ANSWERS TO REFEREE 1

GENERAL COMMENTS:

1. REFEREE: Present paper intends to cover important issue about indicators choice and integration. The idea is current, regardless of the fact that a lot of work has been done, especially in biodiversity indicators choice, development, validation etc. followed with common assessment with soil properties – since site specific conditions prevent establishment of uniform indicators set. Starting from the valid intention in the title, later on through the manuscript this path is lost and without significant corrections study should not be accepted for the publication in SOIL journal. As an main issue, the terminology should be harmonized through the text, thus to decide eater to deal with spontaneous cover, cover crops, weeds or some other term (i.e. native plants).

AUTHORS: Dear Referee, Thank you for the time you devoted to reviewing this manuscript and for your helpful comments. We have taken all your remarks and suggestions into account to improve our manuscript. We are particularly grateful for your effort to improve the readability of the manuscript.

Following your advice, we have changed the title, the introduction, the structure of material and methods, discussion and the tables and figures. In addition, we have harmonized the terminology in the text and have decided to use the term “spontaneous grass cover”.

SPECIFIC COMMENTS:

Introduction

2. REFEREE: Structure of the Introduction part should be changed completely, it is not in the line with study title, objectives and abstract. Starting from definition of soil biodiversity – it is not appropriate, and additional references are needed for the first paragraph. (Some suggestions - Journal of Geographical Sciences, 12(2): 243-252; Ecological Indicators, 9(3): 432-444; Geoderma, 147(3–4):159-171; Trends in Ecology & Evolution, 18(4): 182-188; Agriculture, Ecosystems & Environment, 98(1–3): 1-16)

There is a missing link between first and second paragraph and later on to EU strategies. List of the EU strategies is not appropriate at all and should not be included, maybe only as indication with further reference. Otherwise it can be starting point and pillar on which you can build your introduction. Although, following paragraph about indicators use and one about olive cultivation and associated soil degradation are ones that finally fit with studies objectives and justifies them.

AUTHORS: Thank you for the references. We have added these works and we have adapted the content to the new title and the objectives of the work. We have removed the irrelevant information and the inappropriate references.

3. REFEREE: Page 236; Lines 5-10 – missing reference or references.
AUTHORS: The reference was FAO (2014); however, we have removed this paragraph, following your recommendation.

4. REFEREE: Page 236; Line 12 – Reference Mimee at al., 2014 is not one that main objective is yield improvement.
AUTHORS: We agree with the reviewer that including this reference is not directly to the point: we were citing different examples. We have therefore decided remove it, following the reviewer's comment.

5. REFEREE: Page 237; Lines 7-25 – Under investigation is spontaneous grass cover and this is something that need further discussion, as advantages and disadvantages, without going to wide and again without clear terminology.
AUTHORS: We have changed the text (and removed some parts) to focus exclusively on spontaneous grass cover.

6. REFEREE: Page 237; Line 24 – After improvement, etc. there is a need for reference.
AUTHORS: This sentence has been written by the authors of the manuscript, and so there is no reference.

7. REFEREE: Page 238; Line 6 – Specific objective No. 2 should be modified; instead of meteorology to write meteorological conditions.
AUTHORS: We have corrected this.

8. REFEREE: Materials and Methods – I would like to suggest change of abbreviation in the case of study site "Conchuela". Con is often used in the studies as abbreviation for Conventional agriculture, thus it may be better to use CN (two letters as in the case of other study site - PG). Since description of the study sites is quite long, it may be better to insert one table for both with main characteristics as drainage area, mean elevation, annual precipitation, soil type etc. Like this it will be more clear ease to compare them. Additional important characteristics could be given after the table.
AUTHORS: We have changed this abbreviation and we have included the table as suggested (Table 1).

9. REFEREE: Page 240; Line 1 –Again terminology disparity: subtitle states Weed sampling – that does not mean the same as native or spontaneous cover. Same path should be applied through the text.
AUTHORS: We have clarified that we mean "grass spontaneous cover".

10. REFEREE: In the Figure 2 indications on the pictures a, b, c etc. do not correspond to the legend below the figure.
AUTHORS: Our apologies, we have corrected this.

11. REFEREE: Title 2.3 should be changed, Data analysis most of the time refers to the statistical data analysis, thus it can be placed at the end of M&M section (since statistics is almost missing in the manuscript).
AUTHORS: This title (2.3) has been modified and we have included the new title 2.3.4. to describe the statistical analysis carried out (see also Tables 4-6 and 8 and 9 and Fig. 3). ,We would therefore prefer to keep the current title.

12. REFEREE: Page 240; Line 19 – Explanation of the Richness (R) is not clear and how the values are obtained.

AUTHORS: We have clarified this. Firstly, at each sample point of the grid (Fig. 1 and Fig 2a and 2b), the number of species present were identified with pictures and plant material. Then we calculated the total number of species in each catchment (on the seasonal and annual scale).

13. REFEREE: Page 241; Line 2 – In the description of the Sorensen's index (Is) formula, for C – instead of present should be written common both study sites; This is correct in the case of Sorensen's index (Is). (Why here use of the term farms? Make it uniform through the manuscript)
AUTHORS: Following your advice, we have corrected this.

14. REFEREE: Page 242; Line 3 – Climatology is not something annual; change it to the meteorological data.
AUTHORS: We have corrected this.

15. REFEREE: Page 242; Lines 13-15 – It should be deleted, does not belong to the part of materials and methods.
AUTHORS: We consider that these sentences help to show the procedure we applied; therefore, we would like to keep them.

16. REFEREE: Page 242; Lines 18-25 – This paragraph needs structural changes, authors started with methodology for Organic matter, then about number of samples and way of sampling. It should be opposite, followed by Bulk density. It is not clear why number of samples is different in two study sites. And the last sentence should be part of statistical analysis, not soil indicators.
Part about statistical analysis should be added and additional analyses are desirable.
AUTHORS: We have changed the paragraph following your suggestion. The number of samples is different due to the different tree distribution allowing different intensities of sampling.
We have included a new title where we have explained all the statistical treatments applied (title 2.3.4). If you have any specific suggestion for this, we would be grateful if you could let us know.

17. REFEREE: Results – Number of the Tables is too high. Some of them could be joined and some moved in Supplementary material.
AUTHORS: We have followed the reviewer's instructions about new Table 1 and we have removed Table 4 because its information was included in old Table 3. In addition, we have substituted Table 5 for new Figure 3.

18. REFEREE: Table 2 – Use of the word Example in the Table title is not appropriate, change it with Some or just delete it. In the case of % of clay, sand etc. particles name should go in the first line and then below unit (as in the case of organic matter).
AUTHORS: We have included both changes.

19. REFEREE: Table 3 – In the table body Richness should be with abbreviation, as decided in the part of M&M.
AUTHORS: Thank you. We have done this.

20. REFEREE: Table 3 and Table 4 should be joined and authors need to clarify why just in the case of Sorensen's index they showed seasonal data, while this is not case for others?
AUTHORS: We have joined the tables together (see new Table 4).

The analysis is a direct one through *Is* because we only wanted to compare the degree of similarity of the species composition in the catchments. As for the other indicators, we considered that it would be more useful to carry out the analysis on an annual scale.

21. REFEREE: Table 5 – Frequency is clear even from the n value and there is no need to give same data twice. It will be better to present biological spectrum (life forms) either as n either as Frequency in the form of Figure. In the case of PG sum of the Frequency values is not 100.
AUTHORS: Our apologies, we have replaced this table with new Figure 3.

22. REFEREE: Table 6 – Needs to be moved in the Supplementary material. To be kept within results it could be appropriate in some journal with major scope in botany.

AUTHORS: We would like to keep this table because it might be useful for the reader. What this table does is to allow us to complete the information of biodiversity indices because all the species can be checked (see also final paragraph of the discussion section).

23. REFEREE: Table 8 –It should be deleted, since it gives data already presented: In the case of biodiversity indices in Table 3 and in the case of soil properties in

AUTHORS: As regards this Table, it may be that the reviewer did not notice the t-test results for independent samples applied to evaluate the OM and BD differences. We have improved the organization of the manuscript to clarify this point (see also title 2.3.4).

24. REFEREE: Figure 3. Which is the purpose of column Stat.? Mean and SD should be followed with some kind of Statistical analysis (one way ANOVA could be very informative). And in general part of the statistical analysis should be revised in the Manuscript as a whole.

AUTHORS: Please see answer 23. In addition, the statistics of the figure allow us to observe the histograms and to compare the quartiles of the attributes evaluated.

25. REFEREE: Figure 3 – Number of the samples is given in Materials and Methods, why to write it again and if to keep why after each parameter (it could be better just on the end).
AUTHORS: Following your suggestion, we have modified the figure caption.

26. REFEREE: Page 244; Lines 1-3 – There is missing reference for the statement and this part could go in Discussion part.
AUTHORS: We have included the following reference: Guzmán G and Foraster L.: Manejo de la cubierta vegetal en el olivar ecológico en Andalucía: siembra de leguminosas entre calles. Consejería de Agricultura y Pesca, Junta de Andalucía, pp 78, 2007.

27. REFEREE: Page 244; Line 18 – How to say that difference in OM and BD between study sites were significant if Statistical analysis to confirm this is not presented?
AUTHORS: The values of significance were included in old Table 8 (t-test was explained in chapter 2.3.). Nevertheless, we have improved this point with the new title 2.3.4. (see also comments 23 and 24).

28. REFEREE: Discussion – Text should be revised for the terminology used and enriched with some more current studies. As well adjusted to the changes in paper suggested above.
AUTHORS: We have improved the discussion with the references mentioned by the referee and with others (Magurran, 2004; Mesto et al., 2007; Guzmán and Foraster, 2007).

29. REFEREE: Conclusion – Page 247; Lines 11-17 – This parte belong to the discussion.
AUTHORS: We would prefer to keep these sentences, because they complete the explanation of lines 7-10.

30. REFEREE: TECHNICAL COMMENTS
Page 236; Line 17 – Instead of dedicated to growing olives change to dedicated for olives cultivation.
Line 21 – Southernmost instead of Southern most.
Line 25 – Change have difficulty growing to have difficulties to grow.
Page 237; Line 9 – Authors could think to use some other word then traffic – i. e. passage (same for page 239; Line 5).
Line 24 – our while should be deleted.
Page 238; Line 6 – Change meteorology to meteorological conditions.
Line 23 – for FAO classification indicate the reference (Same for Page 239 – Line 18).
Page 240; Line 8 – Between trees and away you should add comma.
Page 241; line 11 – Double the present in the line, one to be deleted

AUTHORS: Thank you very much for your corrections. All have been included in the manuscript.

ANSWERS TO REFEREE 2

31. REFEREE: The paper is strongly weakned by the choice of the biodiversity indicators, because species richness (R) is a very generic indicator giving no information about the quality of the species, Shannon (H) index gives an absolute value mirroring how a sum is partitioned among it's addenda and Pielou's Index (J, also known as Evenness) is the expression of H in relative form, so that H and J are more or less the same thing. Sorensen index has been used for evaluating the similarity between the catchments in different seasons, but such evaluation is not very linked to the aims of the paper. The paper should have been focused on life-forms, but they have been quite neglected. The starting hypothesis based on the amplitude of ecological niche should have been investigated on the basis of the evaluation of life-forms (diversity, frequency,...), because it is more likely that the life-forms respond to niche constraints rather than the species number.

AUTHORS: Dear Reviewer 2, Thank you for the time you devoted to reading this manuscript and for your helpful comments.

We have to defend that the choice of indicators is suitable to the characteristics of the study environment. In fact, the information provided by them is consistent with the field analysis, where more diverse vegetal communities are present in CN. The selected indices are complementary. We agree that the richness (R) is an absolute index of biodiversity. However, Shanon´s and Pielou´s indices are defined in terms of frequency considering the weight of different species. In addition, the use of both of them allowed contrasting their results in the study catchments. On the other hand, Sorensen´s index allowed highlighting the biodiversity differences of the catchments. The seasonal study is useful because the species or its development degree can change along the year. Nevertheless, this analysis can be simplified if the reviewer considers convenient (only the results in spring would be showed).

Finally, if the work was supported on the life-forms, there would not be conclusive results because we have not been working on natural systems where different biotypes can be described. An extreme simplification of the life-forms represented uniquely by Therophytes and Hemicryptophytes (new Fig. 3), were observed in olive orchards. This is a permanent feature in agricultural systems where grass spontaneous cover is periodically removed to reduce water competition. In order to evaluate the differences, the index R (richness) offers detailed information of the present species in each catchment (new Table 5).

We think that our hypothesis was eventually not appropriate because of the environmental conditions (particularly precipitation and soil properties) resulted more determinant than the management. This can be justified due to: 1) better development conditions derived from lesser water limitations (In CN, there is a higher precipitation, and deeper and clayey soil for storing water) and 2) more effective seed dispersal, associated to greater flow/runoff in the catchments in CN.

ANSWERS TO REFEREE 3

32.REFEREE: The manuscript is focused on an important issue about indicators choice of soil degradation in olive orchards. The idea, described in the title, is not described in depth in the other sections of the manuscript (introduction, discussion)

AUTHORS: Following your advice and the editor´s, we have changed the title to improve the readability of the manuscript. (*Exploring the linkage between spontaneous grass cover biodiversity and soil degradation in two olive orchard microcatchments with contrasting environmental and management conditions*)

33. REFEREE The manuscript shows important data on soil management in orchard in relation to specific site condition and weed biodiversity. Therefore, the manuscript could be accepted for the publication in SOIL after the major revision. Such major revision should mainly be addressed to change the path of the whole manuscript, using the present data. I suggest to use always the same terminology, Weed, spontaneous, cover crop

AUTHORS: We have adapted the content to the new title (see the new version of the Introduction and the new comments of the Discussion). In addition, we have harmonized the terminology following your suggestion and referee 1´s.

34. REFEREE: Page 240; Line 19 – Explain Richness (R) and how the values are obtained. Table 2 move the

AUTHORS: The values of Richness (R) represent the number of different species identified on a sample. We collected the vegetal material in the field and in addition, we took pictures to facilitate its identification and location (see Fig. 2). As for Table 2, we are afraid that the text is incomplete.

Exploring the linkage between spontaneous grass cover biodiversity and soil degradation in two olive orchard microcatchments with contrasting environmental and management conditions

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Abstract. Spontaneous grass covers are an inexpensive soil erosion control measure in olive orchards. Olive farmers allow grass to grow on sloping terrain to comply with the basic environmental standards derived from the Common Agricultural Policy (CAP). However, to date there are few studies assessing the environmental quality and extent of such covers. In this study, we described the biodiversity indices associated to spontaneous grass cover in two contrasting olive orchards in order to compare them and to evaluate its relevance as an indicator of soil degradation. In addition, biodiversity patterns and their relationships with environmental factors such as soil type and properties, precipitation, topography and soil management were analyzed.

Different grass cover biodiversity indices were evaluated in two olive orchard catchments under conventional tillage and no tillage with grass cover, during 3 hydrological years (2011-2013). Seasonal samples of vegetal material and pictures in a permanent grid (4 samples/ha) were taken to characterize the temporal variations of the number of species, frequency, diversity and transformed Shannon's and Pielou's indices.

Sorensen's index obtained in two olive orchard catchments showed notable differences in composition, probably linked with the different site conditions. The catchment with the best site conditions (deeper soil and higher precipitation) and the highest biodiversity indices showed soil losses over 10 $t.ha^{-1}$ and management practices more intense. In absolute terms, the diversity indices of vegetation were reasonably high in both catchments, despite the fact that agricultural activity usually severely limits the landscape and the variety of species. Finally, a significantly higher content of organic matter in the first 10 cm of soil was found in the catchment with worse site conditions, average annual soil losses of 2 $t \cdot ha^{-1}$ and the least intense management. Therefore, the biodiversity indicators associated to spontaneous grass cover were not found to be suitable for describing the soil degradation in the study catchments.

Key words: olive orchard; spontaneous grass cover, biodiversity, management; soil degradation.

1. Introduction

Soil degradation is defined as the deterioration and loss of soil functions, involving processes such as soil erosion, sedimentation problems, climate change, watershed functions and changes in natural habitats leading to loss of genetic stock and biodiversity (Chen et al., 2002). The agricultural intensification of 20th century Europe has led in general terms to a widespread decline in farmland biodiversity across many taxa (Benton et al., 2003). The new 2020 Biodiversity Strategy (European Commission, 2011; 2011/2307 INI) aims to improve the contribution of fisheries and agricultural and forestry sectors to biodiversity. In addition, the Multi-annual Financial Framework for 2014–2020 offers significant opportunities to improve synergies not only in soil biodiversity but also with respect to other degradation processes such as soil loss (European Commission, 2014).

An area of over 2.5 Mha is dedicated to olive cultivation in Spain (MAGRAMA, 2013), which represents about 41% of the world olive production. Olive harvesting and its associated agri-food industries are especially important in rural areas from a socio-economical viewpoint. Over 60% of the area dedicated to olives is located in Andalusia, the southernmost region of the country. A high risk of soil degradation has been described by different authors such as Goméz-Limón et al., (2009) and Gómez et al., (2014) as the result of the interaction of climatological and topographical factors and/or inappropriate soil management. Olive trees have traditionally been cropped under rainfed conditions and on sloping areas where other crops are difficult to grow; they usually provide very low yields or require large investments in order to exploit them properly. The characteristics of the Mediterranean type of climate, where long dry periods alternate with intense rainfall events, in conjunction with soil management systems that pursue bare soils to minimize water competition by weeds entail a high susceptibility to severe water erosion of the soil. Therefore, the use of cover crops has been promoted for soil protection, given their proven effectiveness in controlling water erosion (Gómez et al., 2004; Gómez et al. 2009a, 2009b; Márquez-García et al., 2013; Taguas et al., 2013 among others). In fact, growing in between the olive tree rows is currently a compulsory requirement if the mean slope of the plot is over 15%, according to cross-compliance rules (European Commision, 2014). Spontaneous covers are usually irregular and develop slowly, but tend to achieve a significant gowth during spring which may result in greater competition for water and nutrients during the most critical periods of the olive growing cycle. However, due to its zero cost, it is a common alternative in low production olive farms (e.g. Taguas et al., 2013). Furthermore, additional advantages of spontaneous covers in terms of biodiversity, carbon sequestration and landscape improvement, etc, might make it worth to study their potential contribution.

The study of spontaneous grass cover and their interactions with soil have been traditionally associated with the improvement in crop yield (e.g. Graziani et al., 2012; Kamoshita et al., 2014;) or habitat and species conservation (e.g. Albrecth, 2003; Hyvönen and Huusela-Veistola, 2008; Aavik and Liira, 2009) in agronomical and ecological terms, respectively. However, their importance as indicators of soil loss and degradation has scarcely been explored. In this context, monitoring is a critical aspect in efforts to protect and manage biodiversity (Lamb et al., 2009). One key drawback for the proper implementation of protection policies is the lack of a well-defined quantitative measure or indicator of biodiversity (Büchs, 2003; Spangenberg, 2007; Moonen and Barberi, 2008). The distinction between the use of biotic indicators and biodiversity indicators to determine the state of the environmental aspects of different systems is not usually clear. Measuring the diversity of process-related indicators may be a good way of measuring how well agro-ecosystems react against environmental changes (Moonen and Barberi, 2008).

Bastida et al. (2008) pointed out that biological indicators of soil quality were more sensitive to changes than chemical and physical indicators and that they could give a broader picture of soil quality. The bio-indicators of soil quality are commonly associated to the biological activity of their microorganisms; however, spontaneous grass cover biodiversity may be a simpler way to measure the risk of soil degradation, given that richer and more complex ecological niches might produce more efficient cover and soil protection, as well as habitat and food opportunities for other elements of the trophic chain, such as birds or reptiles.

The starting hypothesis of this study was that wider ecological niches mean lower risks of soil degradation in terms of organic matter decline and soil losses. In addition, we postulate that the interactions of soil and management explain better the diversity of spontaneous grass covers than the environmental site conditions (annual/seasonal patterns).

The specific objectives of this work were 1) to describe and compare the biodiversity indicators associated with spontaneous grass covers in two olive orchards with contrasting management intensities, environmental conditions and yields; 2) to analyze the temporal patterns of these indices, as a result of meteorological conditions and soil management; and 3) to evaluate their relevance as indicators for soil quality, in terms of soil loss and soil degradation.

2. Materials and methods

2.1. Study sites

The study catchments are located in the province of Córdoba (Fig. 1, Table 1), in Southern Spain. Both were described in detail by Gómez et al. (2014) and Taguas et al. (2013) to evaluate the erosive patterns for the periods 2006-2011 and 2005-2011, respectively. The results were considered an accurate representation of the soil degradation state.

The "Conchuela" catchment (CN; 37.6 ºN, -5.0 ºW, Spain) is situated in a fertile area along the old terraces of the River Guadalquivir. The drainage area of the catchment is 8.0 ha, and it presents an average elevation of 142 m and a mean slope equal to 9%. The climate is classified as Mediterranean with an average annual precipitation of 642 mm, which is mainly concentrated from October to March (about 76% of the precipitation). The average annual temperature is 17.5 ºC. The maximum daily mean temperature is usually recorded in July (27.8 ºC) while the minimum is generally observed in January (8.1 ºC). The soil is a Vertisol, according to the FAO classification (FAO, 2006). It is a deep soil, very plastic when wet, but when dry, the presence of cracks induces high infiltration rates. The predominant soil texture is clay-loam (Table 1). The olive trees were planted in 1993 with 6 × 7 m tree spacing. The mean olive yield in the catchment is 8000 $kg\cdot ha^{-1}$ During the study period, the farmer allowed the growth of grass spontaneous cover in the lanes from the end of winter until April. Herbicide (glyphosate and oxifluorfen) treatments were applied to control their growth in the tree line from March to September (Table 2). Occasionally surface tillage was made at selected locations within the catchment to cover rills and small gullies obstructing machinery traffic within the orchard. Mowing in the tree lane was performed in areas of excessive grass cover from late winter to early spring. Harvesting is semi-mechanized using tree-vibrators from late autumn to mid-winter, depending on weather conditions and when the fruit ripens (Gómez et al., 2014; Table 2).

The “Puente Genil” catchment (PG; 37.4 ºN, −4.8 ºW) represented a marginal olive orchard with a very low production. Management operations are kept to a minimum in order to reduce costs. It is located in an area with a long tradition of olive cropping in the upper reaches of the Guadalquivir Valley. The catchment has a drainage area of 6.1 ha and the mean elevation is 239 m. The average slope is equal to 15 %. As for the climate type, the catchment is located in a Mediterranean area with a mean annual precipitation is of 400 mm. The average temperature in the hottest month (July) is 26.5 ºC, while in the coldest month (January) it is 8.4 ºC. The main soil category of the catchment is Cambisol (FAO classification; FAO, 2006) with sandy-loam texture (Table 1 and 3). Calcic parental material is located at different points of the catchment with a very shallow soil, mainly on the Western hillslope (Fig. 1b). In contrast, on the Eastern hillslope, soil depth is more than 3 m. The areas closer to the catchment outlet are old terraces with abundant coarse calcarean material. The mean olive yield is 1300 $kg \cdot ha^{-1}$. The olive trees´ age is 17 years. They were planted on a 7 m × 7 m grid. No-tillage with spontaneous grass cover growing from winter to spring was the management type corresponding with the first few years. Spontaneous grass is removed once (only in spring) or twice a year (September or October and March, April or May), mechanically or using phytosanitary products under the canopies (or combining both; see also Taguas et al., 2013). The details of the management applied during the study period are summarized in Table 2.

2.2. Spontaneous grass cover sampling

Four spontaneous grass cover surveys were performed per year (1 per season) during 2011, 2012 and 2013. Survey dates were based on the preceding meteorological conditions that determined the germination periods, as well as the development of the spontaneous grass cover. A grid was established in each catchment (Fig. 1) with a sampling density between 4 and 6 points/ha. In each geo-referenced grid point, a 0.5 × 0.5-m frame was used to delimit the survey area (Fig. 2). These sampling points were always placed in the lanes between the lines of trees, away from the olive canopy and the areas of drip irrigation and herbicide application. Plant samples were taken in order to identify the species present at each grid point. In addition, pictures of each point were taken (Reflex Olympus E-420, ED 14-42 mm; height 1.4 m-1.7 m; Fig. 2) to check the annual and seasonal differences of the grass spontaneous cover.

2.3. Data Analyses: biodiversity indices, meteorological variables and soil quality indicators

2.3.1. Biodiversity indices

The indices considered to evaluate the biodiversity associated to the grass spontaneous grass cover were richness (*R*), Sorensen’s index (*Is*), transformed Shannon’s (*Hmod*) and Pielou’s indices (*Jmod*), absolute and relative frequency of occurrence and biological spectrum. *R* was determined for the total number of species found per catchment per season and per point. Firstly, in each sample point of the grid (Fig. 1 and

Fig 2a and 2b), the species present were identified with pictures and vegetal material, and then the total number species in each catchment (on a seasonal and annual scale) were calculated.

Is indicates the degree of similarity of two samples (study sites) as regards the species composition (Eq. 1). It ranges from 0 to 1, where 0 means that both samples are completely different and 1 completely equal.

$$Is = \frac{2 \cdot C}{A+B} \qquad \text{(Eq. 1)}$$

Where: *A* is the number of species identified in PG, *B* the number of species identified in CN, and *C* is the number of species common to both study sites.

Shannon's index, *H*, (Eq. 2; Shannon and Weaver, 1949) indicates the probability of finding an individual within an ecosystem. It usually produces values of between 1.5 and 4.5. Minimum values are obtained when most of the individuals belong to the same species or to a limited group of (less diverse) species, while the highest values are produced in communities where all the species have the same number of individuals.

$$H = \sum_{i:1..n}(p_i \cdot Ln\ (p_i)) \qquad \text{(Eq. 2)}$$

Where: $p_i = n_i / N$; n_i is the number of individuals corresponding to the species *i*, and *N* is the total number of individuals. In this case, a modification of Shannon's index, *Hmod*, was used to simplify the analysis, based on the evaluation of pictures.. Therefore, n_i was substituted by the number of grid points where a species was present and *N*, the total number of grid points considered. The suitability of the transformations associated to *Hmod* and *Jmod* was verified with the samples taken in spring 2013 in both catchments.

Pielou's equity index (Eq. 3; Pielou, 1969) measures the ratio of the observed diversity and the maximum expected diversity. It varies between 0 and 1, which would describe systems where all species are equally abundant.

$$J = \frac{H}{Ln(S)} \qquad \text{(Eq. 3)}$$

Where:

H is Shannon´s index and *S* is the number of species. If *H* (Eq. 3) is substituted by *Hmod*, then *Jmod* is obtained.

Finally, the biological spectrum or life-form (Raunkiaer, 1934) was identified for each species according to its behavior during the unfavorable season (June-September): Epiphytes; Phanerophytes Chamaephytes; Hemicryptophytes: Therophytes; Cryptophytes.

2.3.2. *Meteorological variables to describe temporal variability of biodiversity indicators.*

The cumulative precipitation (*P*), cumulative reference evapotranspiration (*ETP*) and average minimum daily temperatures (*Tm*) were considered in order to evaluate their influence on the biodiversity indices. The daily precipitation was recorded in the gauging stations of the catchments, while the daily values of

ETP and *Tm* were collected from “La Reina” and “Santaella-CSIC” meteorological stations for CN and PG, respectively (CSIC, 2014).

2.3.3. Soil degradation indicators: soil loss, runoff, organic matter and bulk density.

The relationships between the mean values of soil losses, runoff coefficients and organic matter content (0-10 cm) in the catchments with *R, Jmod* and *Hmod* were explored to discuss the role of biodiversity indices as a proxy of soil quality indicators. Soil loss (*SL*) and runoff coefficient (*Rc*) were measured in the catchments over 5 years (Taguas et al., 2013; Gómez et al., 2014).

The samples for organic matter (*OM*) analysis were taken between 0-10 cm combining the inter-row and the area under the tree canopies obtained on regular grids with a density of 6-10 samples/ha. The number of samples was 90 and 65 in CN and PG, respectively. The Walkley-Black procedure (Nelson and Sommers, 1982) with samples (2 mm sieve) was followed to determine the organic matter content. Bulk density (*BD*) was measured on the same grid using undisturbed soil cores of approximately 250 cm^3. The differences in grid and number of samples are due to the tree spacing in the catchments.

2.3.4. Statistical analyses

Basic statistics (mean, standard deviation and coefficient of variation) were evaluated for the annual values of *R*, *Jmod*, *Hmod*, *Is* as well as *Tm, ETP* and *P*. In the case of *Is*, the average seasonal values were calculated to observe the possible differences in the study sites over the year. The histograms of the biological spectrum measured in the catchments for the study period were also compared.

In addition, in order to evaluate the influence of the meteorological variables on the biodiversity indices *Hmod*, *Jmod* and *R,* a correlation analysis was carried out with meteorological features: *P*, *ETP* and *Tm*. These were checked for the weighted values for the previous 5, 15, 30, 60 and 365 days.

As for soil properties *OM* and *BD*, box and whisker plots and t-test for independent samples were used to determine whether there were significant differences between the study sites. For *SL* and *R*c, only box and whisker plots were represented because the number of samples was 5. These properties were compared with the biodiversity indices to qualitatively describe the correlation degree.

3. Results

3.1. Variability of the biodiversity indicators

The mean values of *R*, *Hmod* and *Jmod*, were higher in CN than in PG, which probably shows that site-specific conditions have greater importance than long term management effects (Table 4). A lower diversity was identified in PG, which was probably associated with worse environmental conditions in terms of water deficit, as compared to CN (Table 4), coupled with coarser soil texture and lower soil water holding capacity (Table 3). Precipitation was on average 25% lower in PG while *ETP* was slightly higher, with respect to CN (Table 4). The soils at PG were also shallower than at CN and of coarser texture (Table 3), leading to a smaller water storage capacity which might limit the development of vegetation in PG.

With the exception of *Jmod*, the highest coefficients of variation were also observed in PG. Despite the extremely simplified landscapes of both catchments, *Hmod*-values were notably high for agricultural systems, particularly in the driest year (2011) with values near to 2.2 and 1.9 in CN and PG, respectively (Table 4). On the other hand, *Jmod*-values indicated that there were no dominant species in either of the catchments. These features are common in Mediterranean environments, characterized by a high inter-annual and intra-annual variability of precipitation and temperature, with a wide range of colonizing species awaiting their optimal development conditions without any clear dominant pattern. In spite of the selective herbicide treatments (Table 2), differences in *Jmod* between both catchments were small. In addition, they were notably higher than the values quantified for olive orchards with cover crops with leguminous species (Guzmán and Forester, 2007).

Sorensen´s index numerically illustrated the notable differences of species existing in the catchments (Tables 4-5 and Fig. 3). It is worth noting how winter was the period when the floristic composition was the most similar while the spring, the most different. Although close species spectra were found (Fig. 3), a different floristic catalogue was observed in both catchments, and the lack of Monocotyledonous in PG is remarkable (Table 5). From the soil protection point of view, the current spectrum is not appropriate because most of the species are not permanently present for a long period of the year. However, most of the species constitute the nutritional base for insects and birds. Enrichment of the biological spectrum with Hemicryptophytes and Chamaephytes is suggested in locations where e.g. hedges are compatible with agricultural operations (Guzmán and Foraster, 2007).

The coefficients of correlation between weather variables (*Tm, ETP and P*) and seasonal biodiversity indicators (*Hmod*, *Jmod* and *R*) were in general low (Table 6). Significant correlations were only found for PG as a result of the shallow sandy soil with short-term water availability controlling vegetation. In contrast, the deeper clay soil at CN (Table 1, 3) enhanced long-term water availability and weakened the correlations between weather variables and biodiversity indicators. Significant negative correlations for *ETP15, ETP60* (and *Tm60*) are related to water stress, whereas the positive correlations for short-term indicators such as *Tm15* and *ETP5* might indicate optimal conditions for the seed germination and the growth of grass.

3.2. Relationships between biodiversity indices and indicators of soil quality

In addition to *R*, *Jmod* and *Hmod*, the mean annual values of *SL* and *Rc*, measurements of *OM* and *BD* are also shown in Table 7 and Figure 4. *R*, *Jmod* and *Hmod* were not correlated with soil indicators. The highest values of soil losses and the lowest values of organic matter were found in CN. The differences in *OM* and *BD* between the catchments were significant as is shown in Table 7 and Fig. 4a-b (average OM-CN=1.249 $g.cm^{-3}$; average OM-PG=1.479 $g.cm^{-3}$). A large quantity of coarse elements was found in PG, which must be taken into account when understanding the differences in BD (Table 7). Substantial higher mean soil loss in CN(16.1 $t \cdot ha^{-1}$) was found with respect to PG (1.8 $t \cdot ha^{-1}$; Fig. 4c), Likewise, the mean *Rc* in CN(15.3%) tripled the value of PG (5.1%; Fig. 4d),

4. Discussion

Indicators of spontaneous grass cover biodiversity were not correlated with soil losses and organic matter. The role of cover crops in soil erosion is related with dissipation of energy from rainfall and runoff. It was expected that a wider ecological niche would allow for a more efficient occupation of space and a higher efficiency in the flow control on the hillslopes. However, in CN, other factors such as precipitation, soil hydrologic characteristics and the possible dominance of concentrated flow (gullies and rills; Gómez et al., 2014) accounted for higher soil losses and runoff coefficient (much higher than PG values). Lewis et al. (2013) highlighted the potential for soil erosion to impinge the spontaneous grass cover seedbank growth and to improve the biodiversity in agro-ecosystems of Northern Europe. In natural Mediterranean systems Cerdá and García-Fayos (2002) and García-Fayos et al., (2010) described the susceptibility to seed removal by water erosion according to seed and landscape features. In this context, an annual sediment delivery ratio of 4% was found in PG using the SEDD model (Taguas el al, 2011) while in Conchuela, the value was over 90% indicating an efficient rate of transport, as calculated by Burguet (2015). Both the different values of soil losses and the annual sediment delivery ratios might illustrate the very different sediment dynamics which contribute towards explaining the greater biodiversity in CN.

As for the values of organic matter content, these might be explained by the management systems. No tillage operations were applied in PG from 2005 and machinery traffic was usually minimal (Table 2), which implies less mechanical soil disturbance than in CN, where productive farm management is carried out. In two sites with a silt loam texture in the Ebro Valley in Spain, Fernández-Ugalde et al. (2009) also described an increase in soil organic carbon content associated with non-tillage practices.

It is important not to confuse non-tillage allowing spontaneous grass cover vegetation, as used in PG, with non-tillage management with herbicide to maintain bare soil in olive orchards. The later led to larger soil losses, runoff coefficients and soil compaction as compared to conventional tillage and cover crops as was described by Gómez et al., (2004), however, larger carbon and organic matter contents were found in the topsoil, particularly under the canopy (Gómez et al., 1999). As for surface tillage operations in CN, Márquez-García (2013) also found lower values of organic carbon in the topsoil of olive orchards under conventional tillage as compared to cover crops (spontaneous and sown). Near the study catchments, in other agricultural land uses under conservation agriculture, smaller amounts of crop residues, lower soil water contents and larger CO_2 emissions were observed in managements where tillage operations were applied (Cid, 2013).

Despite the annual and seasonal variations of meteorological conditions, overall a larger availability of water was observed in CN, as a result of the higher annual precipitation and the notably deeper soil. More extensive management did not lead to greater spontaneous grass cover biodiversity in PG compared to CN. Benton et al. (2003) highlighted the importance of differential seed or edaphic factors contributing distinctly to plant growth and to patchiness in the presence of insects. Similarly, Albrecht and Mattheis (1998) found that a management change from conventional to integrated farming in dicotyledonous crops in Germany did not lead to a substantial increment of rare species number of spontaneous grass cover.

Hyvönen et al. (2003) found that differences in spontaneous grass cover species numbers between organically and conventionally cropped fields in Finland were small. Similar results were highlighted under Mediterranean conditions by Graziani et al. (2012) for a sequence of six rotations in Italy. They found that the number of spontaneous grass cover species and biodiversity were only slightly higher in organic systems as compared to low-input conventional systems.

Although single measures, such as the application of fertilizers or certain herbicides, may lead to a strong correlation with species diversity, such as the case of monocotyledoneous in CN, no clear sensitivity to the management was found, as described by Albrecht (2003) in Germany or Pysek et al. (2005) in Central Europe for different crops. This is likely to be a result of the site conditions in CN being substantially better for vegetation growth, which becomes evident from the olive yields at both catchments (CN, 5000-8000 kg ha^{-1} and PG < 2000 kg ha^{-1}). In fact, crop yield was also used with other soil properties (such as bulk density, water retention, pH, electrical conductivity, plant-available nutrients, organic matter, microbial biomass, soil enzymes) by Masto et al. (2007) to define a soil quality index in an agricultural area with a rotation of maize, pearl millet, wheat and cowpea in India. In addition, it is a common agronomical factor of soil quality for farmers, which is well-correlated with biodiversity indices of spontaneous grass cover. On the other hand, the traditional metrics used in this study to measure biodiversity - widely used in ecological studies since it is simple to calculate and understand and has been used for a long time (Lamb et al., 2009) – have been criticized because they provide a limited part of the information (Magurran, 2004) and may be unsuitable for monitoring biodiversity intactness (Lamb et al., 2009). These traditional indices, for example, cannot indicate the presence of non-native species or rare plants. In this case, the details of the species shown in Table 5 complete the information provided by the biodiversity indices and allow us to confirm the short-term environmental advantages of the vegetation growth found in CN, which is likely to be linked to greater water availability.

5. Conclusions

Sorensen's index for two olive orchard catchments in the province of Cordoba (Spain) showed notable differences in composition, which were probably associated with the different site conditions. Although CN had a more intense management, its better site conditions (higher precipitation, deeper soils and less steep slopes) can explain the higher values in richness, Pielou's index and Shannon's index. Water stress is a limiting factor for the development of vegetation in the Mediterranean area, so the notable differences in annual precipitation (400 mm in PG versus 600 mm in Conchuela) account for the differences observed. In addition, a more active sediment transport dynamic might contribute to seed dispersal and to increasing the biodiversity indices.

In absolute terms, the diversity indices were high in both catchments, in spite of the major simplifications derived from the agricultural systems. This can be related with the typical Mediterranean dynamics where temporal variability allows different individual species to be incorporated each year according to certain climatological features. The impact of land-use and management in both catchments explains the dominance of short cycle Therophytes, Hemicryptophites and Cryptophytes, which are extremely resistant to mechanical/chemical treatments, since their buds are kept underground. On the other hand, Therophytes and Hemicryptophytes do not provide efficient soil protection, since their aerial parts are not present during autumn and winter seasons. However, these species are ecologically important for feeding numerous insects and local birds such as partridge (*Alectoris rufa* L).

Higher contents of organic matter were determined in PG, the catchment with the worst site conditions in terms of water availability and the least intense management. Additionally, low soil losses have been measured in this catchment. Therefore, biodiversity indicators associated to spontaneous grass cover were not appropriate to describe the soil situation.

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TABLES

Table 1. Summary of the main environmental features in the study catchments

Name	La Conchuela	Arroyo Blanco
Location	Córdoba	Puente Genil (Córdoba)
Drainage area (ha)	8.0	6.1
Mean elevation (m)	142	239
Mean slope (%)	9	15
Mean annual precipitation (mm)	642	400
Max. and min. daily average temperatures	27.8º July/8.1º January	26.5º July/ 8.4º January
Soil type (FAO; see details in Table 3)	Vertisol	Cambisol
Texture	Clay-loam	Sandy-loam
OM content (%, topsoil)	1.1	1.4
Mean olive yield (kg/ha)	8000	1300
Management (see details in Table 2)	Spontaneous grass cover controlled with a combination of mowing, and occasional herbicide application	Non-tillage with a spontaneous grass cover

Table 2. Management operations applied during the study periods in both catchments.

Catchment	Month	2011	2012	2013
Con	January		Harvesting: Mechanical vibrators combined with a buggy with an umbrella to collect the olives.	Harvesting: Mechanical vibrators combined with a buggy with an umbrella to collect the olives.
	February			
	March	Herbicide treatments around trees (glyphosate and oxifluorfen in infested areas)		Herbicide treatments around trees (glyphosate and oxifluorfen in infested areas) Mowing of lane areas
	April	Mowing of lane areas	Herbicide treatments around trees (glyphosate and oxifluorfen in infested areas) Mowing of lane areas	
	May	Drip irrigation	Drip irrigation	Drip irrigation
	June	Drip irrigation	Drip irrigation	Drip irrigation
	July	Drip irrigation Herbicide treatments around trees (glyphosate and oxifluorfen in infested areas)	Drip irrigation	Drip irrigation Herbicide treatments around trees (glyphosate and oxifluorfen in infested areas)
	August	Drip irrigation	Drip irrigation Herbicide treatments around trees (glyphosate and oxifluorfen in infested areas)	Drip irrigation
	September	Drip irrigation	Drip irrigation	Drip irrigation
	October			
	November			
	December	Harvesting: Mechanical vibrators combined with a buggy with an umbrella to collect the olives.	Harvesting: Mechanical vibrators combined with a buggy with an umbrella to collect the olives.	
PG	January			
	February			
	March			
	April	4 tractor passes to mechanically clear the spontaneous grass cover.		
	May	Foliar fertilization (N, Mg & Fe)	4 tractor passes to mechanically clear the spontaneous grass cover Herbicide treatments around trees (glyphosate)	
	June			
	July			
	August			
	September			4 tractor passes to mechanically clear the spontaneous grass cover. Herbicide treatments around trees (glyphosate)
	October			
	November	Harvesting: Mechanical vibrators combined with a buggy with an umbrella	Harvesting: Mechanical vibrators combined with a buggy with an umbrella	Harvesting: Mechanical vibrators combined with a buggy with an umbrella

December	to collect the olives.	to collect the olives.	to collect the olives.

Table 3. Soil properties in two profiles of the catchments (PG= Puente Genil; CN= Conchuela)

Catchment	*Horizon*	*Width (cm)*	*Coarse elements (%)*	*Sand (%)*	*Silt (%)*	*Clay (%)*	*Texture class*	*pH*	*OM (%)*
PG	A	10	22.7	59.5	35.2	5.3	Sandy-loam	8.8	1.59
	C	40	24.4	60.8	34.3	4.9	Sandy-loam	8.8	1.59
CN	A	0-56	0.36	5.9	45.1	49.0	Clay	8.6	0.96
	B	56-110	0.00	5.9	46.4	47.7	Clay	8.7	0.53
	BC	110-138	0.00	-	-	-	Clay-loam	-	-
	C	>138	0.00	-	-	-	Clay-loam	-	-

Table 4. Annual values of biodiversity indices: Richness (*R*), modified Shannon's (*Hmod*) and Pielou's indices (*Jmod*) and seasonal Sorensen's indices (*Is*); and meteorological attributes: average minimum temperature (*Tm*), annual evapotranspiration (*ETP*) and precipitation (*P*) for both catchments. (CV=coefficient of variation).

Index	Catchment/ Season	2011	2012	2013	Mean	St. Dev.	CV(%)
R	**CN**	23	26	28	25.7	2.5	9.7
	PG	24	14	24	20.7	5.8	28.0
Hmod	**CN**	2.194	1.947	1.826	1.989	0.187	9.4
	PG	1.880	1.213	1.751	1.614	0.354	21.9
Jmod	**CN**	0.897	0.839	0.850	0.862	0.031	3.6
	PG	0.840	0.834	0.817	0.830	0.012	1.4
Is	**Winter**	0.231	0.571	0.333	0.378	0.174	46.0
	Spring	0.231	0.100	0.087	0.139	0.080	57.6
	Summer	0.320	0.000	0.363	0.228	0.198	86.8
	Sutumn	0.166	0.333	0.000	0.166	0.167	100.6
Tm (ºC)	**CN**	11.7	11.6	11.1	11.5	0.3	2.6
	PG	12.4	11.6	11.7	11.9	0.4	3.4
ETP (mm)	**CN**	1270.5	1310.2	1230.4	1270.4	39.9	3.1
	PG	1383.7	1359.8	1355.1	1366.2	15.3	1.1
P (mm)	**CN**	401	610	621.1	544	124	22.8
	PG	376.8	434.4	423.8	411.7	30.7	7.5

Table 5. Species identified in the study catchments present in Puente Genil (PG), Conchuela (CN) or both catchments (Both) for the study period.

Species Scientific name	Biological Spectrum	Location
	Dicotyledonous	
	APIACEAE(UMBELLIFERAE)	
Daucus carota L.	Hemicryptophites	CN
	ASTERACEAE(COMPOSITAE)	
Anacyclus clavatus (Desf.) Pers.	Therophytes	Both
Anthemis arvensis L.	Therophytes	Both
Calendula arvensis L.	Therophytes	CN
Centaurea melitensis L.	Therophytes	Both
Cirsium arvense (L.) Scop.	Geophytes	Both
Cichorium intybus L.	Hemicryptophites	CN
Conyza sumatrensis (Retz) E. Walker	Therophytes	PG
Chrysanthemum segetum L.	Therophytes	Both
Picris echoides L.	Hemicryptophites, Therophytes	Both
Senecio vulgaris L.	Therophytes	Both
Silybum marianum (L.) Gaerth	Hemicryptophites	CN
Sonchus asper (L.) Hill	Hemicryptophites, Therophytes	Both
Sonchus oleraceus L.	Hemicryptophites, Therophytes	Both
Taraxacum officinale Weber ex F.H. Wiss	Hemicryptophites	Both
Taraxacum obovatum (Willd) D.C	Hemicryptophites	PG
Pulicaria paludosa Link	Hemicryptophites, Therophytes	Both
	BORAGINACEAE	
Anchusa azurea Mill	Hemicryptophites	PG
Echium plantagineum L.	Hemicryptophites, Therophytes	Both
Heliotropium europaeum L.	Therophytes	Both
	BRASICACEAE(CRUCIFERAE)	
Diplotaxis virgata (Cav) DC	Therophytes	PG
Raphanus raphanistrum L.	Geophytes, Therophytes	Both
Rapistrum rugosum(L.) Bergeret	Therophytes	Both
Sinapis arvensis L.	Therophytes	CN
	CARYOPHYLLACEAE	
Spergula arvensis L.	Therophytes	PG
Stellaria media (L.) Vill	Therophytes	Both
	CISTACEAE	
Fumana ericoides (cav) Gand. In Magnier	Chamaephytes	PG
	CONVOLVULACEAE	
Convolvulus arvensis L.	Geophytes, Hemicryptophites	CN
	CRASSULACEAE	
Umbilicus rupestris (Salisb.) Dandy	Hemicryptophites	PG
	CUCURBITACEAE	
Ecballium elaterium	Hemicryptophites	CN

FABACEAE(LEGUMINOSAE)		
Ononis punescens L.	Therophytes	PG
Trifolium repens L.	Hemicryptophites	CN
Trifolium campestre Screb.	Therophytes	CN
GERANIACEAE		
Erodium cicutarium (L.) L´Her	Therophytes	Both
Erodium moschatum (L.) L´Her	Therophytes	CN
Erodium malacoides (L.) L´Her	Therophytes, Hemicryptophites	PG
Geranium molle L.	Therophytes	CN
LAMIACEAE		
Lamium amplexicaule L.	Therophytes	Both
MALVACEAE		
Malva sylvestris L.	Hemicryptophites	Both
PAPAVERACEAE		
Fumaria officinalis L.	Therophytes	CN
POLYGONACEAE		
Polygonum aviculare L.	Therophytes	PG
PRIMULACEAE		
Anagallis arvensis L.	Therophytes	Both
RANUNCULACEAE		
Ranunculus arvensis L.	Therophytes	Both
RUBIACEAE		
Galium aparine L.	Therophytes	Both
SCROPHULARIACEAE		
Veronica arvensis L.	Therophytes	PG
Veronica heredifolia L.	Therophytes	PG
URTICACEAE		
Urtica urens L.	Therophytes	PG
Monocotyledonous		
LILIACEAE		
Muscari comosum (L.) Miller	Geophytes	PG
POACEAE		
Bromus hordaceus L.	Therophytes	CN
Bromus madritensis L.	Therophytes	CN
Bromus squarrosus L.	Therophytes	CN
Hordeum murimum L.	Therophytes	CN
Hordeum leporinum (Link)	Therophytes	CN
Lolium rigidum Gaudin	Therophytes	CN
Poa annua L.	Therophytes	CN

Table 6. Matrix of correlation between diversity indices (seasonal values) and climatological features: *Hmod* = Shannon´s modified index; *Jmod* = Pielou´s modified index; *R* = richness; *P* = cumulative precipitation; *Tm*= average of minimum daily temperatures; *ETP* = cumulative evapotranspiration. Numbers indicate the interval of previous days (5, 15, 30 and 60).

		P5	*P15*	*P30*	*P60*	*Tm5*	*Tm15*	*Tm30*	*Tm60*	*ETP5*	*ETP15*	*ETP30*	*ETP60*
CN	*Hmod*	0.12	0.33	0.40	0.39	-0.28	-0.26	-0.25	-0.31	-0.35	-0.36	-0.42	-0.43
	Jmod	-0.19	-0.25	-0.20	-0.10	0.55	0.52	0.41	0.17	0.29	0.54	0.55	0.44
	R	0.35	0.52	0.49	0.45	-0.16	-0.17	-0.20	-0.29	-0.25	-0.32	-0.36	-0.37
PG	*Hmod*	0.23	0.29	0.11	0.39	-0.12	-0.05	-0.42	**-0.64**	-0.27	**-0.58**	-0.39	**-0.58**
	Jmod	-0.19	-0.29	-0.42	-0.18	0.40	**0.60**	0.29	-0.01	**0.61**	0.26	0.51	0.36
	R	0.29	0.38	0.16	0.36	-0.22	-0.09	-0.42	**-0.61**	-0.35	**-0.62**	-0.46	**-0.61**

N=12 – Bold indicates correlations are significant at $p < 0.05$

Table 7**.** Means and standard deviations of the annual biodiversity indicators and parameters of soil quality: *Hmod* = Shannon´s modified index; *Jmod* = Pielou´s modified index; *R* = richness; *OM*= organic matter content in upper horizon (0-10 cm); *BD*= bulk density of upper horizon (0-10 cm); *SL* = annual soil loss; *Rc* = runoff coefficient (ratio of the annual values of precipitation and runoff).

Catchment	Stat.	*R*	*Jmod*	*Hmod*	*OM** (%)	*BD*** ($g.cm^{-3}$)	*SL+* ($t.ha^{-1}$)	*Rc+* (%)
CN	Mean	25.7	0.86	1.99	1.25	1.57	16.1	15.3
	St. Dev.	2.5	0.03	0.19	0.37	0.19	20.8	12.7
PG	Mean	20.7	0.83	1.61	1.48	1.50	1.8	5.1
	St. Dev.	5.8	0.01	0.35	0.53	0.25	2.3	4.2

(*) T-test showed p=0.00054 (See also Fig. 4a)

(**) T-test showed p=0.07764 (See also Fig. 4b)

(+) See Figures 3c-d, T-test was not carried out because the number of samples was very low. CN(n=5 years), PG (n=6 years)

FIGURES

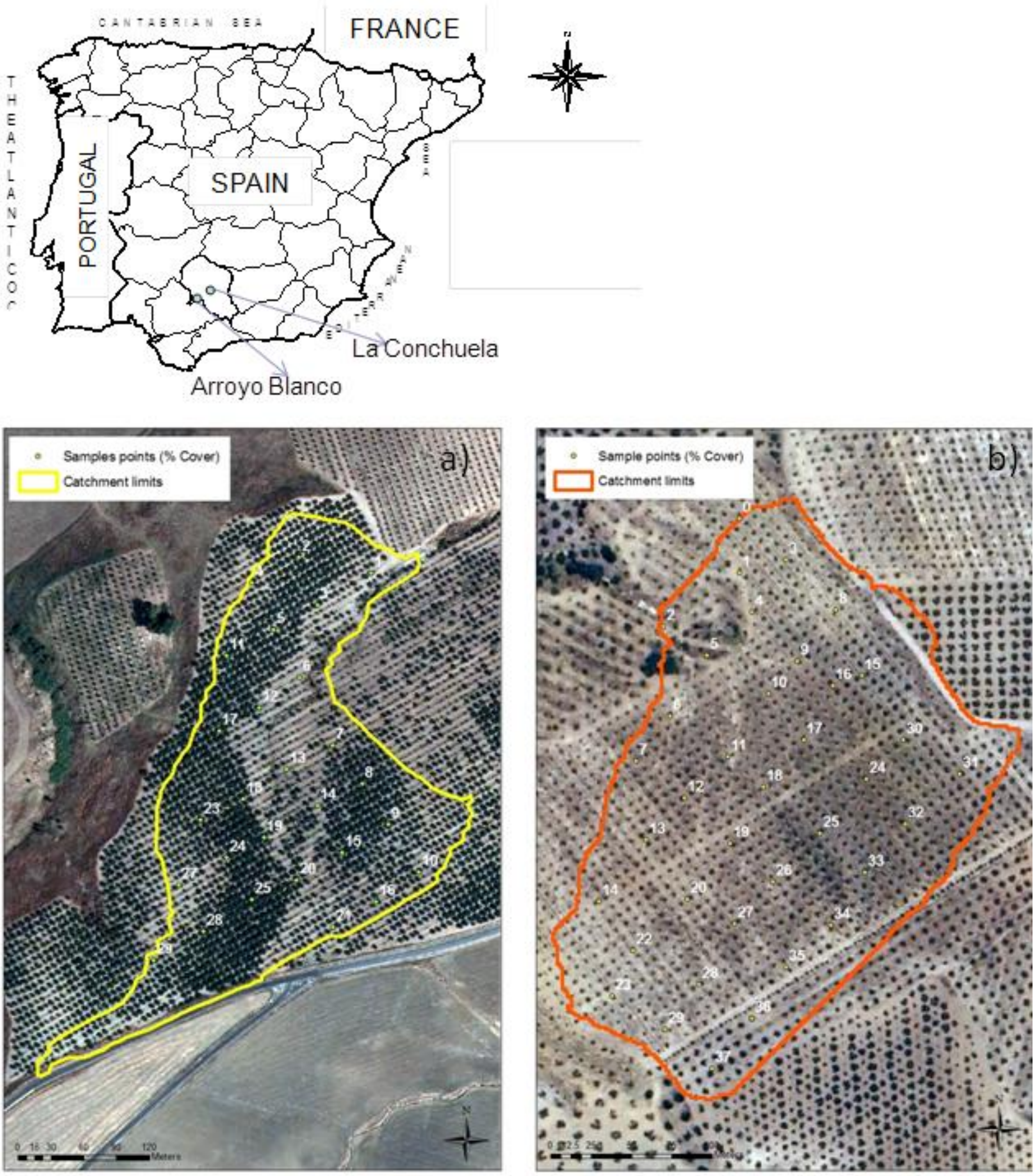

Figure 1. Locations of the study catchments and sample grids: a) La Conchuela (CN); b) Puente Genil (PG).

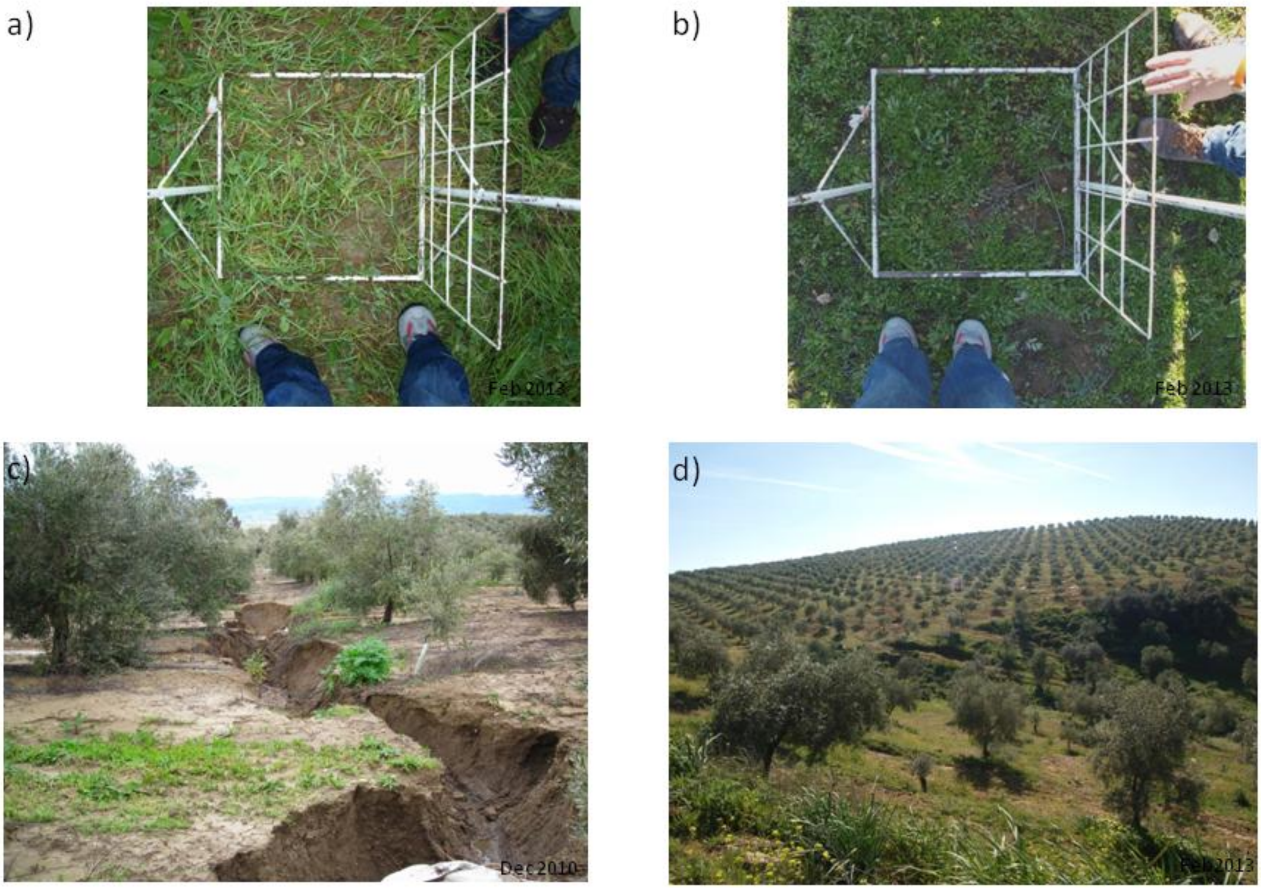

Figure 2. Examples of grass spontaneous cover sample plots and view of the catchments: a) a plot in La Conchuela; b) a plot in Puente Genil; c) gully with cover crop; d) view of a hillslope in PG.

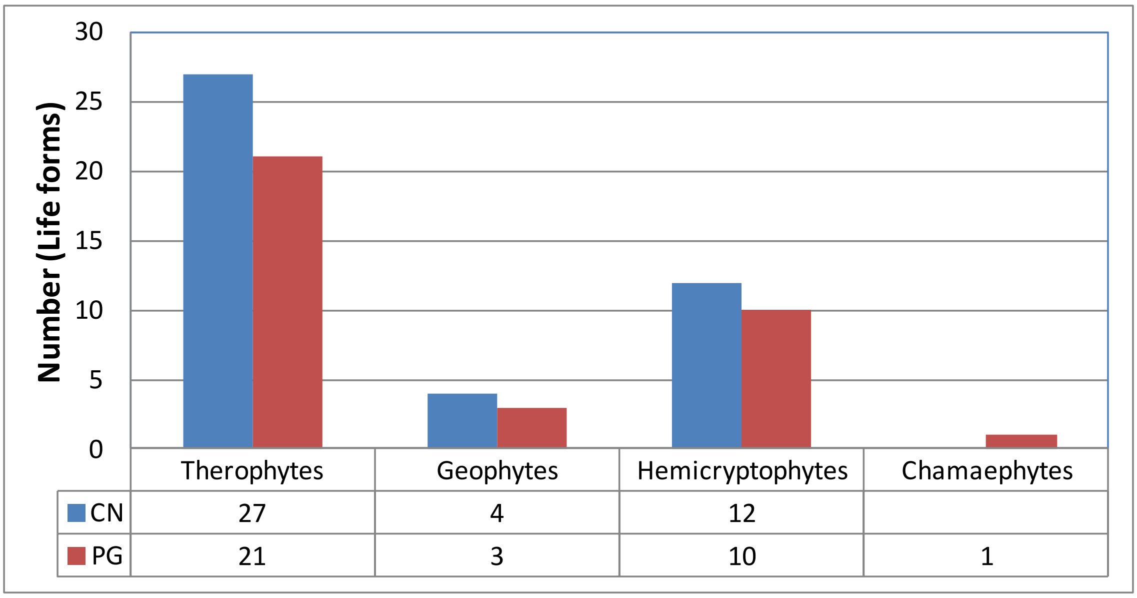

Figure 3. Distribution of life forms (biological spectrum) in the study catchments (CN= La Conchuela; PG= Puente Genil).

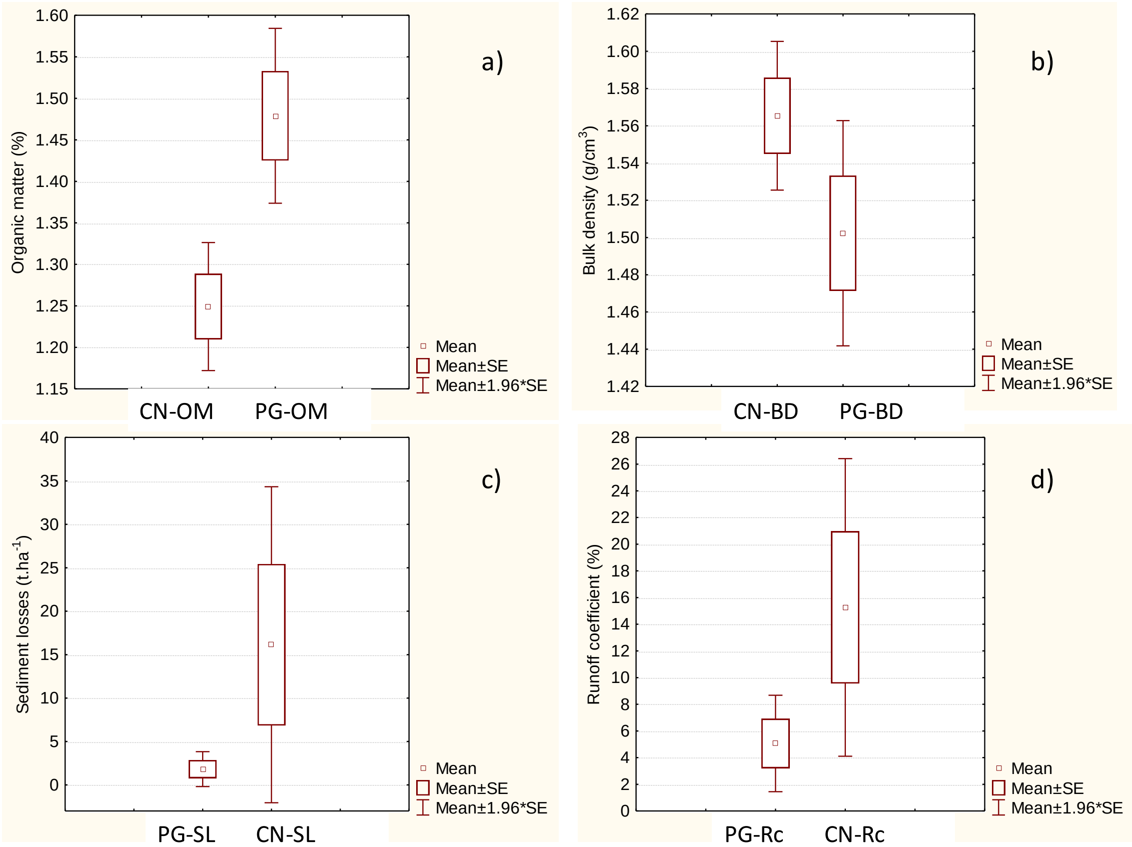

Figure 4. Box and whisker plots of the measurements of soil degradation indicators: (a) organic matter content in the upper horizon (b) bulk density in the upper horizon; (c) annual soil losses in the catchment outlets; (d) annual runoff coefficients (PG= Puente Genil; CN=La Conchuela; SE= Standard error).