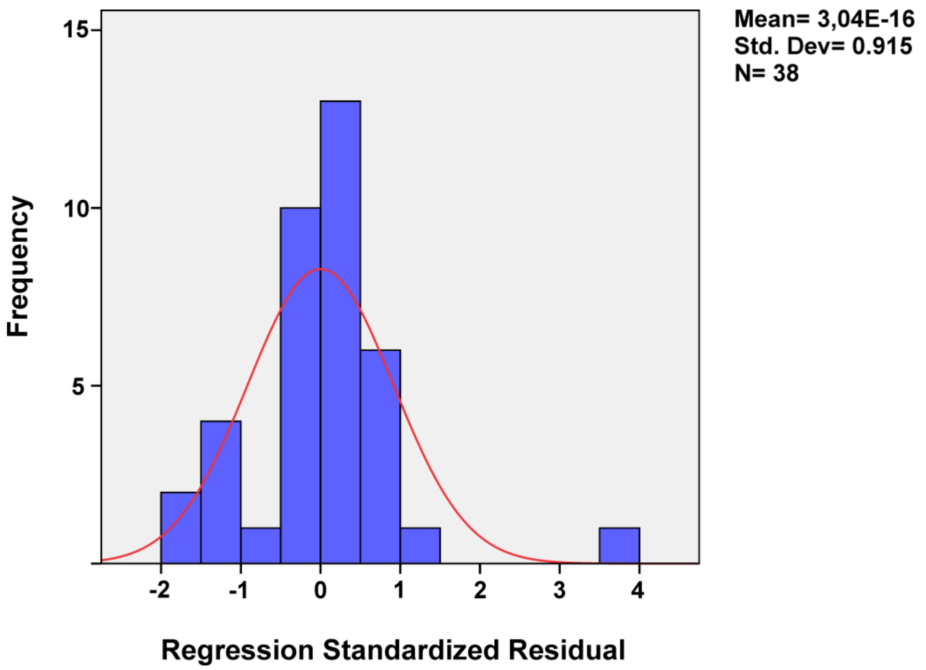

Figure 4: Histogram plot of dependent variable Cum_Movement

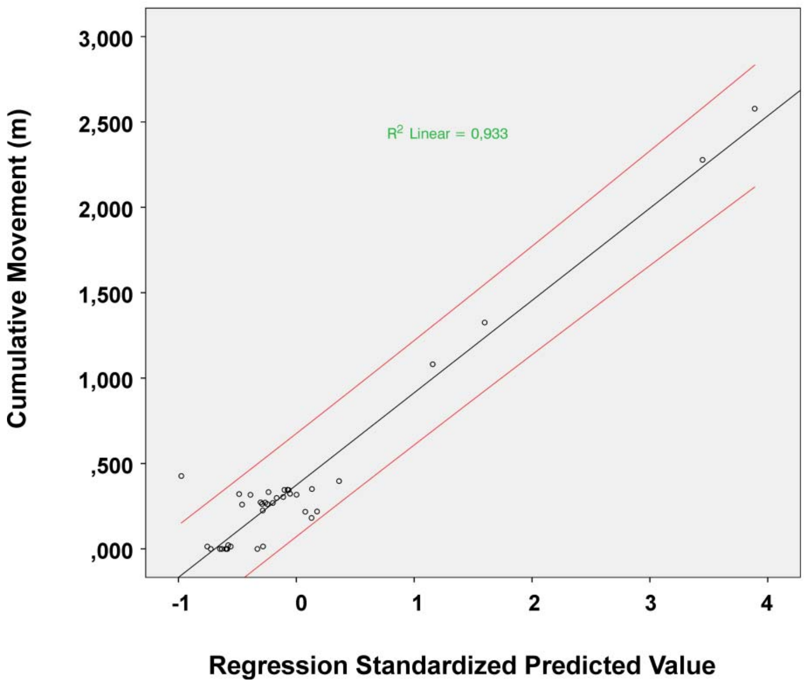

Figure 5: Regression line and 95% confidence interval of regression model lower and upper bounds, with R^2 is 0.933

The regression model is acquired as below

$$y = 7.210E - 17 - 0.764X_1 - 0.021X_2 + 0.157X_3 + 0.091X_4 + 0.166X_5 - 0.033X_6 \qquad (3)$$

The coefficients are X_1 to X_6 , dx, dy, dz, dist_river, dist_road, temperature respectively.
R^2 is the proportion of the total variation in y explained by the regression of y on x values If R^2=0 the *linear regression model* is not able to explain the variation in y. R^2=1 or -1 corresponds to a perfect fit to the regression line. In Figure 5, the least squares criterion is that the linear regression line drawn and coefficient determination R^2 is founded close to the one value. This results give an idea this model is explain the variation between variables.
The regression line that best fits a set of observation data's according to the least-squares criterion.

5. CONCLUSION

The preparations of landslide prediction models are a major step progress in natural hazard management. In these times, many applications can be applied by GIS- based techniques. There are many different useful techniques to analyze the triggering factors investigating to predict landslide areas for early warning systems. This study aim is that to predict landslide with linear regression model with very few factors. For this study, Taşkent landslide test site observations used to create a model of linear regression analysis.
Landslides can occur with different factors, such as precipitations, snow-melts, geological structure, ground water levels, aspect, slope, road cuts, anthropogenic applications, wrong land managements and so on. These kinds of data's are very difficult to acquire. However, for

accurate monitoring landslides, these data's are very necessarily important to predict forward landslide occurrence.
In this study, with linear regression analysis, we had achieved that most of the triggering factors for our data's directions are plays very effective role in landslide displacements.

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