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Management effects in rice field margins: a QBS-ar approach

Abstract. *I margini delle risaie, se gestiti correttamente, possono agire come rifugi e corridoi ecologici, mitigando gli impatti della gestione. Lo studio ha analizzato l'indice QBS-ar in margini di risaia convenzionale e biologica nel Piemonte orientale, confrontandoli con aree naturali. I risultati hanno mostrato che le aree naturali presentano valori QBS-ar significativamente più alti, indicando una maggiore qualità del suolo. Non sono state rilevate differenze statisticamente significative tra le gestioni convenzionali e biologiche, suggerendo che le loro comunità ipogee sono più simili di quanto ipotizzato, probabilmente a causa della gestione non uniforme dei margini. Ulteriori ricerche con campionamenti più frequenti sono necessarie per cogliere la dinamica stagionale dell'ecosistema.*

Rice cultivation techniques, particularly the use of pesticides and chemical fertilizers, have been shown to have severe negative impacts on soil biodiversity, especially on invertebrates, which has been widely demonstrated at a European level (Dermiyati & Niswati, 2014; Tsiafouli *et al.,* 2015). Moreover, the diverse management practices applied in the paddies and their margins, such as water control, seedbed preparation and the grass removal profoundly alter the vertebrate and invertebrate communities (Toffoli & Rughetti, 2017; Giuliano *et al.*, 2018). Rice fields are now primarily composed of three habitat structures: flooded paddies, irrigation canals, and paddy banks. In this context, agricultural margins -the transition areas between the cultivated field and the surrounding environment-play a fundamental role. If correctly managed, they act as refugia for invertebrate populations and other species, providing stable habitats not subjected to the disturbances of agricultural practices (Cardarelli & Bogliani, 2014). They also function as ecological corridors that facilitate the dispersal and movement of species, which is essential for maintaining the connectivity and health of the entire agricultural ecosystem (Vickery *et al.*, 2009). The strategic management of these margins can therefore significantly mitigate the negative impacts of intensive practices, increasing the resilience and functional biodiversity of rice paddies.

Soil invertebrate communities include a wide range of species: from Arachnida and Myriapoda to Collembola and insects. They play a crucial role in the functioning of the ecosystem and in providing essential ecosystem services, including the decomposition of organic matter, nutrient cycling, and soil formation. The Arthropod-based Biological Soil Quality Index (QBS-ar) is a tool used to assess the biological quality of soil by analyzing the community of microarthropod community present in the top centimetres of soil. The index is based on the morphological specialisation of these organisms for hypogean life, known as the Morpho-Ecological Index (EMI). This method is particularly useful because it does not require specialized taxonomic identification, making it a simple and widely applicable tool that provides rapid and synthetic information on soil quality (Menta *et al.*, 2018). Moreover, based on the overall QBS-ar value, soil can be classified into different classes, each characterized by increasing environmental quality (Parisi *et al.*, 2005).

The aims of this work are: 1) to verify if QBS-ar index is a sensitive tool to analyse the different management regimes on rice paddies; 2) to understand if hypogean communities are sensitive to the different rice agricultural managements; 3) to understand if the rice paddy banks are subject to the same cultivation management impacts as the rice paddies.

The project focused on three areas in eastern Piedmont (Italy): Crescentino, Rovasenda, and Casalbeltrame in Vercelli province. In each area, we selected two farms with different crop management: conventional and organic, and a natural freshwater area. In each farm, we sampled the soil on two banks from three rice paddy chambers. A total of 56 points were sampled in two different periods: September 2024 and May 2025. Once the soil cores were collected, arthropods were isolated from each sample with the Berlese-Tüllgren extractor for 15 days. Then, Generalized Linear Mixed Models were used to detect statistical differences between farm management techniques considering QBS-ar, taxonomic richness and Shannon index. Finally, NMDS was applied to analyse beta diversity distances between different microarthropod communities.

A total of 16155 soil arthropods were extracted, belonging to 52 distinct taxonomic units. The most abundant class was Arachnida (N = 6135; Fig. 1) followed by Insecta (N = 5936) and Collembola (N = 3252).

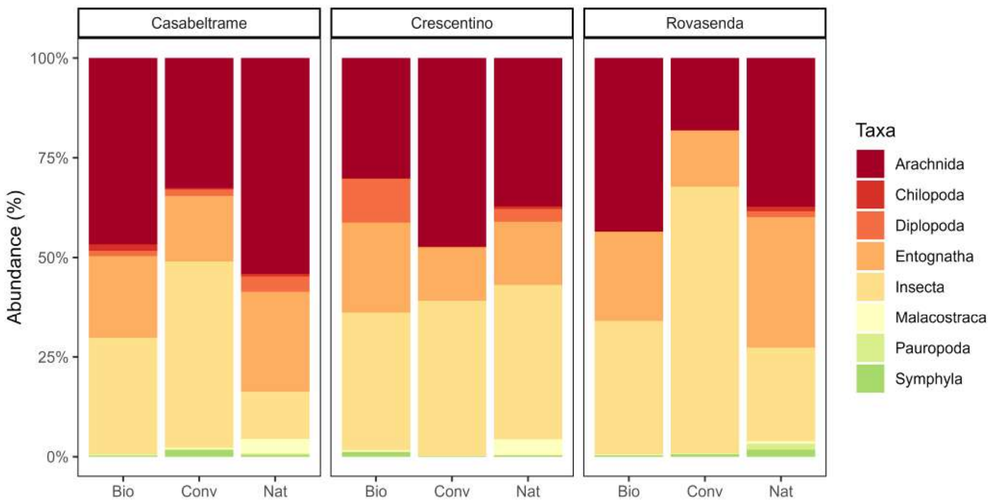

Figure 1 - Abundances of soil arthropod classes for each area and treatment (Conv: conventional crop management; Org: organic crop management; Nat: natural freshwater area)

The mean QBS-ar value was generally higher in natural controls compared to the conventional treatment (EMMs, p-value = 0.01, Fig. 2). This trend was particularly marked in the Crescentino areas, where the mean value for the conventional treatment was lower than both the organic and the natural areas (EMMs not significant). Furthermore, the Rovasenda natural area showed significantly higher values compared to its corresponding organic (EMMs, p-value = 0.0003) and conventional (EMMs, p-value = 0.01) rice paddies. Finally, based on mean QBS-ar values, organic and conventional farming management systems fall into a similar class of 5, while natural areas have a higher quality class of 6-7.

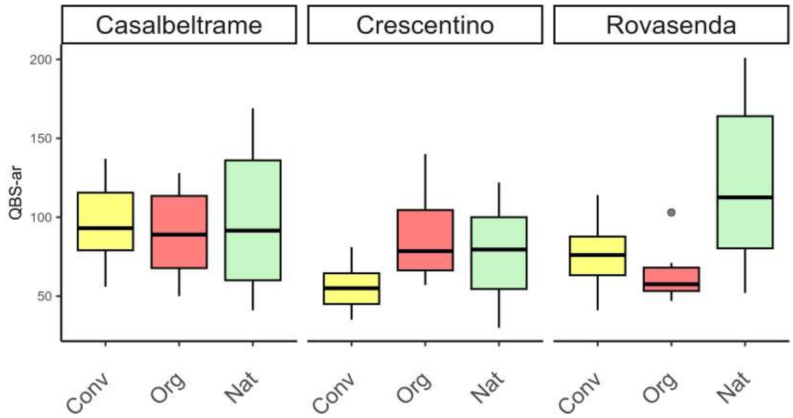

Figure 2 - Boxplots of QBS-ar index for each treatment and area (Conv: conventional crop management; Org: organic crop management; Nat: natural freshwater area)

Taxonomic richness calculated for the different treatments was similar across the various management regimes and natural areas (GLMMs, p-value = 0.1545). An interesting result emerged again from the Crescentino area, where the taxonomic richness of organic treatment was significantly higher than the conventional treatment (EMMs, p-value = 0.03). Shannon index showed no statistically significant differences between the two management and the natural areas. On the contrary, higher mean Shannon values were observed for the Casalbeltrame conventional farm compared to the organic and natural control sites.

In general, the communities in the natural controls from all three areas, with a few exceptions, were more distinct from the organic and conventional crop management (Fig. 3). The latter two generally clustered in the lower part of the NMDS plot, with significant overlap and more similarity, while the natural areas tended to occupy the upper part. The communities from the different treatments were significantly different both overall (PERMANOVA, p-value = 0.046) and within the different areas (PERMANOVA, p-value = 0.012). More specifically, the communities sampled from the organic and conventional management regimes seem to be similar (PERMANOVA, p-value = 0.443), while the community in natural area was more distinct from the others (PERMANOVA, p-value = 0.031 and 0.030) and within the sampled areas (PERMANOVA, p-value = 0.012 and 0.009).

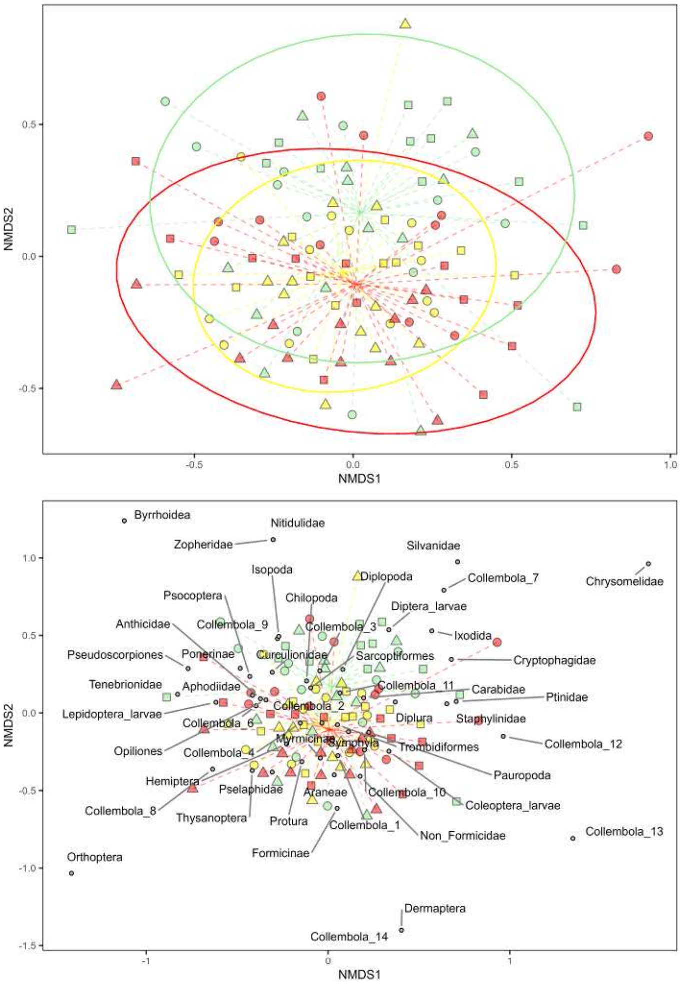

Figure 3 - Non-metric Multidimensional Scaling (NMDS) with Bray-Curtis distances between soil communities; conventional sampling points are in red, organic sampling points in yellow and natural control points in green; triangles represent Rovasenda sampling points, circles represent Casalbeltrame sampling points and squares Crescentino sampling points. In the plot below, taxonomic groups are shown

Soil arthropods are sensitive to agricultural management, being extremely important for the right functionality of soil ecosystems and thus fundamental bioindicators (Menta & Remelli, 2020). Nevertheless, QBS-ar showed no statistically significant differences in the values within conventional and organic, in contrast to other studies in the same region (D'Antoni *et al.*, 2020). However, similarly to this study, QBS values are little greater in organic management (Min = 47, Max = 140) compared to the conventional one (Min = 35, Max = 137). In addition, our study included natural areas that showed significant higher values compared to both management regimes (Min = 30, Max = 201). Thus, in this case, hypogean communities are more similar between different rice paddies management than expected, both in terms of community composition and morphological adaptation. At the same time, it must be noticed that greater distances between communities of rice paddies and natural areas were recorded.

Intensive management in rice field margins produces a severe impact on invertebrates (Cardarelli & Bogliani, 2014). However, in our case, margins management practices across rice fields are not always consistent. This can lead to profound changes, even in the same area and treatment, in invertebrate communities that do not match our hypotheses. Furthermore, our sampling was conducted exclusively during two specific windows of the rice cultivation cycle: spring and late summer. This approach may not have fully captured the dynamic seasonal variations that characterize the rice paddy ecosystem. Given that the rice paddy environment undergoes distinct phenological phases which drastically alter the composition of plant and arthropod communities, future research should integrate a more continuous sampling approach to achieve a more comprehensive understanding of the relationship within management practices (e.g D'Antoni *et al.*, 2020).

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