Supplementary Material

**Artificial intelligence unveils key interactions between soil properties and climate factors on *Boletus edulis* and *B. reticulatus* mycelium in chestnut orchards of different ages**

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**Figure S1.** Climograph displaying mean monthly precipitation (mm) and temperature (ºC) data throughout (**A**) 2018, (**B**) 2020, and (**C**) during the period 1985-2010 (historic) obtained from the AEMET meteorological station closest to the study sites.

# **Table S1.** Full dataset for modelling including as 47 inputs (factors): year. month. plot. and those disaggregated into 20 soil properties and 24 climatic factors plus 4 outputs: concentration (C) and frequency (F) of *B. edulis* (Be) and *B. reticulatus* (Br).

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | 2018 | | | | | | | | | 2020 | | | | | | | | |
| **Month** | Sep | Oct | Nov | Sep | Oct | Nov | Sep | Oct | Nov | Sep | Oct | Nov | Sep | Oct | Nov | Sep | Oct | Nov |
| **Plot** | 40-year-old orchard | | | 10-year-old orchard | | | 3-year-old orchard | | | 40-year-old orchard | | | 10-year-old orchard | | | 3-year-old orchard | | |
| Sand (% | 67.70 | 67.70 | 67.70 | 54.93 | 54.93 | 54.93 | 65.70 | 65.70 | 65.70 | 67.70 | 67.70 | 67.70 | 56.95 | 56.95 | 56.95 | 65.70 | 65.70 | 65.70 |
| Silt (%) | 18.00 | 18.00 | 18.00 | 24.19 | 24.19 | 24.19 | 19.13 | 19.13 | 19.13 | 18.00 | 18.00 | 18.00 | 23.11 | 23.11 | 23.11 | 19.13 | 19.13 | 19.13 |
| Clay (%) | 14.30 | 14.30 | 14.30 | 20.87 | 20.87 | 20.87 | 15.18 | 15.18 | 15.18 | 14.30 | 14.30 | 14.30 | 19.95 | 19.95 | 19.95 | 15.18 | 15.18 | 15.18 |
| MWD (mm) | 0.91 | 0.91 | 0.91 | 1.75 | 1.75 | 1.75 | 1.23 | 1.23 | 1.23 | 1.01 | 1.01 | 1.01 | 1.49 | 1.49 | 1.49 | 1.33 | 1.33 | 1.33 |
| Macroag (%) | 63.80 | 63.80 | 63.80 | 80.19 | 80.19 | 80.19 | 79.23 | 79.23 | 79.23 | 68.62 | 68.62 | 68.62 | 79.60 | 79.60 | 79.60 | 81.01 | 81.01 | 81.01 |
| BD (Kg/ m3) | 961.50 | 961.50 | 961.50 | 1014.87 | 1014.87 | 1014.87 | 1194.28 | 1194.28 | 1194.28 | 894.00 | 894.00 | 894.00 | 922.00 | 922.00 | 922.00 | 1075.60 | 1075.60 | 1075.60 |
| Pt (%) | 62.39 | 62.39 | 62.39 | 60.09 | 60.09 | 60.09 | 53.53 | 53.53 | 53.53 | 64.06 | 64.06 | 64.06 | 62.88 | 62.88 | 62.88 | 57.96 | 57.96 | 57.96 |
| FC %H (v/v) | 20.23 | 20.23 | 20.23 | 34.13 | 34.13 | 34.13 | 25.95 | 25.95 | 25.95 | 24.98 | 24.98 | 24.98 | 29.53 | 29.53 | 29.53 | 24.15 | 24.15 | 24.15 |
| pH | 4.81 | 4.81 | 4.81 | 4.68 | 4.68 | 4.68 | 4.92 | 4.92 | 4.92 | 4.79 | 4.79 | 4.79 | 4.99 | 4.99 | 4.99 | 5.01 | 5.01 | 5.01 |
| C %) | 3.77 | 3.77 | 3.77 | 4.43 | 4.43 | 4.43 | 3.20 | 3.20 | 3.20 | 6.88 | 6.88 | 6.88 | 6.62 | 6.62 | 6.62 | 3.69 | 3.69 | 3.69 |
| N %) | 0.24 | 0.24 | 0.24 | 0.34 | 0.34 | 0.34 | 0.24 | 0.24 | 0.24 | 0.47 | 0.47 | 0.47 | 0.52 | 0.52 | 0.52 | 0.29 | 0.29 | 0.29 |
| C/N | 17.00 | 17.00 | 17.00 | 13.18 | 13.18 | 13.18 | 13.36 | 13.36 | 13.36 | 15.17 | 15.17 | 15.17 | 12.81 | 12.81 | 12.81 | 12.95 | 12.95 | 12.95 |
| P (mg/Kg) | 4.61 | 4.61 | 4.61 | 9.20 | 9.20 | 9.20 | 9.83 | 9.83 | 9.83 | 14.49 | 14.49 | 14.49 | 6.68 | 6.68 | 6.68 | 11.32 | 11.32 | 11.32 |
| Ca2+ cmol/kg | 0.32 | 0.32 | 0.32 | 0.46 | 0.46 | 0.46 | 1.20 | 1.20 | 1.20 | 0.71 | 0.71 | 0.71 | 1.38 | 1.38 | 1.38 | 2.28 | 2.28 | 2.28 |
| Mg2+ cmol/kg | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.46 | 0.46 | 0.46 | 0.30 | 0.30 | 0.30 | 0.48 | 0.48 | 0.48 | 0.67 | 0.67 | 0.67 |
| K+cmol/kg | 0.17 | 0.17 | 0.17 | 0.21 | 0.21 | 0.21 | 0.20 | 0.20 | 0.20 | 0.19 | 0.19 | 0.19 | 0.37 | 0.37 | 0.37 | 0.53 | 0.53 | 0.53 |
| Na+ cmol/kg | 0.09 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 | 0.13 | 0.13 | 0.13 | 0.12 | 0.12 | 0.12 | 0.22 | 0.22 | 0.22 | 0.23 | 0.23 | 0.23 |
| Al3+ cmol/kg | 2.09 | 2.09 | 2.09 | 2.51 | 2.51 | 2.51 | 1.48 | 1.48 | 1.48 | 2.07 | 2.07 | 2.07 | 1.98 | 1.98 | 1.98 | 1.17 | 1.17 | 1.17 |
| CEC cml/Kg | 2.81 | 2.81 | 2.81 | 3.39 | 3.39 | 3.39 | 3.46 | 3.46 | 3.46 | 3.40 | 3.40 | 3.40 | 4.42 | 4.42 | 4.42 | 4.87 | 4.87 | 4.87 |
| V % | 24.21 | 24.21 | 24.21 | 25.40 | 25.40 | 25.40 | 54.87 | 54.87 | 54.87 | 38.47 | 38.47 | 38.47 | 54.12 | 54.12 | 54.12 | 73.34 | 73.34 | 73.34 |
| Tm | 21.10 | 16.20 | 12.20 | 21.10 | 16.20 | 12.20 | 21.10 | 16.20 | 12.20 | 19.80 | 14.60 | 13.70 | 19.80 | 14.60 | 13.70 | 19.80 | 14.60 | 13.70 |
| Tm-1 | 22.70 | 21.10 | 16.20 | 22.70 | 21.10 | 16.20 | 22.70 | 21.10 | 16.20 | 20.10 | 19.80 | 14.60 | 20.10 | 19.80 | 14.60 | 20.10 | 19.80 | 14.60 |
| Tm-1-2 | 21.40 | 21.90 | 18.70 | 21.40 | 21.90 | 18.70 | 21.40 | 21.90 | 18.70 | 21.40 | 20.00 | 17.20 | 21.40 | 20.00 | 17.20 | 21.40 | 20.00 | 17.20 |
| Tmax | 26.70 | 21.60 | 15.20 | 26.70 | 21.60 | 15.20 | 26.70 | 21.60 | 15.20 | 25.20 | 18.30 | 17.50 | 25.20 | 18.30 | 17.50 | 25.20 | 18.30 | 17.50 |
| Tmax-1 | 29.20 | 26.70 | 21.60 | 29.20 | 26.70 | 21.60 | 29.20 | 26.70 | 21.60 | 24.90 | 25.20 | 18.30 | 24.90 | 25.20 | 18.30 | 24.90 | 25.20 | 18.30 |
| Tmax-1-2 | 26.70 | 28.00 | 24.20 | 26.70 | 28.00 | 24.20 | 26.70 | 28.00 | 24.20 | 27.10 | 25.10 | 21.80 | 27.10 | 25.10 | 21.80 | 27.10 | 25.10 | 21.80 |
| Tmin | 15.30 | 11.10 | 9.20 | 15.30 | 11.10 | 9.20 | 15.30 | 11.10 | 9.20 | 14.20 | 10.90 | 9.80 | 14.20 | 10.90 | 9.80 | 14.20 | 10.90 | 9.80 |
| Tmin-1 | 16.10 | 15.30 | 11.10 | 16.10 | 15.30 | 11.10 | 16.10 | 15.30 | 11.10 | 15.30 | 14.20 | 10.90 | 15.30 | 14.20 | 10.90 | 15.30 | 14.20 | 10.90 |
| Tmin-1-2 | 16.00 | 15.70 | 13.20 | 16.00 | 15.70 | 13.20 | 16.00 | 15.70 | 13.20 | 15.70 | 14.80 | 12.60 | 15.70 | 14.80 | 12.60 | 15.70 | 14.80 | 12.60 |
| P | 6.90 | 141.80 | 310.50 | 6.90 | 141.80 | 310.50 | 6.90 | 141.80 | 310.50 | 57.80 | 190.40 | 106.00 | 57.80 | 190.40 | 106.00 | 57.80 | 190.40 | 106.00 |
| P-1 | 9.70 | 6.90 | 141.80 | 9.70 | 6.90 | 141.80 | 9.70 | 6.90 | 141.80 | 92.10 | 57.80 | 190.40 | 92.10 | 57.80 | 190.40 | 92.10 | 57.80 | 190.40 |
| P-1-2 | 44.50 | 16.60 | 148.70 | 44.50 | 16.60 | 148.70 | 44.50 | 16.60 | 148.70 | 92.10 | 149.90 | 248.20 | 92.10 | 149.90 | 248.20 | 92.10 | 149.90 | 248.20 |
| H | 69.00 | 67.00 | 85.00 | 69.00 | 67.00 | 85.00 | 69.00 | 67.00 | 85.00 | 68.00 | 83.00 | 79.00 | 68.00 | 83.00 | 79.00 | 68.00 | 83.00 | 79.00 |
| H-1 | 63.00 | 69.00 | 67.00 | 63.00 | 69.00 | 67.00 | 63.00 | 69.00 | 67.00 | 73.00 | 68.00 | 83.00 | 73.00 | 68.00 | 83.00 | 73.00 | 68.00 | 83.00 |
| H-1-2 | 70.00 | 66.00 | 68.00 | 70.00 | 66.00 | 68.00 | 70.00 | 66.00 | 68.00 | 66.50 | 70.50 | 75.50 | 66.50 | 70.50 | 75.50 | 66.50 | 70.50 | 75.50 |
| P-PET | -92.40 | 81.00 | 276.40 | -92.40 | 81.00 | 276.40 | -92.40 | 81.00 | 276.40 | -31.10 | 139.90 | 66.60 | -31.10 | 139.90 | 66.60 | -31.10 | 139.90 | 66.60 |
| P-PET-1 | -117.30 | -92.40 | 81.00 | -117.30 | -92.40 | 81.00 | -117.30 | -92.40 | 81.00 | -12.10 | -31.10 | 139.90 | -12.10 | -31.10 | 139.90 | -12.10 | -31.10 | 139.90 |
| P-PET-1-2 | -196.10 | -209.70 | -11.40 | -196.10 | -209.70 | -11.40 | -196.10 | -209.70 | -11.40 | -147.60 | -43.20 | 108.80 | -147.60 | -43.20 | 108.80 | -147.60 | -43.20 | 108.80 |
| WD | 92.40 | 0.00 | 0.00 | 92.40 | 0.00 | 0.00 | 92.40 | 0.00 | 0.00 | 31.10 | 0.00 | 0.00 | 31.10 | 0.00 | 0.00 | 31.10 | 0.00 | 0.00 |
| WD -1 | 117.30 | 92.40 | 0.00 | 117.30 | 92.40 | 0.00 | 117.30 | 92.40 | 0.00 | 12.10 | 31.10 | 0.00 | 12.10 | 31.10 | 0.00 | 12.10 | 31.10 | 0.00 |
| WD-1-2 | 122.00 | 209.70 | 92.40 | 122.00 | 209.70 | 92.40 | 122.00 | 209.70 | 92.40 | 147.50 | 43.20 | 31.10 | 147.50 | 43.20 | 31.10 | 147.50 | 43.20 | 31.10 |
| WE | 0.00 | 0.00 | 257.40 | 0.00 | 0.00 | 257.40 | 0.00 | 0.00 | 257.40 | 0.00 | 39.90 | 66.60 | 0.00 | 39.90 | 66.60 | 0.00 | 39.90 | 66.60 |
| WE-1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.90 | 0.00 | 0.00 | 39.90 | 0.00 | 0.00 | 39.90 |
| WE-1-2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 39.90 | 0.00 | 0.00 | 39.90 | 0.00 | 0.00 | 39.90 |
| Conc. Be (mg/g) | 7.33E-10 | 1.28E-07 | 2.60E-11 | 2.17E-09 | 0.00E+00 | 5.30E-08 | 1.32E-09 | 0.00E+00 | 6.02E-08 | 5.44E-07 | 2.32E-06 | 7.32E-06 | 2.34E-06 | 1.44E-06 | 3.83E-06 | 4.56E-07 | 1.69E-06 | 2.25E-06 |
| Conc. Br (mg/g) | 2.73E-08 | 2.01E-09 | 8.25E-09 | 0.00E+00 | 5.58E-04 | 1.12E-05 | 1.67E-10 | 3.93E-10 | 0.00E+00 | 2.58E-09 | 7.41E-09 | 3.93E-09 | 2.32E-11 | 2.07E-11 | 4.07E-06 | 0.00E+00 | 9.81E-08 | 7.85E-11 |
| Freq. Be | 0.17 | 0.17 | 0.17 | 0.17 | 0.00 | 0.17 | 0.17 | 0.00 | 0.33 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Freq. Br | 0.67 | 0.83 | 1.00 | 0.00 | 0.33 | 0.50 | 0.50 | 0.17 | 0.00 | 0.67 | 0.83 | 0.67 | 0.33 | 0.33 | 0.67 | 0.00 | 0.33 | 0.50 |

**Soil properties:**

MWD: Mean weight diameter; Macroag: Macroaggregates; Microag: Microaggregates; BD: Bulk density; Pt: Total porosity; FC: Field capacity; pH: pH in H20; C: Total carbon; N: Total nitrogen; C/N ratio; P: Available phosphorus; Ca2+. Mg2+. K+. Na+. Al3+ exchange cations; CEC: Cation exchange capacity; V: Base Saturation.

**Climate factors:**

Tm: mean monthly temperature; Tmax: mean monthly maximum temperature; Tmin: mean monthly minimum temperature. H: mean air relative humidity; P: monthly precipitation (P); PET: monthly potential evapotranspiration; P-PET: monthly difference between precipitation and potential evapotranspiration; WD: monthly water deficit; WE: monthly water excess.

For all temperatures and humidity parameters the mean of the sampling month (Tm and Hm). mean of previous month (Tm-1 and Hm-1) and mean or two previous month (Tm-1-2 and Hm-1-2) were calculated. For precipitation and water balance parameters the value of the sampling month (P and W). value of previous month (P-1 and W-1) and accumulated value of two previous month (P-1-2 and W-1-2) were calculated.

**Table S2.** Train parameters setting for neurofuzzy logic models I and II.CBe = *B.edulis* concentration, FBe = *B.edulis* frequency, CBr = *B.reticulatus* concentration, FBr = *B.reticulatus* frequency.

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| --- | --- | --- | --- |
|  | Model I | Model II | |
| Minimization parameters (ASMOD): | Ridge Regression Factor: 1e-6 | | |
| Model Selection Criteria: | Structural Risk Minimization (SRM) | | |
| C1CBe: | 0.780 | 0.836 | |
| C1FBe: | 0.836 | | 0.900 |
| C1CBr: | 0.650 | 0.836 | |
| C1 FBr: | 0.600 | 0.760 | |
| C2: | 4.8 | | |
| Number of Set Densities: | 2 | | |
| Set Densities: | 2,3 | | |
| Adapt Nodes: | TRUE | | |
| Max. Inputs Per SubModel: | 4 | | |
| Max. Nodes Per Input: | 15 | | |

Table S3. Physical and chemical soil properties (mean ± SD). A40, A10 and A3 refer to 40, 10 and 3-years-old chestnut orchards sampled in 2018 and B40, B10 and B3 refer to the same chestnut orchards, sampled in 2020. Within rows, means and standard deviation followed by the same letter are not significantly different by ANOVA (α = 0.05) and Tukey´s Studentized Range (HSD) test.

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| --- | --- | --- | --- | --- | --- | --- |
| **Physical properties** | **A40** | **A10** | **A3** | **B40** | **B10** | **B3** |
| **Sand** (2-0.05 mm, %) | 67.70±8.13a | 54.93±2.95a | 65.70±5.70a | 67.70±8.13a | 54.93±2.95a | 65.70±5.70a |
| **Silt** (0.05-0.002 mm, %) | 18.00±4.77a | 24.19±2.08a | 19.13±3.34a | 18.00±4.77a | 24.19±2.08a | 19.13±3.34a |
| **Clay** (< 0.002 mm, %) | 14.30±3.37a | 20.87±1.21a | 15.18±2.52a | 14.30±3.37a | 20.87±1.21a | 15.18±2.52a |
| **Soil Texture** | sandy-loam | sandy-loam | sandy-loam | sandy-loam | sandy-loam | sandy-loam |
| **MWD** (mm) | 0.91±0.16d | 1.75±0.24a | 1.23±0.09bc | 1.01±0.11cd | 1.51±0.06ab | 1.33±0.22b |
| **Macroag** (%) | 63.80±4.35b | 80.19±4.16a | 79.23±2.69a | 68.62±2.21b | 80.44±2.29a | 81.01±4.95a |
| **Microag** (%) | 36.20±4.35b | 19.81±4.16a | 20.77±2.69a | 31.38±2.21b | 19.56±2.29a | 18.99±4.95a |
| **BD** (kg m-3) | 962±129ab | 1015±147ab | 1194±167a | 894±228b | 950±101ab | 1076±100ab |
| **Pt** (%) | 62.39±5.02ab | 60.09±5.22ab | 53.53±6.47b | 64.06±8.56a | 61.80±4.07ab | 57.96±3.74ab |
| **FC** (% w/w) | 20.23±1.02c | 34.13±6.82a | 25.95±4.45bc | 24.98±3.85bc | 30.64±2.79ab | 24.15±1.88bc |
| **Chemical properties** |  |  |  |  |  |  |
| **pH** | 4.81±0.10a | 4.68±0.11a | 4.92±0.17a | 4.79±0.17a | 5.01±0.07a | 5.01±0.24a |
| **C (**%) | 3.77±0.87b | 4.43±1.98ab | 3.20±0.41b | 6.88±2.06a | 6.50±0.24a | 3.69±0.72b |
| **N** (%) | 0.24±0.10b | 0.34±0.15ab | 0.24±0.03b | 0.47±0.18a | 0.51±0.02a | 0.29±0.07ab |
| **C/N** | 17±3.2a | 13±0.4b | 13±0.7b | 15±1.6b | 13±0.1b | 13±1.0b |
| **P** (mg kg-1) | 4.61±3.07a | 9.20±1.30a | 9.83±7.66a | 14.49±8.73a | 6.62±0.10a | 11.32±7.47a |
| **Ca2+** (cmol(+) kg-1) | 0.32±0.27b | 0.46±0.20ab | 1.20±1.05ab | 0.71±0.36b | 1.52±0.43ab | 2.28±1.32a |
| **Mg2+** (cmol(+) kg-1) | 0.13±0.11c | 0.13±0.08bc | 0.46±0.26ab | 0.30±0.12bc | 0.54±0.16abc | 0.67±0.19a |
| **K+** (cmol(+) kg-1) | 0.17±0.09b | 0.21±0.08b | 0.20±0.03b | 0.19±0.06b | 0.41±0.09ab | 0.53±0.23a |
| **Na+** (cmol(+) kg-1) | 0.09±0.02b | 0.08±0.02b | 0.13±0.03ab | 0.12±0.13ab | 0.22±0.02ab | 0.23±0.05a |
| **Al3+** (cmol(+) kg-1) | 2.09±0.28a | 2.51±0.51a | 1.48±0.49ab | 2.07±0.60a | 1.92±0.28ab | 1.17±0.56b |
| **CEC** (cmol(+) kg-1) | 2.81±0.50b | 3.39±0.80ab | 3.46±0.83ab | 3.40±0.90ab | 4.60±0.39ab | 4.87±1.18a |
| **V** (%) | 24.21±11.93c | 25.40±6.33bc | 54.87±16.04ab | 38.47±10.34bc | 57.69±9.62ab | 73.34±15.76a |

MWD: Mean weight diameter; Macroag: Macroaggregates; Microag: Microaggregates; BD: Bulk density; Pt: Total porosity; FC: Field capacity; CEC: Cation exchange capacity; V: Base Saturation.

Table S4. Monthly climate elements. Tm: mean temperature; Tmax: mean maximum temperature; Tmin: mean minimum temperature; H: mean air relative humidity; P: precipitation; PET: potential evapotranspiration; P-PET: difference between P and PET; WD: water deficit; WE: water excess. Key data are bolded.

Interfaz de usuario gráfica, Aplicación, Tabla

Descripción generada automáticamente