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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Mapping the suitability of groundwater dependent vegetation in a semi-arid Mediterranean area" *by* Inês Gomes Marques et al.

Inês Gomes Marques et al.

icgmarques@fc.ul.pt

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Dear Referee1,

Please find enclosed the revised version of the manuscript "Mapping the suitability of groundwater dependent vegetation in a semi-arid Mediterranean area".

All the suggestions were carefully considered and addressed accordingly. In the present letter, you will find the responses to your comments and the changes made, point by point. Particularly, we have clarified comments on the methodology on the calculation of the map of water table. Also, we changed the validation method as suggested. As a result of the introduction of remote sensing datasets to validate the suitability map, we added the author Célia M. Gouveia to the authors list.

We are very thankful for all the comments, which allowed a very significant improvement of the manuscript quality. A version of the new manuscript was uploaded in the journal platform.

All the information included in this manuscript is completely original and has been approved by all authors. The authors declare no conflict of interest. This manuscript has not been published previously or concurrently submitted for publication elsewhere.

Thank you for considering this revised manuscript for publication. Please do not hesitate to contact us if you require further details.

With our best regards, sincerely

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Referee Comments 1

General Comments Gomes Marques et al. present an analysis of the spatial distribution of groundwater dependent vegetation across the Iberian Peninsula. While the method used is perhaps not as novel as suggested in the text, the paper's main strength lies in the validation of the maps created against a fairly robust eternal dataset. The text is generally well written, although it is not as clear as it could be when discussing how the "model" was parameterized and validated. In general, the paper is a solid contribution to the literature on phreatophytes, but needs revision to enhance its clarity and address some lingering questions about the work.

Specific Comments 1. Throughout: What exactly is meant by a "suitability map"? Suitability for what? Or do you mean suitability of the terrain for hosting phreatophtyes? The concept is fine, but the word choice seems odd.

Answer: We appreciate the reviewer's comment on this matter. With a suitability map we aim to ascertain the suitability of the arboreous phreatophyte species to the climatic and local conditions. To clarify this matter, this information was provided in lines 113-114 of the introduction.

2. Line 147 - 149: How heavily managed are these forestry systems? What species are harvested? And with what methods?

Answer: In the Alentejo region, Cork oak, Holm oak and Stone pine represent 83% of the forest cover, covering about 36% of the geographical area. Cork oak covers 46% of the total forest area of the region, Holm oak 30%, and Stone pine only 7%, according to the last forest inventory. These species were already dominant species in the region and in Portugal two millennia after the beginning of holocene (Bugalho et al. 2009, Proença 2009). Since the 15th century, the agro-silvopastoral systems is largely dominant and steady in the province of Alentejo, on flat terrain. The system has a low tree density (40 to 80 trees/ha), trees being exploited for cork or seeds to feed cattle and the understory cleared of shrubs for pasture, crops (mainly wheat, barley and oats), or both. Tree density is determined by the need for space for pasture or cereal cultivation in the understory (Acacio & Holmgreen 2014) and by climate drivers, especially mean annual precipitation (Joffre 1999, Gouveia & Freitas 2008). Agro-silvopastoral systems are considered semi-natural ecosystems, which must be continually maintained through human management by thinning and understory use through grazing, ploughing and shrub clearing (Huntsinger and Bartolome 1992) to maintain a good productivity, biodiversity and ecosystem services. Cork oak trees are protected and cannot be harvested unless the tree has died, while holm oak trees are maintained with a low tree density (20 to 40 trees/ha) to guard against soil erosion and to provide shelter and shadow for cattle. Holm oaks are known to be more resilient to drought (David et al. 2007) and are mostly distributed in the most xeric area, on the oriental part of the Alentejo region. Some of this information has been added to the discussion section in lines 498-505.

Bugalho M , Plieninger T, Aronson J , Ellatifi M, Gomes D Crespo 2009. Revista especializada Cork oak woodlands on the edge. Ecology, adaptive management, and restoration, 1st edn. Society for Ecological Restoration International, Island Press, WashingtonChapter 3. Open Woodlands: A Diversity of Uses Proença 2009, Galicio-

Portuguese oak forest of Quercus robur and Quercus pyrenaica: biodiversity patterns and forest response to fire. PhD Thesis, https://core.ac.uk/download/pdf/12421965.pdf Acácio V. & Holmgreen M. 2009 Pathways for resilience in Mediterranean cork oak land use systems. Annals of Forest Science 71:5-13. DOI: 10.1007/s13595-012- 0197-0 Joffre R, Rambal S, Ratte PJ. 1999 The dehesa system of southern Spain and Portugal as a natural ecosystem mimic. Agrofor Syst 45:57–79 Gouveia A. & Freitas H., 2008 Intraspecific competition and water use efficiency in Quercus suber: evidence of an optimum tree density? Trees, 22 (2008), pp. 521-530 Huntsinger L, Bartolome JW. 1992 Ecological dynamics of Quercus dominated woodlands in California and southern Spain: a state transition model. Veg 99–100:299–305 David T.S., Henriques M. O., Kurz-Besson C., Nunes J., Valente F., Vaz M., Pereira J. S., Siegwolf R., Chaves M.M., Gazarini L.C. and David J.S. Water use strategies in two co-occurring Mediterranean evergreen oaks: surviving the summer drought. Tree Physiology 27(6): 793-803 https://doi.org/10.1093/treephys/27.6.793

3. Line 170: Cite ASTER GDEM data in the manner requested on the NASA webpage (https://lpdaac.usgs.gov/citing_our_data).

Answer: Done. The missing citation was added in the proper place, in line 162-165. The acknowledgement is already properly done in the acknowledgement section.

4. Line 172: What is meant by superficial water use? Shallow groundwater? Surface water in streams? It's used several places but isn't well defined.

Answer: We substituted the expression superficial water/groundwater by shallow soil water, which refers to the water between 0 and 1.5m depth, in lines 166-167. All water below 1.5m depth was considered as groundwater. This was clarified in lines 301-302.

5. Line 179: What were the three classes? How did soil parameters influence in classification?

Answer: The three classes are presented in Table 4 and an additional explanation

to clarify the conditions who led to each scoring was added to lines 175-178. After revision of the suitability model the predictor soil type was no longer included in model fitting, and therefore no further explanation on its effect on the suitability to GDV was added.

6. Line 187-202, Figure 2: The location of piezometer data and well data are quite biased. What is this attributable to and how might it affect the results? It seems like the kriging in the south-central region could be quite problematic. Also, what is the distinction between a well and a piezometer here? This is also concerning because the most dense of the GDV species are roughly in this corridor as well.

Answer: The region under study is an area with a very low population density, which reflected in the lack of points for piezometric level measurement, mainly in unconfined aquifers ($\sim$96% of the total area). Once the correlation between the piezometric level and the topography was successfully tested it was possible to estimate the piezometric level by kriging with external drift in areas where information was not enough. In the studied area, the presence of piezometers (exclusively dedicated structures for piezometric observations) is mostly associated with karst aquifers and areas with high abstraction volumes for public water supply. Oppositely, large wells are mainly devoted to private use and low volume abstractions. To complement the information given on the groundwater level estimation the following sentence was added to the ms, in lines 190-193: "In the studied area, piezometers are exclusively dedicated structures for piezometric observations, in areas with high abstraction volumes for public water supply. Oppositely, large wells are mainly devoted to private use and low volume abstractions."

7. Line 199 -202: I disagree with this method - the groundwater elevations should be determined by first determining the groundwater elevation at the piezometers and then interpolating that through kriging. This should introduce fewer errors and be more realistic.

Answer: The relation between piezometric level and topography is quite high in most of the unconfined aquifers (Marcily, 1986). This relation allows to estimate the piezometry in areas with few piezometric points with enough confidence using external drift kriging. On the other hand, through this method the piezometric surface respects the orographic structures such as valleys, which is not the case with traditional interpolation methods.

"In the aquifer, the water flows toward the outlets, which are the low points in the topography (springs, streams in the surface flow network)." from Ghislain de Marsily, 1986. Quantitative Hydrogeology, Academic Press, Orlando. ISBN: 9780122089169, 9780080917634.

8. Line 303 - 312: The rationale for this validation method is a bit shaky and could use more explanation. If the presence/absence of these trees is a good indicator, why is the rest of the analysis necessary? Is it more expansive? Precise? Also, how is this not a bit autoregressive, given that it sounds like kernal density was derived from the tree data. It starts to make more sense as the results are discussed, but it needs more clarity here. What about using a remote sensing method for validation instead (e.g., Munch et al. 2007, Barron et al. 2012, Gou et. al 2014)? How would that compare?

Answer: After consulting the authors of the EPIC suitability maps (Magalhães M. and Mesquita S.) we understood that the latter were indeed constructed based on the last forest inventories. Therefore, there was indeed autoregression in our validation (see Mesquita, S. and Capelo, J. (2016). Aptidão Bioclimática às Espécies Arbóreas. In Magalhães, M.R. coord): Ordem Ecológica e Desenvolvimento - o futuro do território português. Pp. 63-85. Centro de Estudos de Arquitectura Paisagista "Professor Caldeira Cabral". ISA Press. Lisboa. ISBN: 978-972-8669-64-5).

We thus followed the reviewer suggestion to use remote sensing data to validate our GDV suitability map. We therefore compared our GDV suitability map with NDWI anomalies of June 2005 (extremely dry hydrological year in Portugal) with the median

June NDWI of year 1999-2009 with a dataset shared by Gouveia et al. (2012). We chose the Normalized Difference Water Index (NDWI) for being more representative of water content in vegetation's leaves. This index is thus a proxy for vegetation stress, with low NDWI values representing less leave water content, corresponding to a higher drought stress. The NDWI map we present show in yellow and brown color the areas were the vegetation was more sensitive to the extreme drought of 2005. We obtain a very good agreement between maps that we commented in the results and discussion sections, in lines 477-487, 598-601 and 620-623. The method and dataset used are described in the M&M section lines 341-360.

9. Line 389-397: What soil types were the most likely to host phreatophtyes? What does "soil type 3" represent?

Answer: Soil type 3 represented soils with prevailing water storage at deeper soil depths, and therefore these soils were considered as more likely to host phreatophytes.

10. Line 480-484: This paragraph seems to be saying that there must be some threshold by which no woody species can be supported, even if they are GDVs. These species get replaced by shortlived grasses and forbes, converting savanna to grassland. Is this correct? If so, this seems to contradict the next line about woody vegetation being replaced by shrublands. Wouldn't that presume shrubs are less susceptible to drought than trees? Please clarify.

Answer: The referenced paragraph was removed from the discussion, after the calculation of a new suitability map. Instead we discussed the strong relation between aridity and tree density and the degradation of ecosystems linked to increasing water scarcity, in lines 557-565 and 644-651.

11. Line 495-511: This part of the discussion is problematic, because, as the authors note, the factor expected to be most key is poorly mapped. Regardless, they still say that soil type, as opposed to groundwater depth, is the most influential and claim that soil type defines the capacity for "groundwater storage". This appears to be overreach.

Answer: The most influential factors in the reviewed version of the manuscript are climate drivers. After removing soil types from the final GWR model, the contribution of the GWDepth variable in the model improved (now corresponding to the 3rd most relevant variable in the model), but still remained far less relevant than climate drivers. The part of the discussion was slightly modified according to new results, lines 566-572.

12. Figure 7: This figure needs more color variation. It is difficult to tell moderate, good, and very good apart.

Answer: Done. The colour scale was modified to improve readability in Figure 09.

Technical Corrections 13. Line 88: Replace "genders" with genre

Answer: Done in line 85.

14. Line 102: Replace "5m" with "5 m". Noticed number/unit spacing issues in several other locations as well.

Answer: Done in line 99. All other places where the same issued was found, were corrected.

15. Lines 132 - 135: Replace "chapters" with "sections". But really, this whole paragraph isn't necessary, as the format doesn't deviate from standard expectations.

Answer: Done. The paragraph was eliminated from the manuscript.

16. Line 154: "Proxy for" not "proxy to".

Answer: Done in line 145.

17. Line 175: Is the copyright symbol here a typo?

Answer: No, the copyright symbol is requested to reference the database.

18. Line 201: Don't need to repeatedly cite Spatial Analyst and its version so frequently. Can this be converted to one mention at the beginning of the section?

Answer: Done. We added the sentence “The software used in spatial analysis were ArcGIS® software version 10.4.1 by Esri and R program software version 3.4.2 (R Development Core Team, 2016).” to the ms, under the chapter 2.3 in lines 158-159. All mentions to R and ArcGIS software versions were removed from the text.

19. Line 295: Put equation right after fist mention.

Answer: We have added a general equation of the model (Eq. 4) in lines 330-331 and maintained the equation with the final predictors (Eq. 6) in lines 40-405 so that only in the results section we would present the final model equation used to calculate the suitability map.

20. Line 306: Replace "to a" with "of a".

Answer: This paragraph has been deleted from the ms, after the validation was performed with a different dataset.

21. Line 434, Line 454: Delete first names of authors. Answer: The first reference has been removed from the paragraph. On lines 54, 295 and 517 however, the name “Condesso de Melo” was right, thus remained unchanged.

22. Line 450: Pinpoint is one word.

Answer: Done in line 512.

23. Lines 451-453: Awkward wording makes the sentence hard to parse.

Answer: The sentence was improved in lines 513-515.

24. Line 466: Delete stray "s".

Answer: This paragraph was completely re-structured.

Please also note the supplement to this comment:
https://www.hydrol-earth-syst-sci-discuss.net/hess-2018-208/hess-2018-208-AC1-

supplement.pdf

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2018-208, 2018.

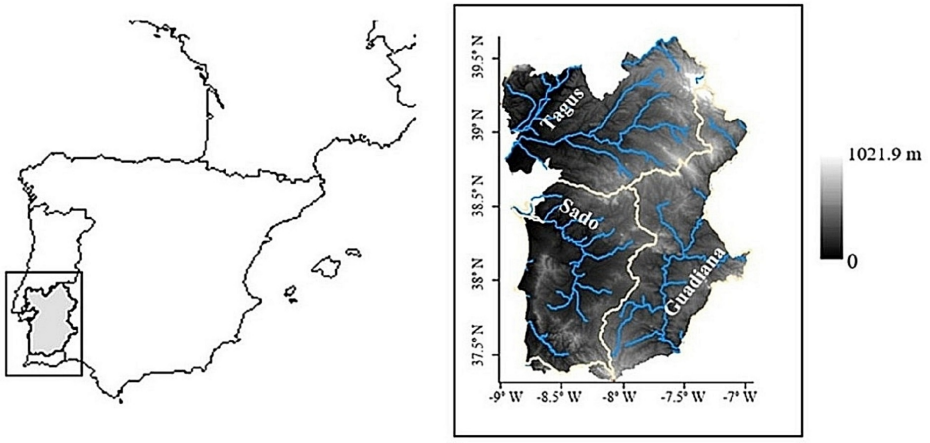

Fig. 1. Fig01

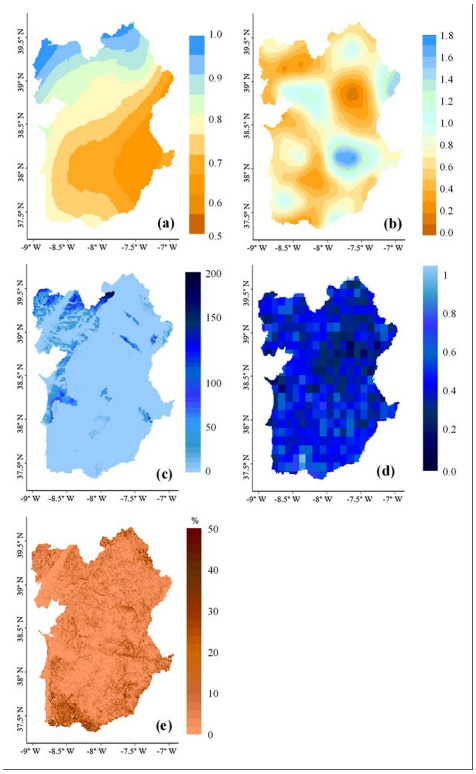

Fig. 2. Fig04

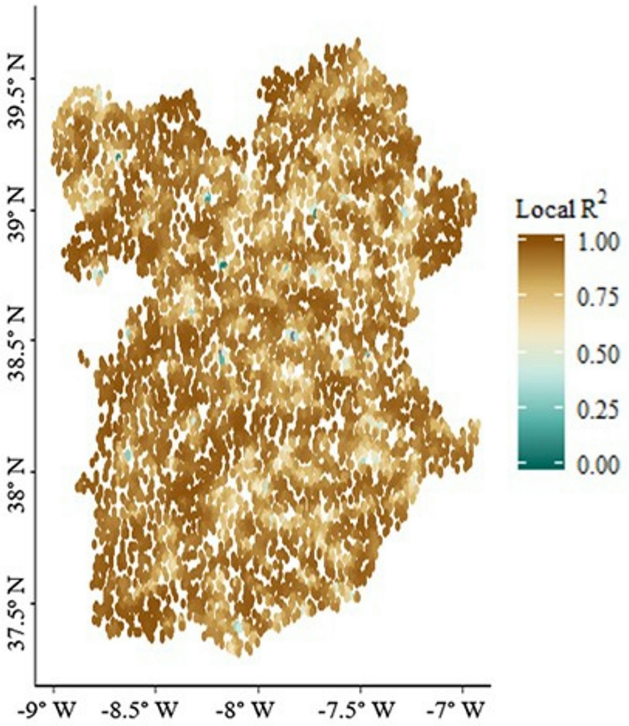

Fig. 3. Fig05

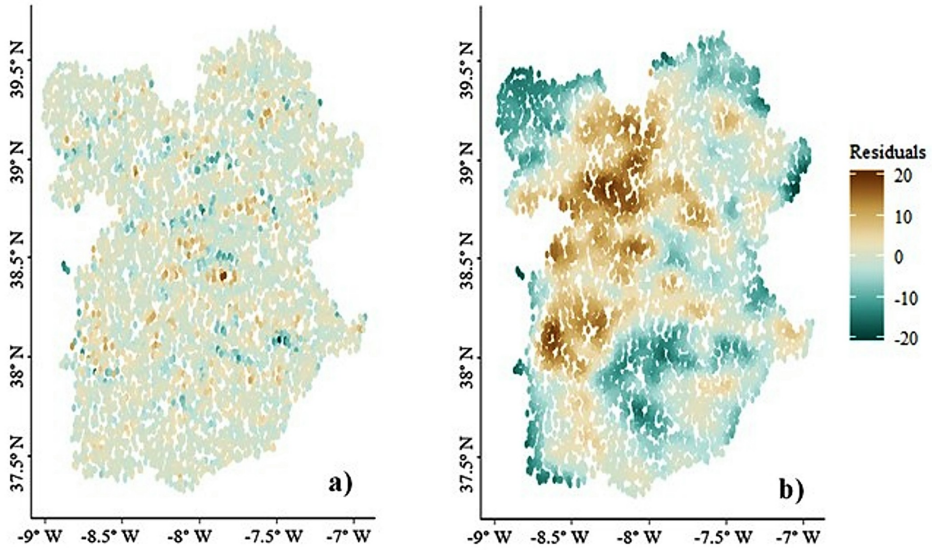

Fig. 4. Fig06

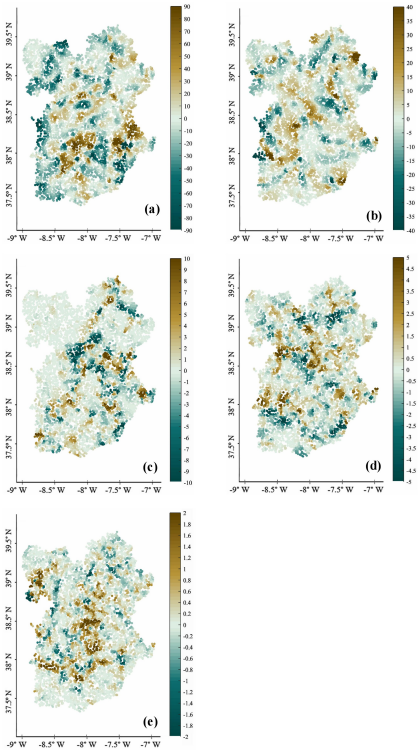

Fig. 5. Fig07

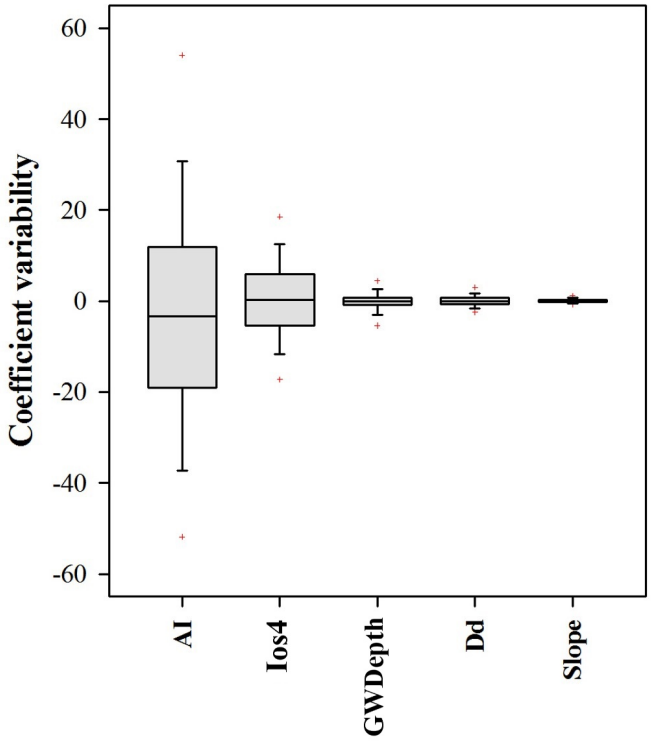

Fig. 6. Fig08

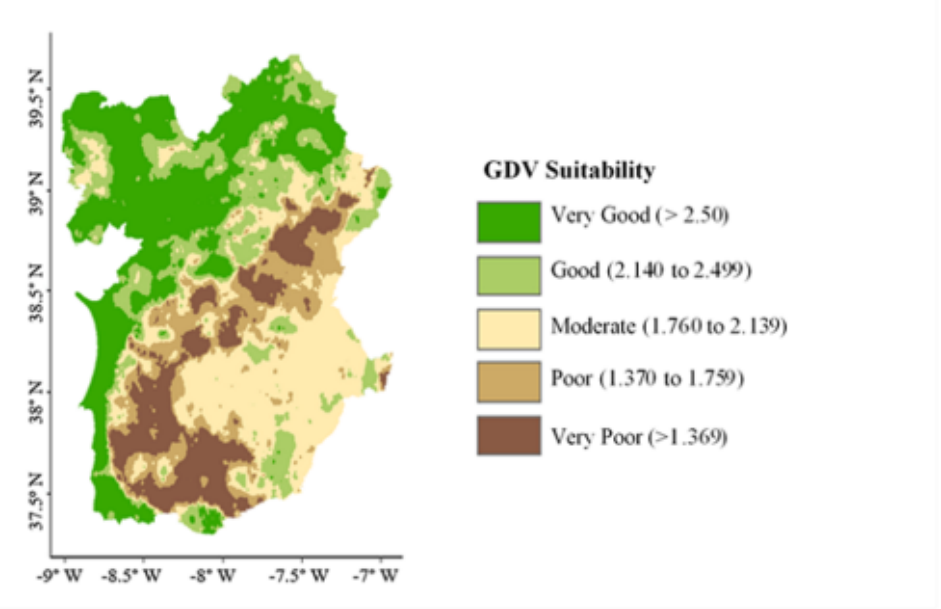

Fig. 7. Fig09

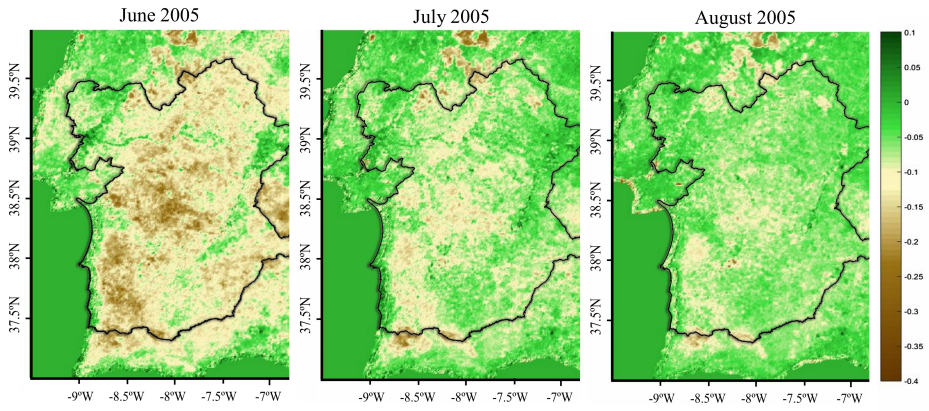

Fig. 8. Fig10

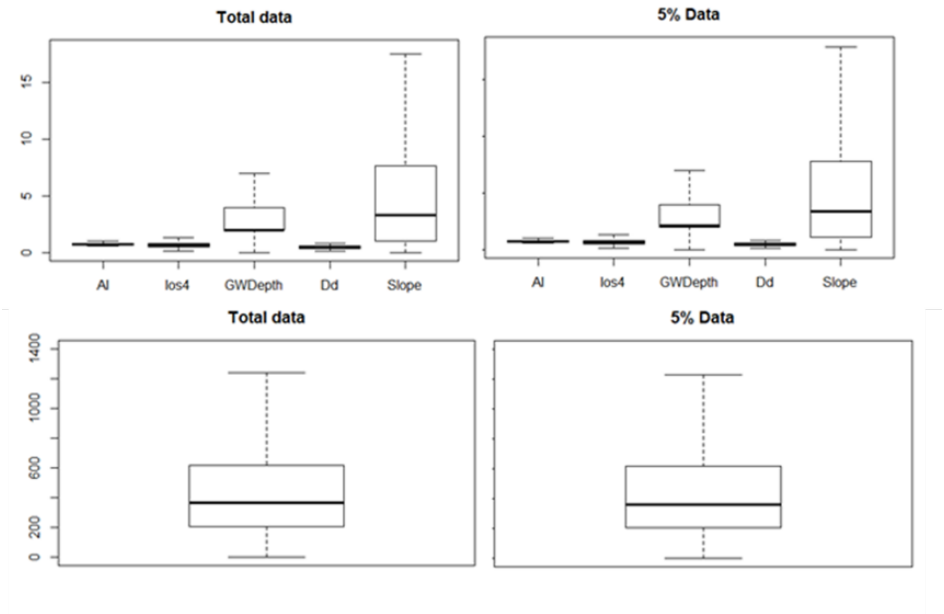

Fig. 9. FigA1

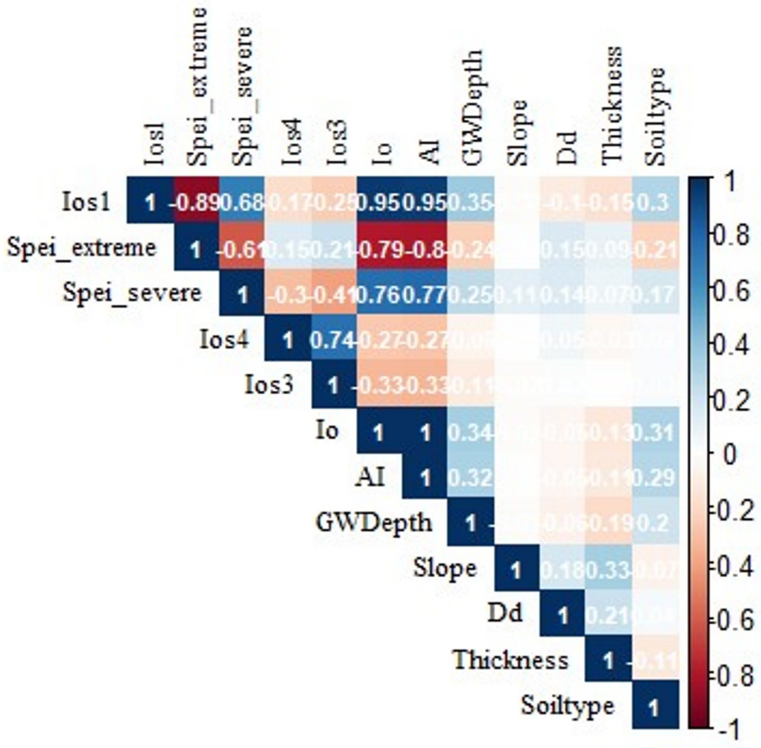

Fig. 10. FigA2

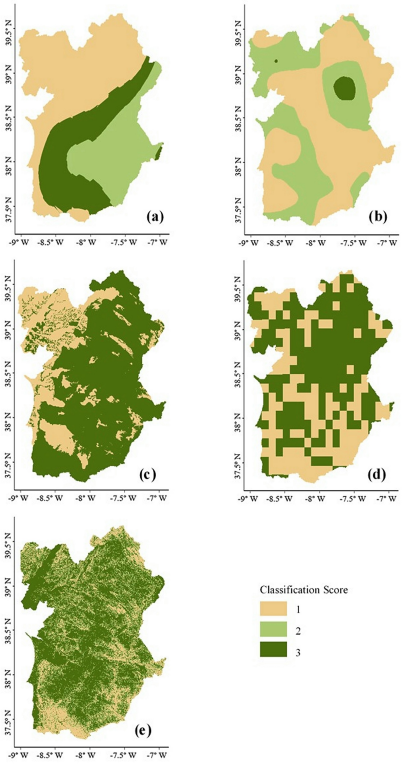

Fig. 11. FigB1