A field guide for evaluation of erosion risk in olive orchards under contrasting environmental and management conditions.

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Introduction

Olive is one of the dominant crops in the Mediterranean basin, although is also an expanding crop in other areas of the World with similar climate type (Camposeo and Gómez, 2023). Olive trees are cultivated in arid and semi-arid areas, and this has resulted in a management strategy oriented towards limited vegetative ground cover to improve water availability for the crop. This fact, combined with cultivation in sloping areas and periodic high-intensity rainfall events, has led to high erosion rates in many olive-growing areas (Milgroom et al., 2007). The proposed field guide is based on a dual approach integrating erosion risk estimation from basic farm and management features, according to simplified RUSLE factors (Renard et al., 1997) combined with erosion symptoms. With this approach, this tool aims to achieve these objectives:

1- To provide a standardized tool valid across multiple environments and cropping conditions to evaluate water erosion risk in olive cultivation.
2- To develop an educational tool to provide training on prevention of water erosion in olive orchards valid for any stakeholder.

Materials and Methods

The field guide has been developed with a similar approach to Milgroom et al. (2006), following two steps:

Appraisal I, which is based on RUSLE (Renard et al., 1997) and calibrated using ORUSCAL (Gómez et al., 2020). RUSLE, [1], summarizes the main factors related to erosion risk:

$$A = R \cdot K \cdot LS \cdot C \cdot P \qquad [1]$$

Where A: annual average soil loss, R: rainfall erosivity factor, K: soil erodibility factor, LS: slope length and slope steepness factor, C: cover-management factor, and P: conservation practices factor.

Each factor has been pre-calculated for different orchard conditions, so that users have a decision tree to determine the factor values. These values are normalized on a 1-10 scale, except LS factor, **Fig.3,** which is logarithmically transformed and scaled 1-30 due to its wider range. The C factor, [2], is the product of subfactors as:

$$C = c_c \cdot g_c \cdot s_r \cdot r_h \cdot s_b \cdot s_c \cdot s_m \qquad [2]$$

Where C: cover-management factor, c_c: canopy subfactor, g_c: ground cover subfactor, s_r: soil surface roughness subfactor, r_h: ridge height subfactor, s_b: daily soil biomass subfactor, s_c: daily soil consolidation subfactor, and s_m: soil moisture subfactor.

In order to simplify the cover management factor C, (see **Fig.4** and **Fig.5**), an exploratory analysis was performed, and highlighted the sub-factors of canopy cover (cc), ground cover (gc) and soil biomass (sb) as the ones that explained most of the variability of factor C value in the simulations carried out.

The last factor of RUSLE, P, is a factor that reduces the value of the overall erosion risk according to the conservation practice(s) applied to the crop, **Fig.6**. Thus for the **Appraisal I** it will behave in the same way. Note that the values presented refer to conservation practices (Renard et al., 1997), specifically for arid and semi-arid climates (Muñoz et al., 2023).

All these factors are integrated into an additive index to facilitate its use and interpretation, [3]. The interpretation of the absolute value of this index was calibrated against the erosion rate predicted for the simulated conditions, see **Fig.7.**

$$\textit{Synthetic index} = R_n + K_n + LS_{n30} + (s_b + (c_c \cdot g_c))_n \cdot P \qquad [3]$$

Regarding the second step, **Appraisal II**, it includes visual field evaluation of selected erosion symptoms on a normalized scale, **Fig.8.** Grouped into two categories, the first one corresponds to those symptoms that occurs after a rainfall event. The second group includes symptoms that might be assumed to be permanent.

These steps aim to cross-correct between the two types of appraisals, ensuring that the erosion evaluation takes into consideration the management as well as the actual response under erosion events. Therefore, the field guide integrates the results of the two appraisals into a single evaluation based on a chart for overall interpretation of the erosion risk, **Fig.9.**

The field guide was tested during two field visits to 36 commercial olive farms from the Appellation of Origin of Estepa (Southern Spain), on March 6th and April 5th, both after rainy periods, obtaining the results shown in **Fig 10.**

Results

Appraisal I: Erosion risk estimation

The next figures show the normalized classification for rainfall erosivity factor, R,(**Fig.1**), and soil erodibility factor, K,(**Fig.2**) on the overall area. These maps were determined from global data bases freely available from the European Soil Data Centre (ESDAC).

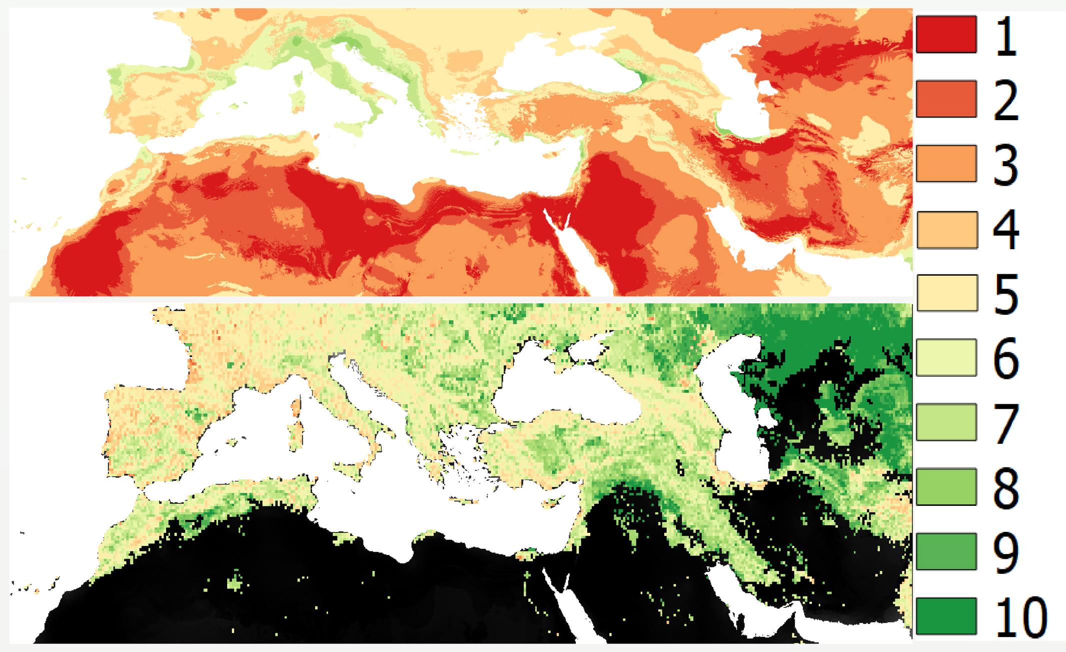


Figure 1: Normalized R factor classes on the overall area, covering the entire Mediterranean basin.

Figure 2: Normalized K factor classes on the overall area, covering the entire Mediterranean basin. Please note that the areas in black are those for which no data are available or are desertic areas.

Fig.3 shows the decision tree for the LS factor and its respective normalized classes, considering the wide range of topographic characteristics within the overall area.

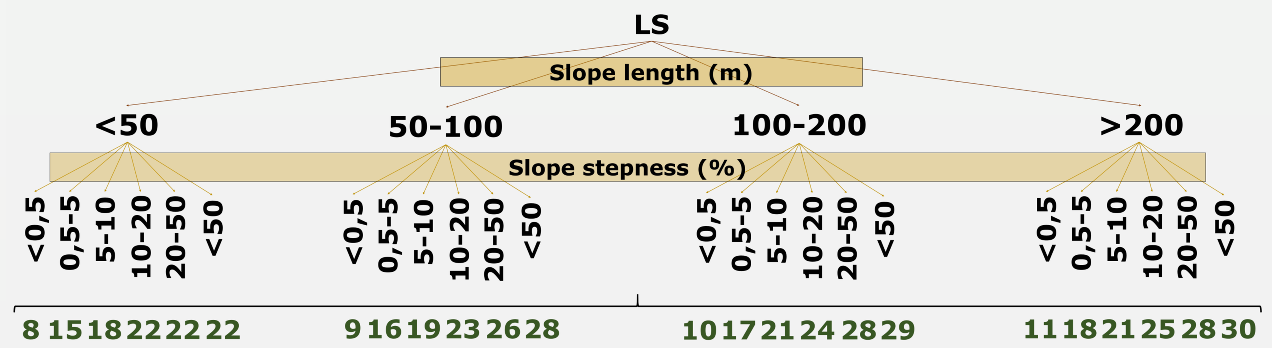


Figure 3: Classes of the LS factor. Normalized values of the proposed situations are in green.

The following figures show the normalized values for the cover management factor, C. **Fig.4**, shows sequentially the surface cover by canopy, stones and mulching and ends with the integration over the calibrated management practices (Gómez et al., 2023). **Fig. 5**, is directed exclusively to the soil management practices mentioned above.

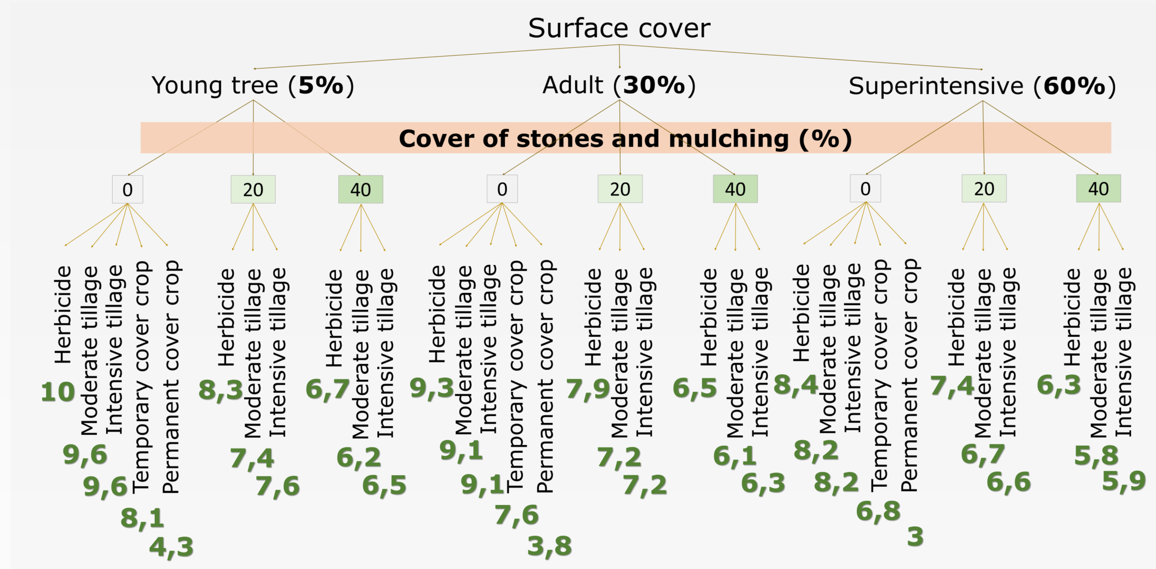


Figure 4: Classes for C factor. Normalized values of the proposed situations are in green.

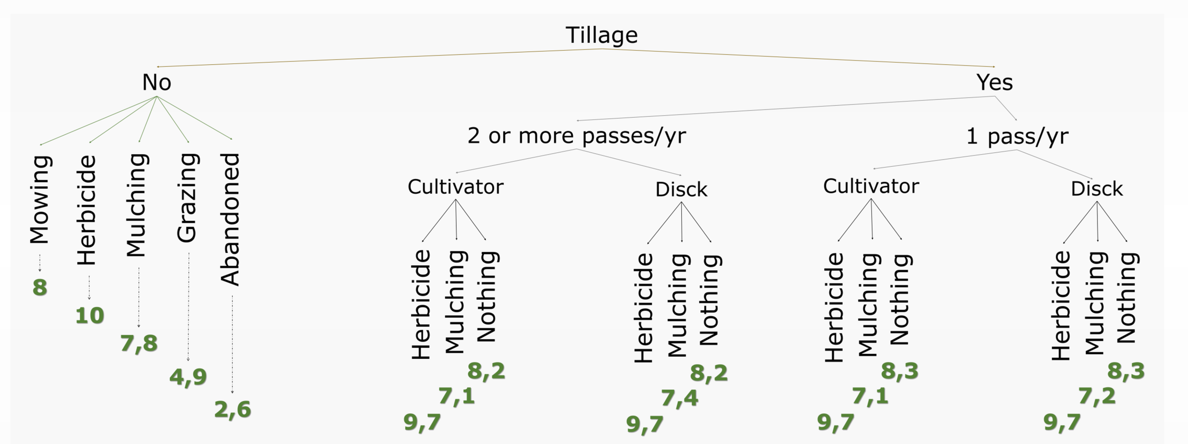


Figure 5: Classes for C factor in terms of soil management. Normalized values of the proposed situations are in green.

Fig.6 presents the final version of the soil conservation practices in arid and semi-arid climates, with the reduction values based on RUSLE. **Fig.7** illustrates the calibrated index and the proposed threshold for the soil erosion risk by water.

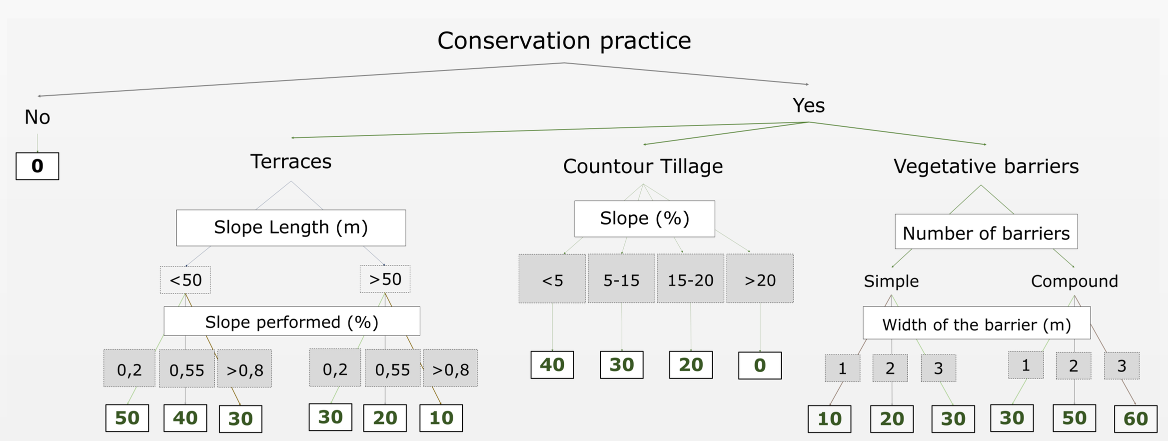
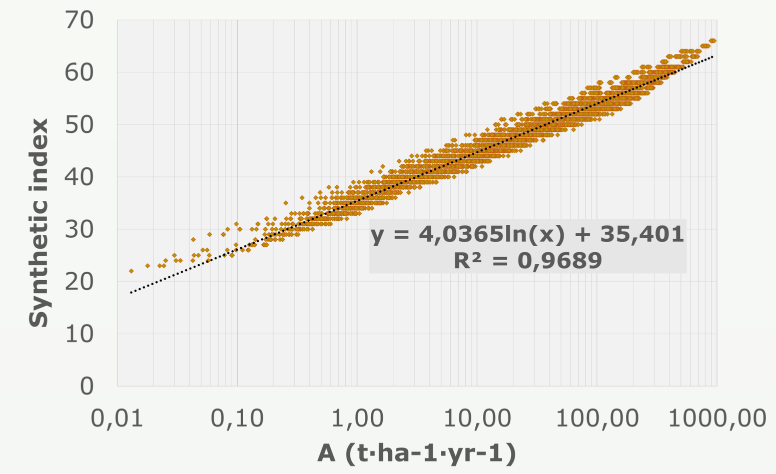


Figure 6: Reduction, expressed as a percentage, due to conservation practices.



App I

Synthetic index	$t \cdot ha^{-1} \cdot yr^{-1}$	Erosion risk
22-35	0,01-1	Tolerable
35-45	1-10	Moderate
45-48	10-25	High
48-54	25-100	Very high
54-66	>100	Extremely high

Figure 7: Calibration of thresholds for water erosion risk in **Appraisal I.**

Appraisal II: Visual assessment of soil erosion

Fig.8 presents the symptoms evaluated at visual assessment of soil erosion.

		0	1	2
After rain event	Ground cover	More than 70 %	Between 30 and 70 %	Less than 30 %
	Rills	None	Sporadic (one or less than one in three streets)	Profuse (more than one every three rows)
	Compaction and surface crust	Absence of both symptoms	Presence of both symptoms of slight magnitude, covering approximately less than 30% .	Presence of both symptoms but of moderate magnitude, clearly covering more than 30%.
Permanents	Erosion mounds	None	Differences between the base of the tree and the row.	Significant difference between the row and the base of the tree.
	Gullies	None	Inactive gully of any size or active but shallow (less than 30 cm deep).	Active gully of any size or inactive of a certain depth (more than 30 cm deep).

Figure 8: Visual symptoms of soil and its scores. The normalized value for each symptom are at the top of the chart.

Combination of appraisals

Combining both appraisals, the user obtains an intuitive insight of the potential erosion risk into a unique chart, **Fig.9.** From this chart, the user can now cross-check whether the potential erosion rate, obtained by **Appraisal I**, is consistent with the visual assessment, using by **Appraisal II.** With this field guide users also gain an improved picture of the status of olive orchard, and in turn can be guided in slight changes in the current soil management or implementation of conservation practices.

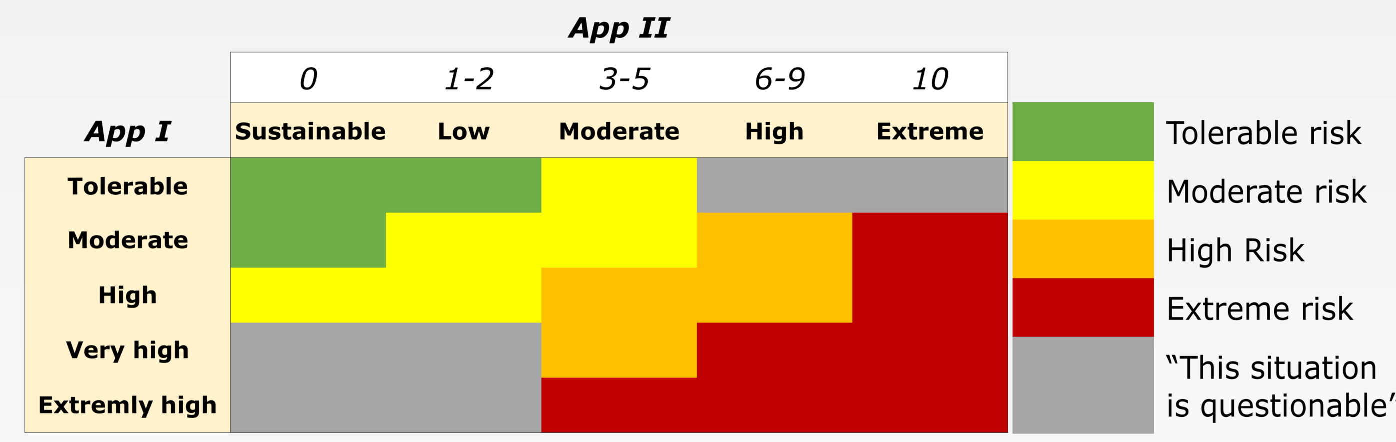


Figure 9: Interpretation chart for soil erosion risk by the two appraisals proposed.

The evaluation of the field guide resulting from its use in olive orchards in the Appellation of Origin of Estepa provided a clear correlation among the field observations (**Appraisal II**) and the model predictions (**Appraisal I**), as shown in the violin plot (**Fig 10a**) and in the photographs taken during the field visits (**Fig 10b**).

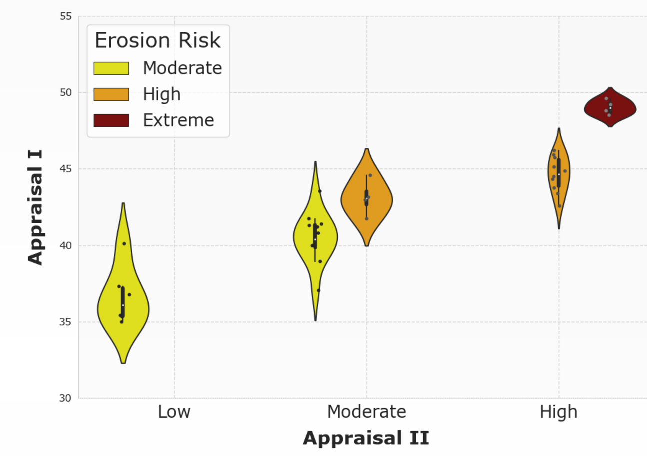


Figure 10a: Relationship between Appraisal I and Appraisal II in the context of erosion risk.

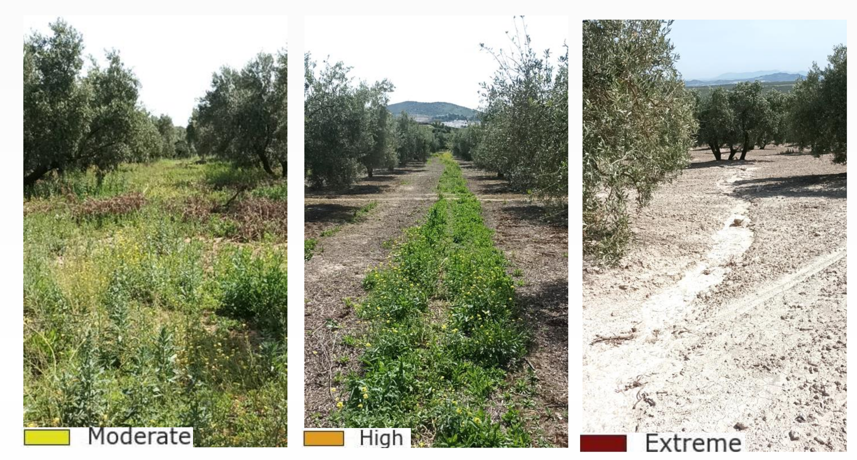


Figure 10b: Distribution of the olive orchards evaluated for each erosion risk category.

Conclusions

1- This field guide is operational; printed and digital versions are currently under development.
2- The next step forward is to link the appraisal made to this field guide through proposals for changes in soil management and the implementation of specific conservation practices.

References

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Acknowledgments

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