Soil Erosion and Landslides Risk Management

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Abstract. This paper presents a simple and inexpensive alternative risk management of surface soil erosion and landslides for vineyards farms. The application is cheap because it uses very cheap or even free of charge techniques and tools. Furthermore, this method can be also applied and used for other type of farms. At the same time, the method can be applied to any land and not only for the risk management of the soil erosion and landslides, but also for managing data and records of land parcels with different uses.

The main idea is using free GIS software in order to obtain the necessary geometric data required for the relevant area relief. GIS software can archive geometrical characteristics of terrain data, soil data, vegetation covering data, etc. Risk estimators calculation is achieved by two basic models of soil erosion and landslides. Risk maps are performed using the same GIS software.

Keywords: landslide, maps, risk, soil erosion.

INTRODUCTION

At the present moment, the integrated environmental and agricultural holdings management is an important direction of development, being in the forefront of current concerns in the field, (Gascuel et al., 1998; Van Westen, 2005). Integrated management ensures a good environmental protection and ecological agricultural production.

World level and national level background

The last 10 – 20 years, the problem of agricultural exploiting simultaneously with preserving the natural resources, especially soil resources led to necessity of elaborating more and more efficient instruments for the management of agricultural farms and forestry exploitations. These specific actions should aim at conserving the respective resources, ensuring appropriate and sustainable agricultural productions and increasing the exploitation safety degree. Therefore, extensive actions were undertaken for identifying and mapping all soil deficiencies, aiming at enabling their amelioration or, finally removing them. This sort of instruments, such as –maps- have been drawn up and used in the field of soil erosion, landslides, agricultural productions, chemicals remained in the soil, humidity, saline soils, sandy soils, etc.

There were developed extensive projects both at continental and planetary level in these fields, fact which brought strong evidences for the statement above. (Kirkby et al., 2004), (Tóth, et al., 2009).
**World level situation**

At a world level, for example in United States, the soil characteristics, the risks of erosion and landslides phenomena are very well elaborated (very fine resolution), and only at regional level in the rest of the world, or at country level, these features are reproduced with big resolution, which is practically useless for local restoring actions. For European space, there are programs developed by EU related to researches on soil, agriculture, natural disasters, etc.

Generally, the maps performed are rather expensive, using either land surveys or very expensive software instruments.

**National level situation**

For Romania, the maps of risks of erosion and landslides are drawn up at a global scale (big resolution, of kilometers size), eventually only for small regions of tens of meters. In order to enable managers to precisely, efficiently and locally intervene according to precision agriculture, the resolution should be under 20 m (namely, the ground should be divided in squares with sides below 20m). At the same time, for a map used in precise interventions, the main ground marks should be emphasized, which is not the case for current maps. (Anghel and Todică, 2008; Munteanu et al., 2009; Voiculescu, 2009).

**Paper’s concrete context**

The paper is elaborated within a CNMP agreement, entitled „Prognosis of agricultural soil losses determined by erosion and landslides, aiming at finding the necessary preventing or/and restoring solutions”, contract no. 31-091. The project should create a method of diagnosis of erosion and landslides phenomena and, at the same time, the methods of improving or, finally eliminate them. Some of final results of this project are precisely the maps of risk of that kind of phenomena.

This method drawing up, proposed within the paper represents a cheaper alternative than the current methods found in specialty literature and, furthermore, it better refers to field marks, and makes these maps be more useful for undertaking the appropriate managing restoring actions.

Therefore, the contents of the paper frames within the modern directions in the field: environmental protection, resources conservation, agricultural exploitation management and other types of agricultural exploitation, precision agriculture. In order to achieve the proposed scope, it has been used state-of-the art tools: GIS software, aerial photographs from specialized archives, mathematical models of phenomena of surface soil erosion and landslide, software techniques to create risk maps and their overlapping.

One of the purposes of this paper is to present a management approach as cheaper agricultural holdings - particularly for plantations of vines - which method is accessible to those who have limited financial and material resources. Essentially, the method consists in the acquisition of geometrical characteristics of the interest relief area by aerial photographing, area parceling and surface erosion risk and soil erosion and landslides calculation for each parcel. After obtaining these risk measurements, distribution maps of their values in the territory of interest should be elaborated. These maps are used for identifying the increased risk of erosion or/and landslide locations, facilitating the local remedying interventions, with the smallest extent possible, techniques which resemble to those used in precision agriculture. Improving the accuracy of the erosion risk maps and producing landslides can be done either by measuring and checking activities in the land and / or by using fairly expensive commercial software.
**Case-studies presentation**

The working method which is presented represents the specific case of vineyards on the ICDVV Valea Calugareasca territory. The working steps of the method are:

HR1) Demarcation of the territory borders aimed to estimate the risk of erosion and landslides.

HR2) Planning in mesh plots with approximately uniform geometric characteristics.

HR3) Determining the main geometrical characteristics of each parcel of territory: length and average slope.

HR4) Filling in the data necessary to calculate the risk of surface erosion and landslides production, according to mathematical models that were chosen for these phenomena.

HR5) Calculating the physical quantities which express the risk of surface erosion and landslides, for each parcel.

HR6) Drawing up the risk maps for landslides and erosion: setting the risk ranges and parcels according to legend.

HR7) Achieving the statistical study of erosion risk and landslides distribution on the whole mapped territory.

HR8) Indicating the areas with high risk of erosion and landslides, in order to facilitate remedial interventions;

HR9) Optionally, the precision of risk maps developed can be increased.

**RESULTS AND DISCUSSION**

HR1 stage was achieved by marking the borders of ICDVV territory by means of a GPS device. GPS marks have been directly downloaded on the images archive files of GIS program Google Earth, the free version. ICDVV territorial delimitation as shown in the Fig. 1 has been performed.

![Fig. 1. ICDVV territory parceled](image-url)
HR2 stage consists in dividing the territory of ICDVV into parcels. It has been used free version Google Earth program. Within this activity or subsequently, the database containing information about the parcel should be ensure. The territory has been digitized into 363 plots, respecting the natural border of wine plots, but some of the parcels contain more wine plots, plots with common properties in terms of calculation.

HR3 stage should be made by direct measurement, in Google Earth. It was approximately determined the direction of maximum slope and the elevation has been read for various distances.

By elementary calculation, the average slope and length of parcel on the direction of maximum slope should be determined.

Stage HR4 includes data acquisition required to calculate erosion risk and landslides risk producing. For each division (plot) in which the territory to be mapped has been divided, the factors from USLE formula, (Wischmeier and Smith, 1978) should be determined. Model parameters are given in Table 1. It was shown how to determine the geometric factors, namely the length of the plot and its slope. Using these data, for each field L and S factors of USLE formula should be calculated, they being dependent only on the plot geometry.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Signification</th>
<th>Dimension</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>long-term average annual soil loss</td>
<td>ML−2T1 (ML−2)</td>
</tr>
<tr>
<td>R</td>
<td>rainfall erosivity factor</td>
<td>ML−4 (MLT−3)</td>
</tr>
<tr>
<td>K</td>
<td>the soil erodibility factor</td>
<td>L−1T1</td>
</tr>
<tr>
<td>L</td>
<td>surveying length factor</td>
<td>M0L0T0</td>
</tr>
<tr>
<td>S</td>
<td>surveying slope factor</td>
<td>M0L0T0</td>
</tr>
<tr>
<td>C1</td>
<td>cropping management factor of vegetal cover</td>
<td>M0L0T0</td>
</tr>
<tr>
<td>C2</td>
<td>cropping management factor of tillage</td>
<td>M0L0T0</td>
</tr>
<tr>
<td>P</td>
<td>conservation practices factor</td>
<td>M0L0T0</td>
</tr>
</tbody>
</table>

*Different authors use different definitions for $A$ and $R$. For the USLE variables dimensions reference is recommended (Foster et al., 1981).

P factor should be determined for each plot depending on anti-erosion facilities management, (Wischmeier and Smith, 1978). For our particular case, has been considered $P = 0.1$ for terraces, $P = 0.5$ for the vine rows oriented to the approximate direction of level lines and $P = 1$ when rows are hill-valley oriented (approximately perpendicular to the line level).

The factors of vegetal coverage and tillage management have been considered as annual averages, according to (Cardei et al., 2009).

Soil erosion factor $K = 0.033$ has been considered as $K = 0.033$ (Cardei et al., 2009). It was considered that its values are the same on all plots. Rain erosion factor has been considered the same for all plots (ICDVV territory divisions), $R = 587$ being the value which resulted by calculation according to (Cardei et al., 2009).

Constant factors for all parcels are motivated by the small extent of ICDVV territory and small variations in rainfall and soil composition on the same territory.

For estimating the risk of landslides arising, Mohr-Coulomb model of the non-cohesive soil is considered (Ritter, 2004), because it requires less data and is readily available (only the angle of internal friction and slope gradient, i.e a geometric feature of it). Consideration of more complicated models for landslide (Ritter, 2004) requires supplementary knowledge about slopes and soil characteristics at different depths, and arrangement of internal water routes in slope, which is not impossible, but can be made during an advanced enough stage of estimation. This analysis is very expensive. Generally, even the angle of
friction is not a constant, depending, for example, on humidity, or being able to locally vary, too. (i.e. soils are not homogeneous and isotropic for this property). Because ICDVV surface area can be considered small compared with Dealu Mare habitat area, it should simply suppose that, the friction angle is constant throughout all the area. The angle of internal friction value was considered as being of $23^\circ$.

HR5 stage comprises the calculus of the annual soil losses per hectare - the measure of erosion risk of surface and the calculus of the slope stability factor - as the risk of landslides. Both should be made in accordance with the above two mathematical models. The results can be registered within the database for each of the plots in which the field is divided.

In HR6 stage the limits of legend intervals for each of the maps should be chosen. The legend should not be necessarily linear, having as reference limits the warning critical values which generate each of the above phenomena.

Coloring maps is made directly in free version Google Earth. Staining with a transparency degree ensures easy identification of the objectives in the field. Erosion risk map of the ICDVV territory appears in Fig. 2, and the landslides risk production map in Fig. 3. Color variations of these maps can be viewed at (http://www.inma.ro/pagina_web_parteneriate/petrica/ERALSOL_eng.htm).

![Fig. 2. Erosion risk map of ICDVV territory](image)

![Fig. 3. Landslide risk map ICDVV area – Valea Calugareasca](image)
Statistical study made within HR7 stage provides statistical data on the relief: minimum, maximum and average elevation, minimum, maximum and average slope. A superior version of the Google Earth software, which is not free of charge, allows statistical evaluation of the parcels area.

Surface soil erosion in ICDVV area is characterized by an average soil loss per hectare per year, with a value of 4.047 t/ha annually, the maximum 28.517 t/ha per year and the minimum 0.219 t/ha/year. The weighted average of the soil loss from the total divided surface gives the value 4.55 t/ha per year. For the landslides risk production has been found that, only 5 (1.377%) plots are uncertain in terms of stability, 10 (2.755%) have questionable safety, 25 (6.887%) are acceptable in terms of stability, 22 (6.061%) are satisfactory even for dams and 285 (78.512%) are very safe. Graphical representation of these data is shown in Fig. 4 and 5.

![Fig. 4. Plots distribution on erosion intervals, according to the map from Fig. 2.](image)

![Fig. 5. Plots distribution in stability factor intervals](image)

Erosion percentage distribution weighted by surface fraction out of the total mapped area, per reference intervals of erosion is shown in Fig. 4. It should be noted that only 34.927
% of the mapped area in terms of erosion risk, frames between 0 and 2 t/ha annually, 67.07 % of surface erosion frames within the class of 0 and 5 t/ha annually and 78.073 % of the surface records soil loss values less than 7 t/ha annually.

It is also interesting the correlation between the problem’s variables and the expected annual soil loss per hectare. Correlation between these variables values are:
- correlation between annual soil loss per hectare $A$ and the terrain slope, $p$ is set to 0.5 ;
- correlation between the annual soil loss per hectare $A$ and development of the land factor, $P$ is set to 0.434;
- correlation between the annual soil loss per hectare $A$ and the length of the parcels $x$ has the value of 0.35;
- correlation between the annual soil loss per hectare $A$ and the plots surface, $Sp$ has the value of 0.156. As a result, the erosion risk depends on: field slope, culture planning, parcels length and parcels area.

Within HR8 stage, maps from Fig. 1 and Fig. 3 should be used for identifying the high risk areas of surface erosion and landslides. These maps, obtained directly from the archives of Google Earth aerial photographs, allow the easy identification of dangerous areas, because all landmarks are visible on the field.

The accuracy of these two maps can be enhanced. Increasing map accuracy should be achieved, because the aerial photographs are not able to seize all earth's crust "accidents", sometimes concealed by vegetation or other formations. It is also recommended to increase the estimating accuracy of the geometric characteristics using GIS software and the relief digital models. The results obtained after the erosion risk estimation were compared with the experimental data and the literature data.

The results obtained by this method are according to all the estimates found on the test area – Valea Călugărească.

CONCLUSIONS

The method of elaborating risk maps for plots erosion and landslides production, presented above is an original method. In the specialty literature, most times, such maps are created by means of some programs using digital models of the relief. Overlapping the aerial photography on these maps is complicated. Maps presented in this article are done on aerial photography. Such maps allow a good orientation in the field, and a more accurate and faster identification of high risk areas.

This method is not expensive. It has been used the free version of Google Earth GIS software and for the remaining operations MS Office programs are sufficient.

The accuracy of these maps can be improved using GIS software and special topographic surveys, but these techniques lead to increased implementing cost.

The method is applicable to various agricultural plantations and lands with other destinations.

REFERENCES


