Chapter 3

Effects of Agricultural Land Use on the Ecohydrology of Small-Medium Mediterranean River Basins: Insights from a Case Study in the South of Portugal

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Additional information is available at the end of the chapter

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Abstract

Southern Europe has been experiencing an accelerated intensification of agricultural systems in the last decades with consequent environmental effects. This study aimed to evaluate the effects of agricultural land use in two small-medium river basins in the South of Portugal, regarding: (i) water quality and stream habitat; (ii) fish fauna; and (iii) soil. Sampling included fish captures, water, and soil sample collection. Hydromorphological habitat features were also assessed. Land use was quantified at the basin and local scales. Results showed that the most negative effects were associated with intensive, heavily irrigated, fertilized, and pastured local systems, mostly represented at the basin scale by olive groves, irrigated crops, and pastures. Conversely, local agricultural intensity did not prove to be a threat to the integrity and quality of the soil, seeming to ensure the sustainability of the local uses and their systems. Negative effects were observed on water quality and instream habitat and degradation of riparian vegetation, resulting in fish assemblages' impoverishment. This study contributes to a comprehensive approach to the effects of agricultural land use, highlighting the need to integrate the results of different natural resources to efficiently support policy and decision makers toward a sustainable agriculture, water management, and land use planning.

Keywords: agricultural intensity, agricultural systems, water quality, stream habitat, fish assemblages, soil quality, sustainable agriculture, water management, land use planning

1. Introduction

Land use includes different landscape elements that are very dynamic, having low temporal and structural stability [1, 2]. Land use/land cover changes (LULCC) are playing an important role on the global and local change phenomena with major impacts on the environmental and sociocultural sustainability. The European landscapes have been subject to rapid changes in land use throughout the second half of the twentieth century arising from developments in technology and management driven by socioeconomic and political forces [3]. Southern Europe has been shaped by human activity and maintained by traditional farming practices for centuries, but important changes in land use have occurred following the strong production incentives launched by the European Common Agriculture Policy Framework. Under this scenario, the South of Portugal has experienced a rather accelerated change in farming systems in the last three decades, due to the perspective of a profitable intensive and irrigated agriculture. Many of the agro-silvopastoral systems have been severely reduced due to intensification trends, sometimes followed in other areas by extensification or even abandonment [4–6]. Simultaneously, artificial water bodies have increased due to the construction of many dams (e.g., Alqueva dam) mainly for irrigation purposes. As a result, the irrigated area has increased considerably in the last decade and is currently about 30% of the cultivated land in Portugal [7].

The intensification of agricultural land use has raised the question of the long-term sustainability of agroecosystems [8]. The growing expansion of intensive agrosystems is expected to promote environmental degradation, including soil erosion, water resources depletion, risk of floods and landslides, water and soil contamination, and biodiversity loss [9, 10]. It is urgent to reverse this trend by encouraging farmers to adopt more sustainable practices that optimize the use of natural resources on which they depend, so that future generations will be able to meet their needs, while maintaining biodiversity.

Intensive farming, such as irrigated arable crops, pastures, and orchards, can result in several different types of stress, which alone or together affect the structure and functioning of aquatic ecosystems and biodiversity [11, 12]. For instance, decreased river discharge due to water overexploitation for irrigation purposes may change river hydrology (both groundwater and surface), increasing siltation and reducing habitat heterogeneity, with negative effects on the aquatic biota [13–16]. Soil and water can be contaminated by the random uses and the overdoses of synthetic fertilizers and other agrochemicals used to increase land productivity. The downstream effects of runoff from these systems may result in the increase of nutrient concentration in the water bodies leading to water eutrophication, dissolved oxygen depletion, and the loss of fish fauna integrity [12]. This phenomenon is particularly aggravated in Mediterranean climate regions, where floods alternate with long dry and hot periods, promoting the conditions to increase soil erosion and nutrient leaching, particularly in watersheds with high LULCC.

Soil erosion is also one of the most serious environmental problems associated with farming intensification, as well as loss of soil structure and stability [17]. Changes in soil aggregate stability may largely influence soil susceptibility to degradation [18, 19]. Soil structure stability has a key role in the functioning of soil, its capacity to support plant and animal life, water availability, and therefore is a good indicator of land integrity [18, 19]. The conversion of natural forest to other forms of land use can lead to a reduction in soil organic content, loss of soil quantity, and modification of soil structure [20]. Soil characteristics negatively affected by intensive agrosystems with tillage practices are soil organic matter, total porosity, aggregate stability, and bulk density [21]. Land use change also may affect water retention at field capacity in the soil; lower water content at the field capacity would be expected upon conversion of natural to cultivated lands [22]. Many examples of activities related with agrosystems acting as sources of soil change can be referred: biomass burning, fertilizer application, species transfer, plowing, irrigation, drainage, livestock grazing, pasture improvement [17], deforestation and site abandonment [23], breaking up of large tracts of grassland, expansion of cultures which promote erosion (e.g., maize and sugar beet), and farming of fields in the fall line [24]. The sustainability of cropping systems demands a focused attention to monitor soil quality because of the growing concern about the decline in soil productivity and the impoverishment of soil organic carbon caused by intensive agriculture practices [25].

Although considerable research has been conducted on the effects of land use on terrestrial environments in Mediterranean regions, studies on aquatic habitats are more limited. Furthermore, even though soil and aquatic degradation are widely recognized as major environmental problems resulting from land use intensification, integrated and comprehensive approaches considering the possible soil and water interconnections have received far less research.

Therefore, this study aimed to assess the effects of agricultural land use on water quality, stream habitat, structure and functionality of fish assemblages, and soil quality, based on a case study developed in two small-medium Mediterranean river basins in the South of Portugal.

2. Methods

2.1. Study area

The study was conducted in two small-medium river basins located in the South of Portugal (Alentejo region): Azambuja (261.92 km^2), a sub-basin of the Guadiana River, and Alcáçovas (429.64 km^2), a sub-basin of the Sado River (**Figure 1**).

This region is influenced by the Mediterranean climate, presenting high susceptibility to drought events [26]. The hydrological regime is very variable, with severe droughts and floods. Flow is strongly dependent on the seasonal distribution of rain, mainly concentrated in October–March. Small-medium river basins are particularly affected during the summer dry season (June–September), when streams became completely dry or reduced to isolated pools where fish fauna has to survive until the reestablishment of river continuity in the following rains [27]. Fish assemblages generally present low species richness and include many

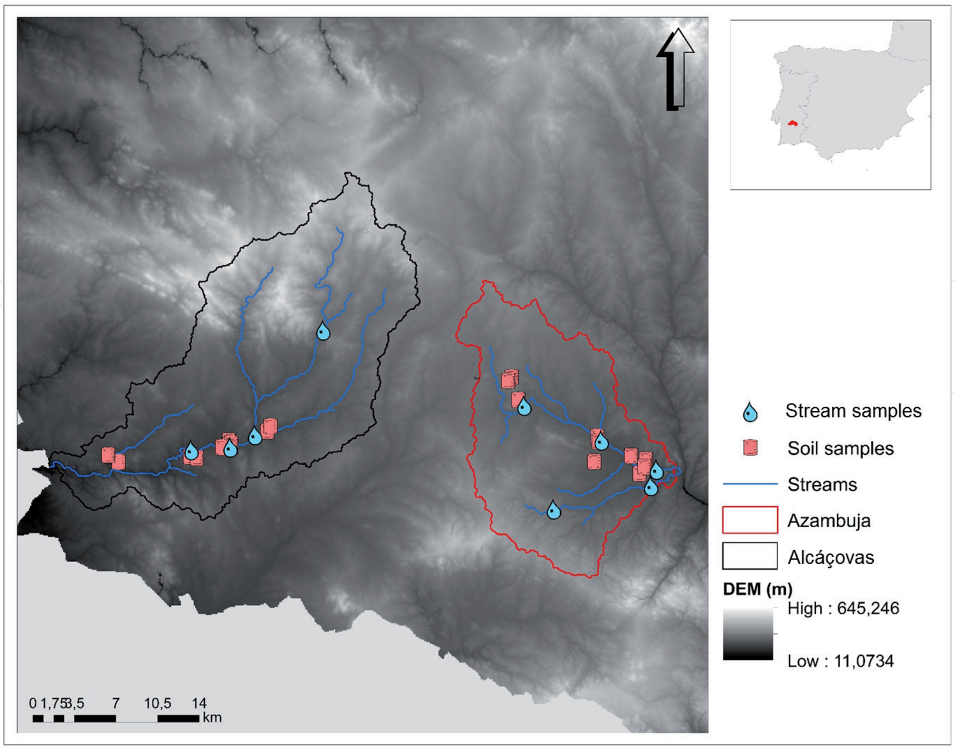

Figure 1. Location of the sampling sites in the Azambuja and Alcáçovas river basins in the South of Portugal.

endemic species with high conservation status, particularly in the Guadiana basin [28]. The most abundant and frequent species is roach (*Squalius alburnoides* Steindachner), followed by different species of barbels and nase.

The geomorphology is characterized by large lowland extensions (a mean altitude of 200 meters) with some more prominent areas, but without mountainous characteristics. In general, soils are incipient and slender with more aptitude for forest-pastoralism. The most representative types are lithosols, litholic soils, Mediterranean brown soils, and podzols, primarily derived from shale, clay, and limestone [29].

The Alentejo region is markedly rural, representing more than half of the agricultural area used in the country [7]. This landscape is dominated by olive groves and montado, an agroforestry system that has evolved from the Mediterranean forest by the planting of large areas of cork and holm oak, combined with low shrubs, and integrating livestock production. Extensive rainfed systems are also a mark of the Alentejo landscape and are generally present in large areas, combined with other productions [7].

The landscape has been changing with the intensification of the agricultural practices, cattle production, and the introduction of new crops. The irrigated land has registered a significant increase, mostly in permanent and temporary crops, olive groves, and vineyards, with the possibility of expansion in the future [7, 30]. Livestock production maintained high important in the agricultural activity, with an increase in cattle heads and a decrease in sheep and goats [30]. Consequently, pastures are mainly used as grazing area for livestock production, and this use has increased by about 42% in the last decade. Although livestock is mostly produced in extensive systems, there is often a high number of animals per farm (>300) [7]. The management of livestock is based on the rotational grazing of cattle on partitioned pasture areas, so that at each moment, a high stock rating may be observed. During the summer, when pastures become dry, livestock is often found in paddocks with free access to streams.

2.2. Site selection and sampling

2.2.1. Stream habitat, water quality, and fish

Sampling was held during 2012 in two small-medium river basins located in the South of Portugal: Azambuja (N = 5 sites) and Alcáçovas (N = 4 sites) (**Figure 1**). Sampling sites were selected based on a preliminary GIS analysis using ArcGIS software and considering a digital elevation model, slope, and exposure maps as well as flow direction and accumulation.

Fish captures took place in early spring, following the protocol developed and adopted for Portuguese rivers under the implementation of the Water Framework Directive [31]. Samplings were always carried out in flowing water conditions, immediately after the floods and previously to the strong reduction of flow during the summer period, in order to ensure high habitat diversity in the streams. Fishes were collected using backpack battery-powered electrofishing equipment (IG 200/2B, PDC Hans-Grassl GmbH, Schonau am Konigssee, Germany). All the necessary fishing permits were provided by the National Institute for the Conservation of Nature and Forests (ICNF). Captured fishes were identified to the species level and measured (total length, mm). Individuals of native species were returned alive to the water, whereas individuals of non-native species were removed and euthanized by thermal shock (freezing), in compliance with the Portuguese legislation and following the ethical guidelines of the Directive 2010/63/EU on animal welfare [32].

The environmental characterization of sites was carried out during the sampling procedure and included:

i. physicochemical parameters measured with a multiparameter probe—water temperature (°C), conductivity (μs cm^{-1}), pH, and dissolved oxygen (mg L^{-1});

ii. water nutrients evaluated through laboratory analyses according to the Standard Methods for the Examination of Water and Wastewater [33], after water sample collection—5-day biological oxygen demand—BOD_5 (mg L^{-1}), orthophosphate—PO_4^{3-} (mg L^{-1}), nitrite—NO_2^- (mg L^{-1}), nitrate—NO_3^- (mg L^{-1}), ammonia—NH_4^+ (mg L^{-1}), and total suspended solids—TSS (mg L^{-1}); and

iii. anthropogenic disturbance variables reflecting hydromorphological alterations induced by local land use practices—riparian vegetation, sediment load, hydrological regime, and morphological condition. Each variable was scored from 1 (minimum disturbance) to 5 (maximum disturbance) following [12] and based on [34].

Physicochemical parameters and nutrient concentrations were used to classify the water quality of the sampled sites into five classes, based on the water features for multiple uses, according to the Portuguese Environmental Agency guidelines [35]: excellent, good, reasonable, poor, and very poor.

2.2.2. Soil

Soil samples were collected in the dominant soil types from the slopes that drain into the stream section immediately upstream the stream sampling sites. The specific location of the soil samples depended both on soil maps [36] and land use/land cover maps, in order to achieve the highest number of possible combinations and replicates, in a total of 19 samples (Azambuja = 10 samples; Alcáçovas = 9 samples) (**Figure 1**).

Samples were collected at the root zones of 0–30 cm using a soil auger. This superficial soil layer is the most sensitive to material entraining through runoff, to washing and leaching of nutrients into deeper layers and groundwater, to the accumulation of nutrients from fertilization, to the accumulation of organic matter, and to structure degradation that influences infiltration and runoff, all these with potential consequences on the water quality of adjacent streams.

Each soil sample was air dried and passed through a 2-mm screen, and the coarse fraction (>2 mm) was separated. The fine soil fraction (<2 mm) was then subjected to laboratory analysis using standard procedures, and a wide range of parameters was analyzed, giving preference to the chemical characteristics, since it was intended to evaluate the relationship between soil results and water quality: textural class (relative proportion of sand, silt, and clay), pH (soil reaction), percentage of organic matter in the soil (OM), concentration of exchange bases ($cmol^+ \cdot kg^{-1}$) (Ca^{2+} (calcium), Mg^{2+} (magnesium), Na^+ (sodium), and K^+ (potassium)), S (sum of bases) ($cmol^+ \cdot kg^{-1}$), T (cation exchange capacity) ($cmol^+ \cdot Kg^{-1}$), V (percentage of base saturation), P (available phosphorus) ($mg \cdot kg^{-1}$), and H^+ (exchange acidity) ($cmol^+ \cdot kg^{-1}$). Particle size distribution was determined by the hydrometer method [37]; soil pH was determined using a pH meter in a soil/liquid suspension of 1:2.5 [38]; organic carbon was determined using a chromic wet oxidation method [39]; available phosphorus was determined using the Bray II solution method [39]; exchangeable Mg^{2+} and Ca^{2+} were determined using ethylenediaminetetraacetic acid (EDTA) [40], while exchangeable K^+ and Na^+ were extracted using 1 N Neutral $C_2H_7NO_2$ and then determined using a flame photometer [40]; exchangeable acidity was measured titrimetrically using 1 M KCl per 0.05 M of NaOH [41], and effective cation exchange capacity was calculated from the sum of all exchangeable bases and total exchangeable acidity; percentage base saturation was calculated by the sum of the total exchangeable bases divided by the effective cation exchange capacity and then multiplied by 100.

2.2.3. Land use

The land use was assessed both at the catchment and local scales. At the catchment scale, the proportion of the most representative land use classes was calculated for the influence area of each sampling site, based on the land cover map applying the CORINE Land Cover Legend Level 5 at a scale of 1:10000 and aggregated to the level 3 [42]: irrigated arable land, nonirrigated arable land, vineyards, olive groves (mostly irrigated), pastures, annual and permanent crops, agroforestry (montado), hardwood forest, resin forest, mixed forests, and water plains. At the local scale, the dominant local land use observed at the surrounding area of each stream site was registered.

As in most sites, different land uses were present with possible effects on streams, and the overall level of agricultural intensity was also evaluated, based on the presence of irrigation, fertilization, and animal grazing. For each site, these three variables were scored between 0 (null impact) and 2 (high impact). The sum of these scores represented the total agricultural intensity, and three classes were established to classify the sampled sites: low (0–1), moderate (2–3), and high (≥4). For soil samplings, the exact local land use of the sample site was registered.

2.3. Data analysis

Fish captures were quantified as density (the number of individuals·100 m^{-2}) and fish assemblages were analyzed considering: (i) structural metrics (proportion of native and non-native species); (ii) functional guilds related to habitat (relative abundance of limnophilic, eurytopic, benthic, and water column species), breeding (relative abundance of lithophilic and phytophilic species), feeding (relative abundance of omnivorous and insectivorous species), and tolerance to degradation (relative abundance of tolerant species). Captured species were assigned to functional guilds according to the published literature [34, 43, 44] and expert judgment based on the available knowledge.

Soil quality was assessed regarding the performance of three ecological functions related to environmental regulation, biomass production, and reserves of water and biodiversity, through the soil quality index (SQI) using five indicators: chemical fertility, drainage, reaction (pH), organic matter (OM), and phosphorus (P). These five qualitative and quantitative indicators were scored from 1 to 3, following [45], and the SQI was calculated using the formula.

$$\mathrm{SQI} = \Sigma\, Ind/n \tag{1}$$

where *Ind* represents the score of each indicator and **n** the number of indicators. The SQI ranges between 0 (complete inability to perform the functions of environmental regulation, production of biomass, and ensure biodiversity) and 1 (full ability to perform the functions of environmental regulation, production of biomass, and ensure biodiversity).

Redundancy analysis (RDA) [46] was used to explore relationships between land use variables (both at local and basin scales) and: (i) water parameters and stream habitat features; (ii) structure and functionality of fish assemblages. A linear ordination method was selected after a preliminary detrended correspondence analysis that has shown a gradient length smaller than 3 SD [47]. A stepwise forward selection of the variables was used, and the final model was tested with Monte Carlo test under 999 permutations. Correlations higher than $|0.4|$ were used in gradient interpretation.

A bivariate approach was used to analyze the proportion of water quality classes along the local agricultural intensity gradient, and the Friedman test was performed to search for significant differences. This approach was also used to evaluate the pattern of chemical soil parameters under different local land uses and along the local agricultural intensity gradient.

Prior to multivariate analyses, data were either log (x + 1) (linear measurements) or arcsin [sqrt (x)] (percentages) transformed to improve normality [48]. Statistical analyses were performed using the software Statistica 10 and Canoco 4.5.

3. Results and discussion

3.1. Land use vs. stream habitat and water quality

Seven significant variables ($p < 0.05$) were selected for the ordination model, including both local (N = 3) and basin scale (N = 4) land use variables (**Figure 2**). According to the canonical coefficients and inter-set correlations, axis 1 was mainly defined by irrigated arable land percentage (r = −0.63), pastures percentage (r = −0.70), and agroforestry (montado) percentage (r = 0.56). Axis 2 was mostly related with olive grove percentage (r = 0.63) and local levels of irrigation (r = 0.70), fertilization (r = 0.69), and animal grazing (r = −0.52) (**Figure 2**).

The ordination diagram (triplot) showed a good spatial segregation of sites along the first two axes, revealing also a good association of land use types with different water parameters and stream habitat features (76.3%). The first axis evidenced a clear association of extensive areas of irrigated olive groves and irrigated arable land in the drainage basin, as well as high local levels of irrigation and fertilization, with the degradation of most of the

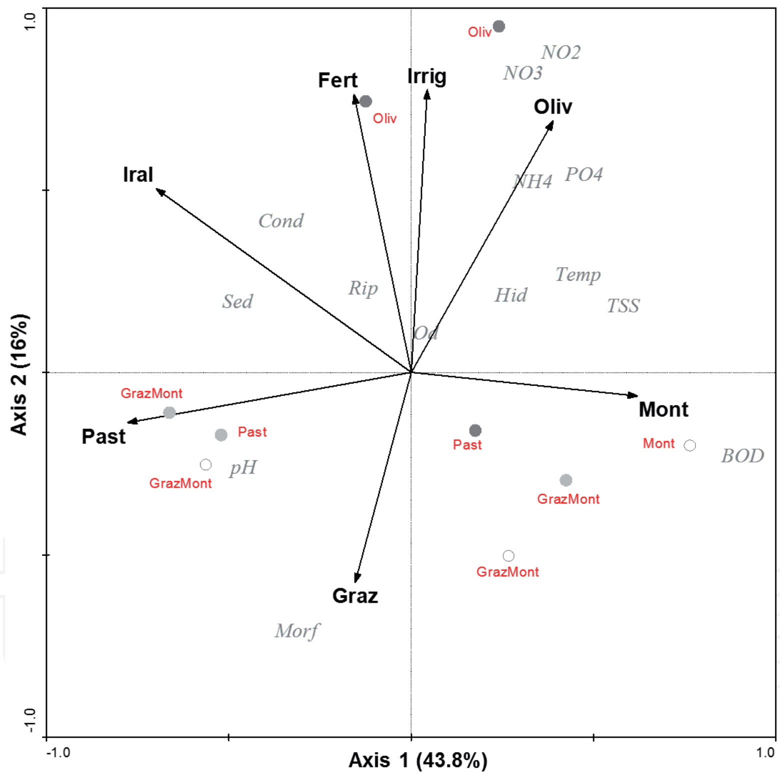

Figure 2. Ordination diagram (triplot) of the redundancy analysis between land use variables (at the local and basin scales) and aquatic habitat features in sampling sites located in the Azambuja and Alcáçovas river basins (N = 9). Sampling sites were identified by the dominant local land use (red) and were coded according to the classes of the agricultural intensification level: low (white dots), moderate (gray dots), and high (black dots). Abbreviations of land use variables: irrigated arable land (Iral), olive groves (Oliv), agroforestry-montado (Mont), pastures (Past), local level of animal grazing (Graz), local fertilization level (Fert), and local irrigation level (Irrig). Abbreviations of water parameters and stream habitat features: ammonia (NH_4), nitrate (NO_3), nitrite (NO_2), orthophosphate (PO_4), dissolved oxygen (Od), conductivity (Cond), water temperature (Temp), total suspended solids (TSS), biological oxygen demand (BOD), sediment load (Sed), riparian vegetation (Rip), hydrological regime (Hyd), and morphological condition (Morf). Abbreviations of local land uses: olive groves (Oliv), pastures (Past), grazed montado (GrazMont), and agroforestry-montado (Mont).

water parameters and habitat features: increase in nutrient concentrations, high conductivity and water temperature, hydrological alterations, degradation of riparian vegetation, and high sediment loads. These results are strongly related to soil erosion, high surface runoff, and high levels of fertilization and irrigation commonly associated with intensive agriculture practices, as the high amount of organic material produced represents a considerable input of nitrates and phosphates leaching into superficial and groundwater very easily [49, 50].

Soil erosion is cited as one of the principal environmental problems associated with olive farming in Mediterranean regions [51]. In intensive olive plantations, farmers usually keep the soil bare of vegetation throughout the year, such that severe erosion occurs during heavy rains. Soil erosion and water runoff into nearby streams can be a major source of suspended sediments, nutrients, and pesticides in watersheds dominated by agricultural land [52, 53]. Natural stream flow can also suffer alterations [54, 55], by exacerbating the effects of seasonal or longer term droughts through water abstraction [56, 57], or by augmenting flows through irrigation returns, in some cases maintaining flowing rivers which would normally dry [58, 59].

The removal or degradation of riparian vegetation associated to the land use [60, 61] can further aggravate all the problems mentioned. Due to its position at the interface between terrestrial and aquatic ecosystems, riparian vegetation has the ability to prevent sediment runoff and to hold excess nutrients and modify their inputs to the stream [62], preventing negative consequences in overall water quality [63], and the increase of water temperature [64].

Large upstream areas of pastures and high local levels of animal grazing (mostly cattle) were mainly associated to higher pH values and instream morphological alterations. Livestock grazing with unrestricted access to streams has negative impacts on aquatic ecosystems [65, 66]. This practice increases instream trampling, habitat disturbance, and erosion from overgrazed stream banks, as well as reducing sediment trapping by riparian and instream vegetation and decreasing bank stability [67, 68].

Sites located in drainage basins with large areas of agroforestry (montado) did not show stream habitat alterations, although they were associated with the high values of BOD, TSS, and water temperature. This was possibly due to the fact that this site is located near an urban area and may be influenced by the drain treatment plant.

The water quality of the sampled sites ranged between moderate and very poor (**Figure 3**). Moreover, the relative proportion of the water quality classes of sites showed significant differences along the agricultural intensification gradient ($p < 0.05$), revealing a trend toward a progressive degradation. Nevertheless, even in sites with a low agricultural intensity, the water quality was predominantly moderate, with some percentage of poor quality. These results are in accordance with the fact that both local and basin scale variables were selected for the RDA (**Figure 2**), demonstrating that the effects of land use on water quality and stream habitat depend not only on the degree of intensity of the main local culture but also on cumulative multi-pressures acting at the basin scale. Scale is a particularly important issue in analyses of land use impacts on ecosystems because different perturbations, processes, and responses operate at different scales [69–72].

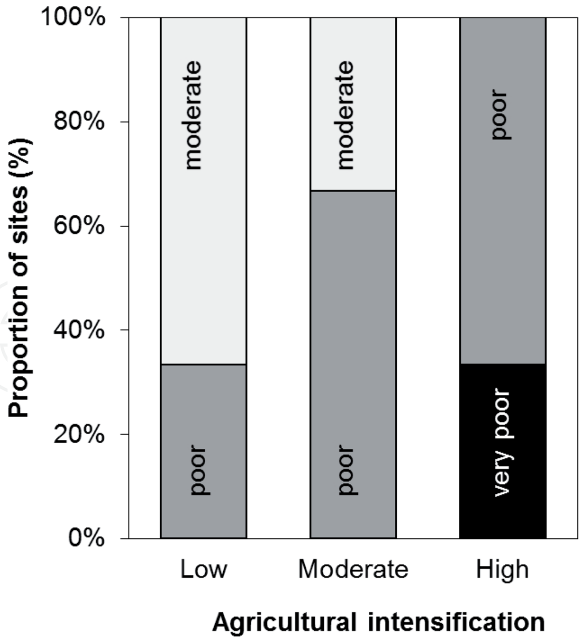

Figure 3. Relative proportion of the water quality classes along the agricultural intensification gradient in the sites sampled in the Azambuja and Alcáçovas river basins (N = 9).

3.2. Land use vs. fish assemblages

A total of 10 fish species were captured, including six native and four non-native species. On average, non-native species represented nearly 60% of the mean density per site. Native species only dominated fish assemblages in three sampling sites and are all endemic to the Iberian Peninsula, with high conservation status [28].

The RDA showed a reasonable segregation of the sites along the first two axes, which together explained 44% of data variability (**Figure 4**). Nevertheless, these axes revealed a good association between the relevant variables and fish metrics/guilds, explaining most of the species-variable relation (80.8%), thus supporting the interpretation of the results. Five variables were selected for the model, all reflecting land use at the catchment scale. Axis 1 was mainly defined by pasture percentage ($r = -0.48$), agroforestry (montado) percentage ($r = 0.4$), and olive grove percentage ($r = 0.55$). Axis 2 was mostly related with olive grove percentage ($r = -0.44$), and irrigated arable land ($r = 0.42$).

The ordination diagram (biplot) revealed different groups of fish metrics/guilds with which different land uses were particularly related. Sites under the upstream influence of large pasture areas were dominated by non-native, tolerant, omnivorous, and limnophilic species. Eurytopic and benthic species were associated with large areas of olive groves in upstream catchment areas. These results showed a clear impoverishment of the fish assemblages with the increase of the area occupied by more intensive agricultural uses in the drainage basin. Fish responds to the changes in the water parameters resulting from land use alterations [73] through interrelated impacts on water quality, hydrology, and habitat [54, 74], as seen in **Figures 2** and **3**. These impacts have been shown to substantially change fish assemblages [75], decrease species richness/diversity and sensitive species, while increasing tolerant and non-native species,

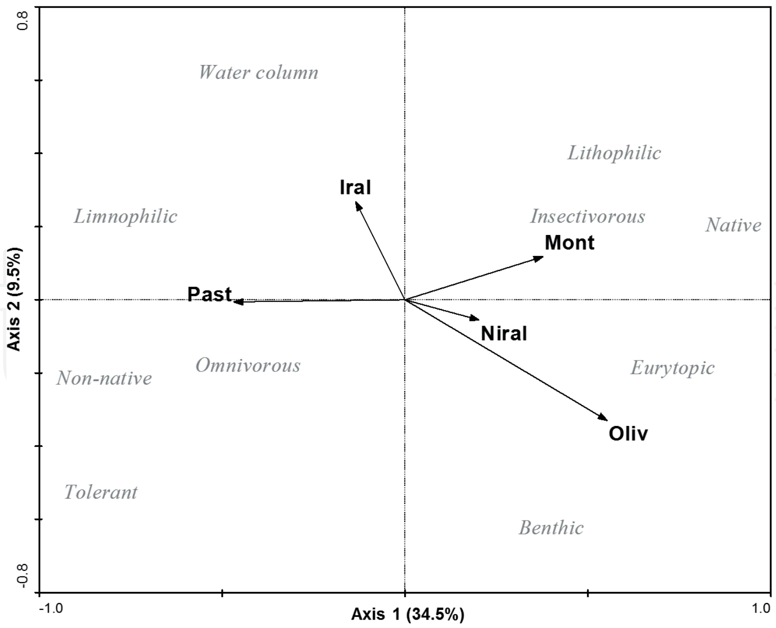

Figure 4. Ordination diagram (biplot) of the redundancy analysis between the land use variables (at the local and basin scales) and the fish metrics/guilds in sampling sites located in the Azambuja and Alcáçovas river basins (N = 9). Abbreviations of land use variables: irrigated arable land (Iral), nonirrigated arable land (Niral), olive groves (Oliv), agroforestry-montado (Mont), and pastures (Past).

and ultimately influencing the integrity of fish assemblages [12, 76, 77]. Conversely, extensive areas of agroforestry (montado) were related to high abundance of native, lithophilic, and insectivorous species, evidencing a lower disturbance level and enabling the support of more native specialist species [78].

Only basin scale variables were selected for the model, suggesting that the effects of land use on fish assemblages' structure and functionality operate at a larger spatial scale, as reported in other studies [79]. In fact, most agricultural and urban land uses occur at the larger watershed scale and their impacts cannot be fully understood by looking at adjacent riparian lands [80].

3.3. Land use vs. soil

Based on the most relevant soil variables, a consistent pattern was observed between the quality and chemical fertility of the soil and the local land uses (**Figure 5**), as well as regarding the intensity of the agricultural practices associated with them (**Figure 6**).

The organic matter content (OM) increased gradually along the agricultural intensity gradient, leading to an improvement in soil quality and health, since OM improves the soil structure and consequently increases the total porosity and friability, thus enhancing the overall resilience [81]. Similar results were obtained by Havaee et al. [82], even though different findings were reported by several authors, who concluded that there is a degradation of the soil by changing the uses for more intensive systems [83–88]. This was probably due to the inputs of organic matter and water irrigation used in the local land uses studied, which resort to these external factors in order to increase the land productivity. Simultaneously with the increase in the OM in most intensive local land uses, high data dispersion was also observed, probably

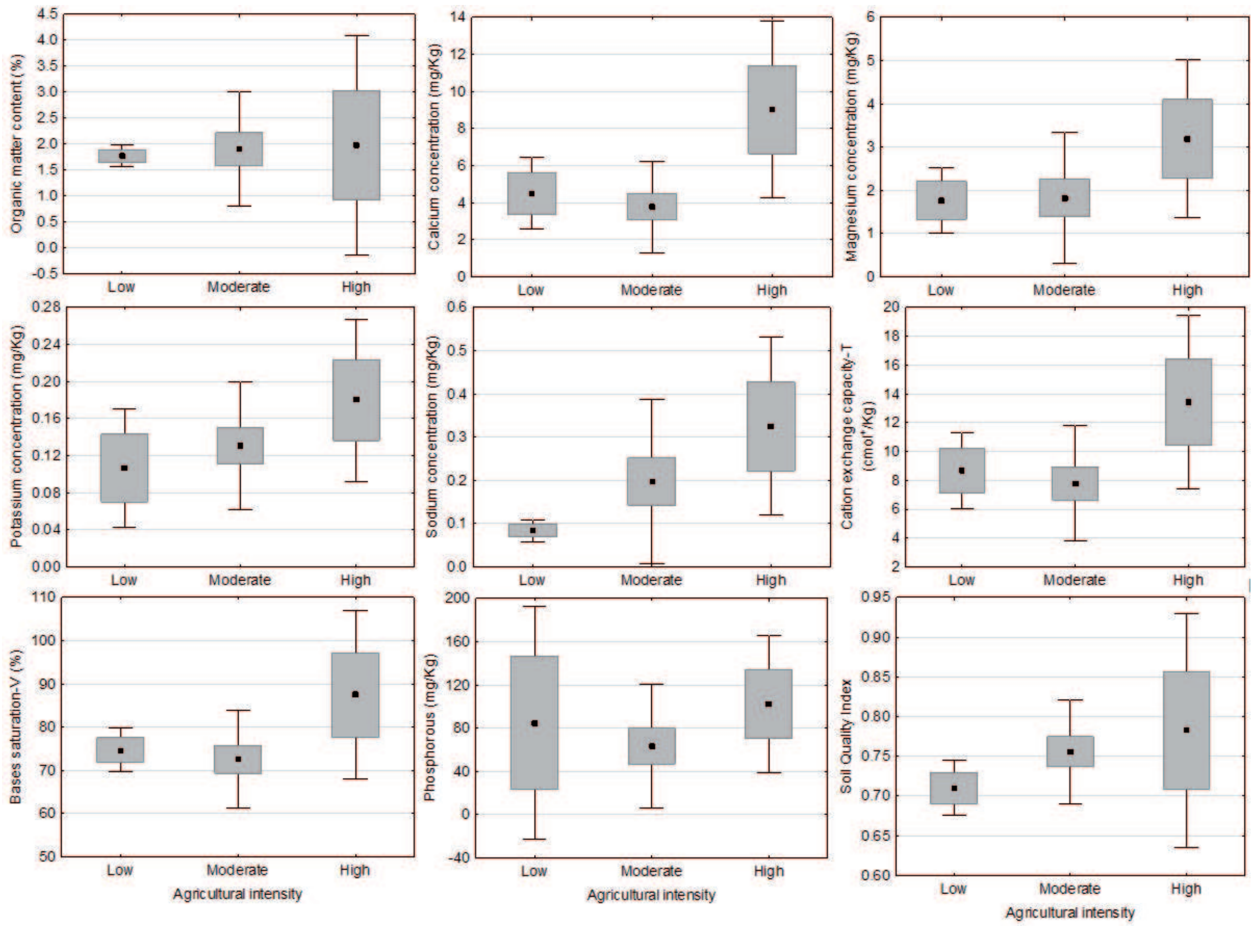

Figure 5. Box plots of the most significant results for soil characteristics along the agricultural intensity gradient. (▪): mean; box: ±SE; and whisker: ±SD.

due to the different sources of inputs in each of the local uses (**Figure 5**). The values of OM were higher in olive groves and in irrigated arable crops, possibly due to the input of external OM, whereas in pastures and in grazed olive groves, the origin of OM may be internal to the system, resulting from the presence of cattle. On the other hand, maize crop, which is also intensive, does not use OM supplementation.

The physical behavior of soil is controlled by the OM that is complexed with clay [89]. Although bulk density has not been evaluated in this study, this characteristic can be deduced from the OM/Clay ratio [82]. So, since the textural classes of the studied soils were always coarse, except in a single case in which it was median, it can be affirmed that the behavior of the bulk density, in face of the different land uses and corresponding intensity of the agricultural systems, was opposite to that of OM. Therefore, the higher the OM content, the higher the OM/Clay ratio, the lower the bulk density and, consequently, the lower the compaction, the higher the total porosity and the infiltration rate. In this way, the water that infiltrates the soil is retained by the high retention power of the OM [90, 91].

Several studies reported a reduction in the cation exchange capacity (T), which reflects a reduced chemical soil fertility, as the greatest impact of land use intensification on soil [83, 87, 88].

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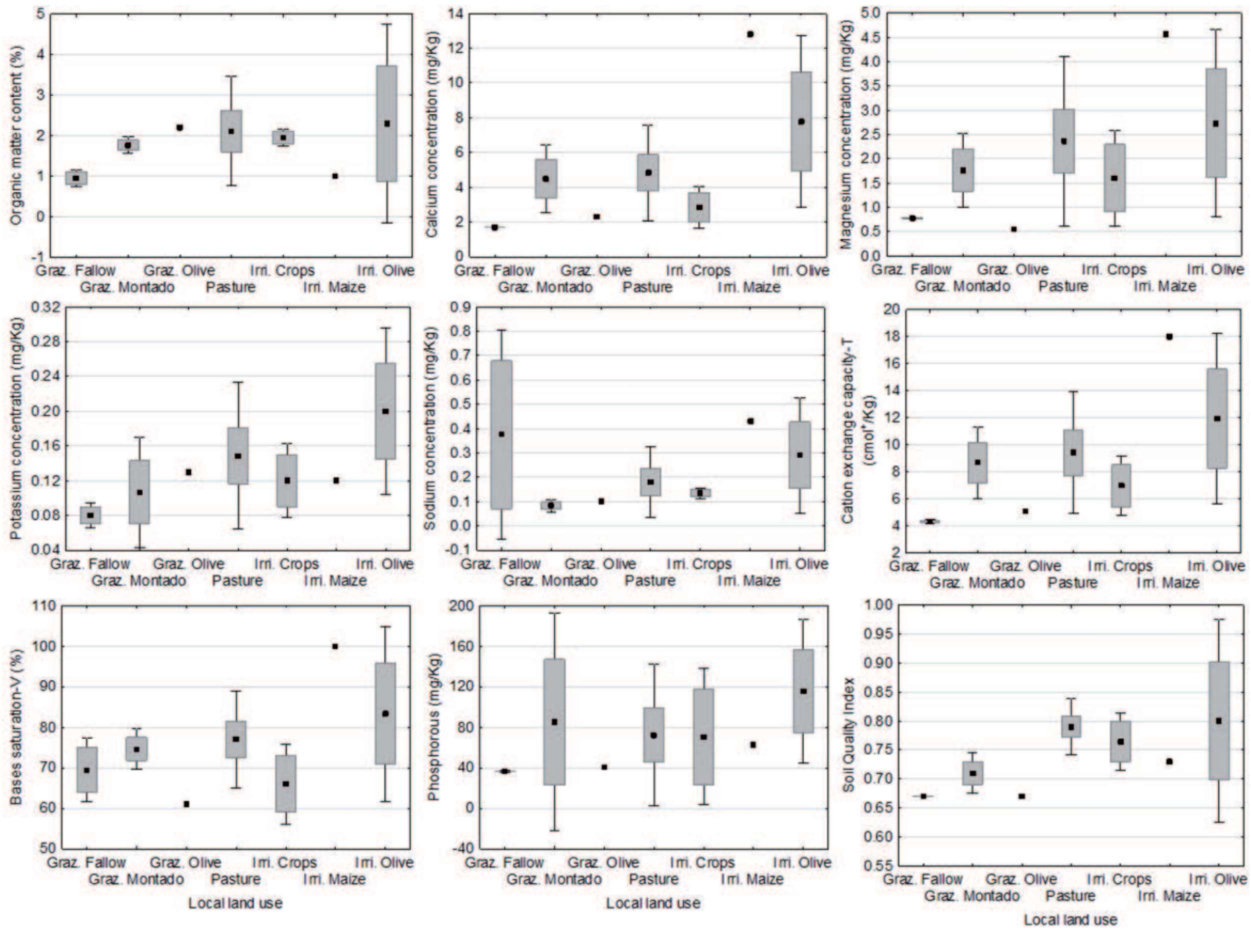

Figure 6. Box plots of the most significant results for soil characteristics in different local land use types. (▪): mean; box: ±SE; and whisker: ±SD.

However, in this study, the T, the bases of exchange (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}), as well as the degree of saturation with bases (V), showed an increase along the gradient of agricultural intensity. This was possibly a consequence of the influence of the OM, since the texture of most soil samples was coarse, and therefore, in these cases, clay had little influence on soil properties. As shown in **Figure 6**, the bases of exchange showed different increases, certainly due to the practices of liming, fertilization, and irrigation proper of the uses to which they were associated.

Regarding the available phosphorous (P), as for all the other chemical characteristics, it increased in the soil in land uses with more intensive systems of exploitation (**Figure 6**). These results contradict other studies registering a phosphorous decrease when a change in the land use for more intensive systems occurs [84, 88, 92], due to the crop mining and the removal of waste and erosion. This unexpected pattern was better understood when observing the results obtained for each local land use (**Figure 5**), perceiving that they derived from the fertilization used in systems associated with more intensive uses, where productivity and yield are important [93].

The SQI revealed a pattern similar to the other analyzed characteristics, increasing with the agricultural intensity of the systems, despite showing high data dispersion (**Figure 6**), and explained when analyzing the results obtained for each local land use (**Figure 5**). Although the SQI was evaluated based on the parameters presented here, to which information about the drainage was added (considering the texture, the shape of the terrain, and the average annual precipitation), this did not alter the trend of the results, and some conclusions can be drawn about the consequences of different land uses on the quality of the soil and, in turn, on the adjacent aquatic ecosystems.

The obtained results showed that the higher the OM, the higher the rate of infiltration and the water retention in the soil, apparently with little influence of soil chemical constituents on aquatic ecosystems, since the water that solubilizes or suspends them is mostly retained in the soil. Only in situations where land use practices implies leaving the soil bare during the beginning of the rainy season, it will be possible to verify this type of consequences through the surface runoff [94].

4. Conclusions

Agricultural land use has shown to have strong negative effects on water quality, stream habitat, and degradation of riparian vegetation, ultimately resulting in fish assemblages' impoverishment and clearly benefiting non-native species, which thrive under altered conditions [95]. The most negative effects were associated with intensive, heavily irrigated, fertilized, and pastured agricultural systems, mostly represented at the basin scale by olive groves, irrigated crops, and pastures. Conversely, agroforestry (montado) results emphasize the potential contribution of this stable production system to biodiversity conservation.

Since Mediterranean rivers exhibit high levels of fish fauna endemicity, human impacts on these systems have the potential to extirpate native species and reduce local, regional, and global native biodiversity [96]. It should be further highlighted that considering the forecasted climate changes and their possible joint effects with land use changes, far reaching effects are likely to occur on ecological communities in Mediterranean regions in the future [97, 98].

Regarding soil, local agricultural intensity did not prove to be a threat to the integrity and quality of the soil, seeming to ensure the sustainability of the local uses and practices, contrary to what is usually found. The intensification of agricultural systems, by means of a high consumption of water or energy, can be carefully planned, thus preventing soil degradation through the known threats defined by Thematic Strategy for Soil Protection [99], namely, decline in organic matter, compaction, floods, soil erosion, salinization, contamination, landslides, and sealing. The careful planning and execution of agricultural practices that intensify the production systems (but not involving degradation) are the recommendations of several authors [88, 100, 101].

These are preliminary findings based on a case study, and more detailed research is further required to substantiate the results and assess the direct relationship between soil and the aquatic ecosystem, namely, by considering more soil characteristics and diversity, covering larger spatial and temporal scales, and considering climate data. This would allow a better understanding of the complex pathways underpinning the interaction among the processes and factors involved.

Nevertheless, this study emphasizes the tight interaction between streams and the terrestrial ecosystem and shows that both direct and indirect aspects of this linkage are relevant to stream ecosystem functioning. Moreover, the effects of the agricultural practices do not have the same spatial and temporal expression on the natural resources involved, namely, soil and water. As such, river basin management must integrate a vision of compromise between the intensification of agricultural systems and the conservation of different natural resources and ecosystems. Planners and policy makers should bring stakeholders together, based on the understanding of land-water relationships in a watershed, to plan for a sustainable agriculture, targeting and balancing locally specific environmental and socioeconomic needs.

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Conflict of interest

The authors declare no conflict of interest.

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