Application of a Physically based Model for Terrain Stability
Mapping in North of Iran

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Abstract
In This paper, we studied of the landslide occurred in the northern of Iran in the southern Sari in the road of Kiasar using a physically based model has been named SHALSTAB and landslide instability mapping of study area is determined. The Aim of This paper is to determine the Effectiveness of road construction in the landslide occurred. The model runs to base on geotechnical data extracted from laboratory testing on the 15 landslide points. A landslide inventory map along the road Kiasar, including 63 landslide points was prepared for study area. The results of field investigations, analyzing geological data, laboratory tests and running model indicated that 88

Index terms—landslide, road, SHALSTAB, stability mapping

andslides are one of the main geological problems in study area. Multiple causal environmental factors influence on the occurrences of landslides in along the road. Forested slope of northern a lborz mountainous in north of iran is one of the most hazardous sliding area. In the last few years, the landslide events have been increased due to large-scale and major land-use changes by agricultural and housing development, road and building constrictions in areas susceptible to landslides. The area’s most seriously affected by landslide occurrence and caused destruction road accessing and rural settlements.

There are many approaches [fig. 1] to assessing slope stability and landslide hazards ??Sidle et al., 1985;Montgomery and Dietrich, 1988;Dietrich et al., 1992;Sidle, 1992;Dietrich et al., 1993;Montgomery and Dietrich, 1994; ??u and Sidle, 1995;Pack, 1995). The most widely used include (Montgomery and Dietrich, 1994): (A) field inspection using a checklist to identify sites susceptible to landslides ; (B) projection of future patterns of instability from analysis of landslide inventories; (C) multivariate analysis of characterizing observed sites of slope instability; (D) stability ranking based on criteria as slope, lithology, land form, or geologic structure; and (E) failure probability analysis on slope stability models with stochastic hydrologic simulations. Each of approaches is valuable certain applications ??Pack et al., 2001).

The geotechnical model, which is deterministic or probabilistic, has been widely employed in civil engineering and engineering geology for slope stability analysis. A deterministic approach was traditionally considered sufficient for both homogenous and nonhomogenous slopes. The index of stability is a wellknown safety factor, based on an appropriate geotechnical model and on the physical mechanical parameters. Calculating the safety factor requires geometrical data, data for the shear strength parameters and information on pore water pressure.

Montgomery and Dietrich (1994) developed a physically-based model based upon a combination of the infinite slope equation, and a hydrological component based on steady-state shallow subsurface flow. This model, called SHALSTAB, has been used extensively by researchers within the forestry field in the western US ??Montgomery et al., 1998) and in Italy (Borga et al, 1998). Other slope stability models developed by the US Forest Service are the Level I Stability Analysis (LISA) and Stability Index Mapping (SINMAP) which are both based on the infinite slope equation. All the deterministic models were executed using special extension in the spatial analysis in recent types of the Arc GIS software (Safaei et al., 2010) The Digital elevation model (DEM) of the study area shows that the topographic elevation is from 210 to 1976 meters. Furthermore, the weather statistics show that the greatest amount of rainfall was occurred during December with a mean value of 110 mm. A landslide
inventory has been mapped using the landslides that occurred within the area after construction road. The
topographic attributes (slope and contributing area) were generated from the DEM with a 10-10 m grid size
for the study while the Characteristics of Soil (thickness, hydraulic conductivity, density, cohesion and friction
angle) obtained from field investigations and laboratory testing in 15 landslide points.

SHALSTAB(Shallow Landsliding Stability) is a deterministic model for predicting the rainfall shallow
landslide, based on topographic control and has been developed since the early 1990s (Dietrich et al., 1992(Dietrich
et al., 1993;Dietrich et al., 1995;Montgomery and Dietrich, 1994) .

SHALSTAB combines a steady-state hydrological model with an infinite slope stability model. The model
tested and applied first in United States and then in around the world and the results has been often satisfactory,
It performs as an extension to the GIS program Arc View on DEM (digital elevation models). Equation (1) shows
the main equation to the model to compute for each grid cell as unite mapping. Although it can be solved for
the critical rainfall (Qc) required to trigger landslides in the study area, since we did not have much reliable data
concerning the spatial variability of soil transmissivity (T), we used the ratio Qc/T, as mentioned by ??ietrich
tan ? ? )?(1)

Where: Qc is the critical rainfall necessary to trigger landslides; T is the soil transmissivity (as a product of
soil thickness and saturated hydraulic conductivity); a/b is the contributing area per contour width? ? Is the
local slope, ? w is the density of water; g is the acceleration of gravity, z is soil thickness; ?s is soil bulk density,
? is the soil friction angle and ?? Is cohesion. The levels of instability base on Log Q?T -1 classes have been
shown in Table ??2.

1 Results
The Figure (4) shows a Geology and landslide distribution of the study area and that the places of highest
instability is located in the around the main road of the region. Contribution area and slope map extracted from
DEM map using the model that shown in figures ( ??) and (6). The landslide susceptibility of study area based
on different stability classes has shown in figure (7).

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3 Conclusion
In order to predict future landslides in the region, landslide susceptibility mapping has prepared in the area.
Major part the slopes are covered by vegetation, which mainly consists of alder, hornbeam and maple then the
model, is unable to calculate of Root Strength in slope stability. Therefore, this is an important limitation
for application to the model in the area. Figure (7) is shown different instability classes base on -log (q/T)
parameter (Table 4). Approximately, 30% of the entire slope stability modeling area study area was classified as
unconditionally stable.

Furthermore, about 10 percent of observed landslides located in the stable zone that indicated error of the
model. About 70% of the area classified as an unstable area that illustrated high-potential landslide hazard.
About 16% of area classified as unconditionally unstable with 15 observed landslides and also on 50% is shown as
a high instability zone with 37 landslide locations and about frequency of 60%. SHALSTAB instability classes on
different lithology have been shown which Miocene information makes up nearly 90% of the underlying lithology
that classified as instable or moderate instability. Therefore, the lithology is a most important intrinsic causal
factor in study area. Overall percentage of landslide points correctly classified up to 88%. Therefore, the results
have shown that even using a small scale (1:50.000), the model is a considerable predictive tool to recognize
landslide susceptible zones. Base on results, the model is more accurate in compare with other models for
prediction rainfall induced landslide.
Figure 1: Introduction

Figure 2: Figure 1:
Figure 3: Figure 1:
Figure 4: Figure 2:
Figure 7: Figure 5:

Figure 8: Figure 6:
The model has evaluated by comparison between landslide predictions by the model with occurrence landslide in the area. Furthermore, this model has been applied successfully by several researchers in different parts around the world (Rafaelli et al, 2001; Csadei et al, 2003; Claessenss et al, 2005; Santini et al, 2009; Cervi et al, 2010). The methodology is a couple with a hydrological model and an infinite slope stability model using ARC GIS software.
Classes SHALSTAB Interpretation of Class
Chronic instability Unconditionally unstable and unsaturated
Log Q/T -1 < -3.1 Unconditionally unstable and saturated
-3.1<Log Q/T -1 < -2.8 Unstable and saturated
-2.8<Log Q/T -1 < -2.5 Unstable and unsaturated
-2.5<Log Q/T -1 < -2.2 Stable and unsaturated
Log Q/T -1 > -2.2 Unconditionally stable and unsaturated
Stable Unconditionally stable and saturated

IV.

Figure 14: Table 2:

<table>
<thead>
<tr>
<th>Region (km 2 )</th>
<th>Area</th>
<th>% Area</th>
<th>Number of Landslide</th>
<th>%Landslide</th>
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</thead>
<tbody>
<tr>
<td>Total</td>
<td>10</td>
<td>25.9</td>
<td>7</td>
<td>11.2</td>
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<tr>
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<td>10</td>
<td>3.8</td>
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<tr>
<td>High</td>
<td>10</td>
<td>13.46</td>
<td>4</td>
<td>6.3</td>
</tr>
<tr>
<td>High instability</td>
<td>10</td>
<td>96.5</td>
<td>37</td>
<td>58.7</td>
</tr>
<tr>
<td>Unconditionally unstable</td>
<td>10</td>
<td>31.5</td>
<td>15</td>
<td>23.8</td>
</tr>
<tr>
<td>Unconditionally stable and saturated</td>
<td>10</td>
<td>195.97</td>
<td>63</td>
<td>100</td>
</tr>
</tbody>
</table>

Figure 15: Table 4: