

Article

Identifying Problems in Watering Ponds with Different Purposes

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Abstract: The main goal of this study was to identify the problems that are putting the viability of watering ponds at risk. For doing that, we have analyzed five different study cases: (I) livestock consumption, Mediterranean climate (rangelands of SW Spain), (II) multifunctional ponds (Arroyo de la Luz, Spain), (III) ecotourism (Valdepajares de Tajo, Spain), (IV) crop irrigation and fish farming, semi-arid climate (the wilaya of Ouargla, Algeria), and (V) livestock consumption, humid subtropical climate (Prudentópolis, Brazil). The identification of problems was made through surveys, personal interviews, local knowledge and literature review as well as through the analysis of water quality parameters such as the concentration of phosphates and fecal coliforms in some ponds. We have identified problems of water shortage (ca. 50% of rangeland farmers), pollution induced by agriculture (maximum values of phosphates = 1.33 mg L⁻¹) and livestock farming (maximum value of fecal coliforms ≈ 7000 cfu mL⁻¹), low potability for human consumption (score: 2.8/7.0), invasive species such as *Azolla filiculoides* (10 out of 17 watering ponds), high water temperature for aquaculture in summer (Algeria) and the increase of turbidity in nearby water courses due to the actions of free-fattening pigs (Brazil), among many other problems. We conclude an extra effort by stakeholders is still needed in order to agree mitigation strategies.

Keywords: watering ponds; livestock; ecotourism; fish farming; shortage; *Escherichia coli*

1. Introduction

It has been estimated that about 50% of Earth's land surface are drylands [1] and more than 4 billion people are usually facing problems of water scarcity [2]. These numbers could be higher if we consider water scarcity is not an exclusive problem of arid regions since it is common in semi-arid and transitional areas (e.g., Mediterranean climate type), particularly in summer [3]. Furthermore, climate change could extend its negative effects on water resources to other parts of the world that have not experienced problems of water availability yet [4] within a global context of overpopulation and great pressure on vital resources [5].

The effects of water scarcity have been mitigated by humanity since ancient times through the construction of infrastructures (reservoirs, aqueducts, cisterns, etc.) [6]. Nowadays, these big infrastructures to store and distribute water for human supply, power, and agriculture are very frequent, at least in countries such as Spain in which dry periods are recurrent [7]. Nevertheless, little attention is usually paid to small-size infrastructures such as watering ponds designed by farm owners and/or

municipalities for different purposes: livestock, hunting animals and human consumption, agriculture, fish farming, ecotourism, recreational use, wildfire extinction, biodiversity preservation, etc. [8].

The construction of watering ponds is therefore a nature-based solution aimed at storing surface water during the wet season to overcome the scarcity in rainfall and losses by evaporation of the dry periods. They have been mostly designed for agricultural purposes (livestock consumption and crop irrigation) within a large list of functions that they can fulfill (fish farming, recreational use, ecotourism, preservation of amphibians, etc.). The rationale of the most of watering ponds is a nature-based solution by using water harvesting techniques [9]. In other words, they are designed to store as much water is possible in the rainy season in order to face the increasing in consumption and evapotranspiration of the dry season.

The sources of water stored in ponds can be diverse: rainfall direct interception, surface and subsurface runoff, upwelling by contact with the water table, ephemeral or permanent dammed water courses, surface deposit to derive water from irrigation canals, etc. [10]. So, the most common problems related to these infrastructures are a priori the lack of tools and/or knowledge to their construction, an inappropriate location, a poor design that reduces their storage capacity, water pollution, pond silting induced by soil erosion, diseases transmission, etc. [11].

The main goal of this research was therefore to identify problems in a set of watering ponds representative of some study cases. For doing that, we have selected some rangelands farms (dehesas) of the Spanish Region of Extremadura in order to cover the fulfilling of the function of water supply for livestock consumption in a water-limited environment [11]. We have compared this land system (dehesas) with Brazilian faxinals, also a traditional land system based on extensive livestock husbandry, where water is not a limited resource [12].

We have also considered watering ponds aimed at fulfilling other purposes. We have selected the municipality of Arroyo de la Luz (Extremadura, SW Spain) because its long tradition in water management for different purposes [13]. We have compared this municipality with the wilaya of Ouargla (Algeria) in which ponds are used both for irrigation and fishing farming under arid conditions [14]. Finally, we have highlighted the role of one of the abovementioned rangeland farms selected for the study (Valdepajares de Tajo) in which ecotourism is one of the main inputs.

We hypothesize that, on one hand, water shortage and pollution are the main problems livestock farmers have to face, at least under Mediterranean conditions, and, on the other hand, watering ponds experience problems at a local scale that can be only identified by indigenous people with contrasted experience in land management. We also think our findings could be of great interest for both scientists and stakeholders because they will allow the comparison between single study cases, representative of different climatic conditions and valuable cultural legacies of long tradition, as well as for the reflection about incoming problems that will be increasingly more frequent in future scenarios in which climate change, overpopulation and new diseases can be serious threats.

2. Materials and Methods

Since the difficulty of coordinating a multi-national study, particularly in times of COVID-19 pandemic, we have combined some research conducted by using different techniques. After an in-depth literature review and some previous meetings to agree methodological details, we have surveyed both farmers in Extremadura and citizens of the municipality of Arroyo de la Luz. We have interviewed personally local experts on Saharan aquaculture and irrigation agriculture, and faxinal farming system as well as the managers of the farm (protected natural site) Valdepajares de Tajo. Finally, we have analyzed some water quality parameters in a sort of watering ponds belonging to rangeland farms (Valdepajares de Tajo was included).

2.1. Study Cases

The study covered three territories: Spanish Region of Extremadura, the municipality of Prudentópolis (Paraná, Brazil), and the wilaya of Ouargla (Algeria). Within Extremadura the study was

carried out in 5 rangeland farms (1 of them is Valdepajares de Tajo), in which some quality parameters (phosphates and fecal coliforms) were assessed, and also in the municipality of Arroyo de la Luz where local people were surveyed (Figure 1).

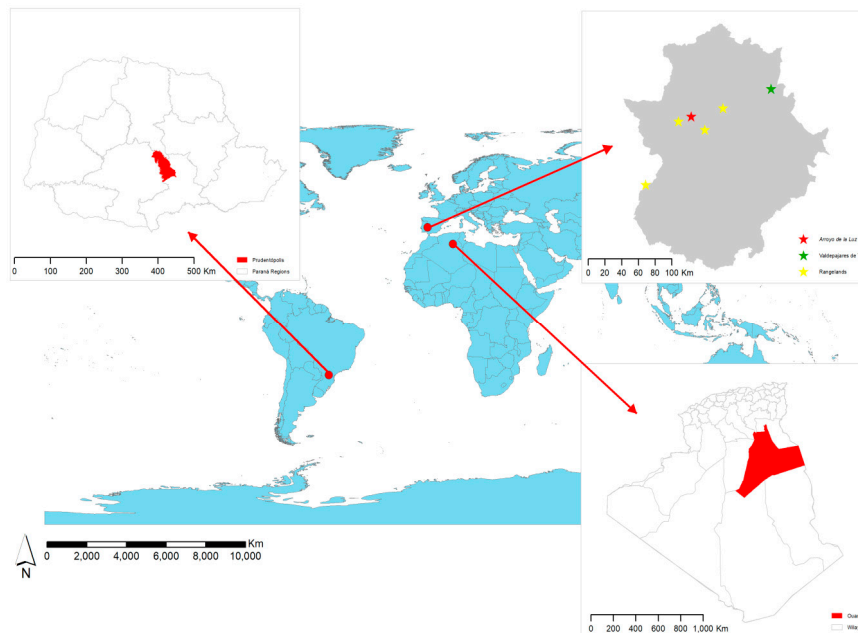


Figure 1. Geographical location of the study cases.

In addition, other rangeland farmers of the region were surveyed in order to have a wider view of the problematic situation. The identification of problems in Ouargla and Prudentópolis were made from the indigenous knowledge of Mohamed A. Abdennour (Agronomist and co-author of the manuscript) and Valdemir Antoneli (Professor of the UNICENTRO University of Paraná and soil scientist whose research career of 15 years has been made on faxinal farms), respectively. One of the responsible leaders of land management in the farm Valdepajares de Tajo (Carmen Perona) was personally interviewed in order to better understand what problems a rangeland farm can have when livestock husbandry is not the main economic income.

Extremadura was represented, on one hand, by 4 privately-owned rangeland farms whose main activity is the extensive livestock husbandry although they are managed in different ways (Table 1). The farm Valdepajares de Tajo (VT) is also a natural protected site by the Regional Government of Extremadura where water is used for attracting wildlife and the conservation of their habitats, among other functions. All these farms are located in a geographical area with a Mediterranean climate type where the average annual rainfall ranges between 500 and 700 mm and evapotranspiration always exceeds the amount of 1000 mm [15].

On the other hand, the municipality of Arroyo de la Luz ($39^{\circ}29'03''$ N; $6^{\circ}35'04''$ W) with a population about 5800 inhabitants represents a water management of centennial tradition based on its 4 small reservoirs and 4 important watering ponds on its water courses (Pontones River and tributaries) as well as on the dam of the Pontones River which crosses the town. Two small reservoirs (Petit I and II) were designed in the 19th and 20th centuries to obtain power. The water consumed by local citizens comes from the reservoir called Molano in which also fishing is authorized.

The dam of the Pontones River is the heart of the municipality and it has been traditionally used for recreational use (fishing, swimming, etc.). Furthermore, the management of the watering ponds has propitiated a network of small orchards (regionally known as huerta arroyana) since the Middle Ages focused on the production of vegetables consumed by local people and sold in nearby important markets (Cáceres, the second largest city in Extremadura). Nowadays, this network still persists, and

it is used for producing products of self-consumption and also for the sale of organic products in specialized markets.

Table 1. Main characteristics of the rangeland farms studied in Extremadura. ETP: Potential evapotranspiration. The names of the farms have been replaced by their acronyms.

Farm ¹	Land Management	Size (ha)	Cows	Pigs	Sheep	Goats	Rainfall (mm)	ETP (mm)
PAR	Conventional rangeland	797	38	-	1200	-	541	1451
BR	Conventional rangeland	926	135	100	-	60	496	1151
VT	Protected site	257	-	60	120	-	579	1361
VAL	Conventional grassland	69	40	-	-	-	482	1258
DEF	Holistic management [16]	551	260	-	-	-	512	1240

¹ We have used acronyms instead of the farm names because some farmers have preferred to keep anonymous.

The wilaya of Ouargla is inhabited by more than 600,000 people in a land surface of 211,980 km² that represents a way of water management aimed at fishing farming and irrigation agriculture within a geographical area climatically dominated by arid conditions (induced by the Sahara desert) and economically by the petrol extraction. In other words, these activities related to water management mean a sustainable alternative of development for local people.

In addition, Ouargla is one of the Algerian wilayas (administrative unit comparable to Spanish and Italian provinces) in which important reservoirs have not been built yet. It means activities such as irrigation agriculture (mainly potatoes and dates) and fish farming (aquaculture) are based on the proper management of watering ponds and subsoil aquifers. Ouargla is therefore a territory where water management forms part of different national programs of agriculture modernization.

Prudentópolis has been selected because is one of few places where the traditional faxinal farming system (inherited from European colonizers of the 18th and 19th centuries) still persists.

This land system is grosso modo comparable to Extremenian rangelands because its rationale is based both on extensive grazing and progressive clearing of the autochthonous forest (*Araucaria angustifolia*). They are large farms in which private owners use their communal lands (grasslands and cleared *Araucaria* forests) for extensive grazing and all of them own a piece of land for agriculture of self-consumption or sale in short-chain markets (e.g., yerba mate) [17]. The most interesting of this system is to understand how local farmers use their water (usually permanent streams and rivers) in farms aimed at extensive livestock husbandry in areas where water shortage is not common. Finally, we have to emphasize that faxinals are competing for surface water with large commercial cultivations of tobacco leaves that are also frequent in Prudentópolis [18].

2.2. Rangeland Farmers' Surveys

The survey to rangeland farmers was based on a socioeconomic questionnaire composed by 17 questions conducted during a research project focused on land assessment (Supplementary Material 1). The questionnaires were delivered during formation courses for livestock farmers organized by the Cáceres local headquarter of a well-known farmers union. This survey was responded by 54 farmers (around a half of those registered in this kind of activities). The first 11 questions of the survey were of economic matter and they have not been therefore considered in this research. The rest of questions were focused on water management: [Q12] temporal frequency of problems, [Q13] reasons, [Q14] degree of importance of some infrastructures and practices related to water for his/her farm, [Q16] role that public entities should play, and [Q17] management strategies. The most of questions were open with multiple choices and in case of scoring a degree (Q14) we have provided ordinal options

followed a Likert scale from 1 to 5, from the worst to the best conditions. Regarding the infrastructures and practices asked for the Q14 watering ponds, wells, transhumance and transterminance as well adequate stocking rangelands were dealt.

2.3. Arroyo de la Luz's Citizens Surveys

The survey to local people from the municipality of the Arroyo de la Luz was made in situ at Christmas 2018 during the holiday period by the second author of the manuscript (Alberto Alfonso Torreño). This period was selected because it is the time of the year when it is much easier to meet more people in the street and their responses are not biased by the feeling of heat. The questionnaire was composed by 28 questions divided into 4 blocks: [Q1–Q4] respondent characterization, [Q5–Q11] human consumption (Molano Reservoir), [Q12–Q16] traditional irrigation agriculture (huerta arroyana), and [Q17–Q28] scoring the degree of importance of several aspects related to water management (Supplementary Material 2). The most of responses were designed to obtain a single value within a Likert scale from 1 (lowest value) to 7 (highest value) although respondents had free to express their opinions in each question (these opinions were gathered and they have been used for contextualizing quantitative values). The questionnaire was responded to by 109 people. It supposed a level of confidence about 97% and an error range of 10% if we consider total sample is the number of inhabitants of the municipality (5811 in the last population census). Finally, we consider the responses given by local people are reliable because most of them felt excited by the fact of being surveyed since they consider their opinions can be helpful to improve some problems commonly accepted.

2.4. Water Quality

Water quality was assessed in a set of 22 watering ponds (ca. 80% of the existing ponds in the studied farms) that are belonging to the 5 rangelands farms of Extremadura by estimating only two parameters since laboratory analyses have a high cost: fecal coliforms and phosphates. They are indicators of water pollution provoked by animal excreta (released by the animals while drinking or transported by surface runoff) and agricultural activities made nearby (within the same hydrological basin), respectively. Sampling was carried out in September 2019 after a hydrological year 2018/2019 relatively dry (total rainfall: 300–450 mm). Water was collected from an undisturbed part of each pond by using a sterile 2-L plastic pot. These pots were transported in a portable refrigerator from the study sites until the laboratory where they were cold-stored at 4 °C until the beginning of the determination analysis. The concentration of phosphates (mg L^{-1}) was estimated by the ion-selective electrode (ISE) analytical technique [19] using spectroscopy and fecal coliforms (cfu mL^{-1}) by plating on violet red bile lactose agar (VRBL) incubated at 44 °C during 48 h (ISO standards No. 11133 and 4832). The determination analyses were made in a private laboratory regionally recognized by its long experience in the determination of this kind of chemical and microbiological analyses (CTAEX, *Centro Tecnológico Alimentario de Extremadura* (former laboratory of the company Nestlé), located in Villafranco del Guadiana (Badajoz), Spain).

2.5. Data Analysis

The study has combined data extracted from multiple sources of information: two different questionnaires surveys (qualitative and quantitative data), one water quality sampling campaign (two parameters in 22 sites), and opinions given by local experts (qualitative data used for describing remote cases and discussing our findings). The questionnaire surveys provided mostly descriptive data that were treated by basic statistical methods such as tables of frequency, percentage ratio, and descriptive parameters such as mean, median, minimum, maximum, standard deviation, coefficient of variation, etc. Water quality parameters were also treated by using basic descriptive statistical methods but the mean values of every 5 farms were compared by using the Kruskal–Wallis H test in order to find significant differences between groups. Bivariate analysis methods such as correlations (Pearson or Spearman depending on parameters show a normal distribution or not) were also performed with

the quantitative data (e.g., Likert-scale scores) gathered in the questionnaire surveys. The statistical analyses were made by the Statistica 6.0 software package.

3. Results

3.1. Extremenian Rangelands

From the questionnaire survey made to 54 rangeland farmers, knowledge on the 5 rangeland farms used as study cases (farms in which we are working in contemporary research projects) and the results of the two water quality parameters (phosphates and fecal coliforms) analyzed at the end of dry hydrological year (a priori the worst conditions), we confirmed water shortage conditioned by the lack of infrastructures and water pollution are the main problems identified in Extremenian rangelands. The source of these problems is multiple: erratic rainfall distribution, excessive numbers of animals, inadequate infrastructures, increasing of the pressure for water by livestock and hunting animals, eutrophication in reservoirs used as tributaries of the watering ponds, excessive content of nutrients in water bodies due to agriculture (fertilizers used in irrigation agriculture) and urban residues nearby, etc.

Figure 2 shows the table of frequencies in which respondents expressed the temporal frequency of their problems in water supply. Only 2 out of 54 admitted having problems every year meanwhile 15 out of 54 never have problems. 19 of them have problems during the dry years (annual rainfall below 500 mm). Curiously, only 7 out of 54 respondents (question 14) said water quantity is generally scarce contrasting to 16 out of 54 that recognized water quantity is usually abundant. Logically, a significant Spearman correlation ($r = 0.465$, $p < 0.05$) was found between the amount of water (Q14) and the temporal frequency of the problems (Q12) perceived by the farmers. In spite of all of them are managing farms within comparable climatic conditions and animal stocking rate did not show any significant correlation with any other parameter (questions of the surveys) the construction of watering ponds is significantly correlated to the construction of (borehole) wells ($r = 0.356$, $p < 0.05$). It means one-half of the Extremenian farmers are progressively adapting their farms to face climate change in terms of water supply while the other half could disappear in case of climate conditions become more arid.

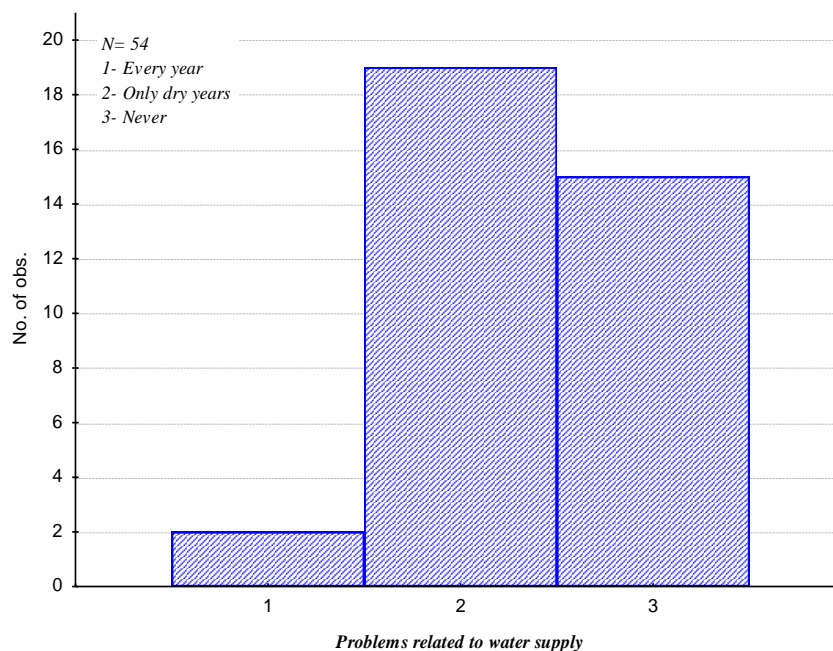


Figure 2. Temporal frequency of problems related to water supply in Extremenian rangelands.

Figure 3 shows the mean values of the concentrations of phosphates and fecal coliforms by farm in water sampled in September 2019, after a relatively dry hydrological year 2018/2019 (annual rainfall:

300–450 mm). The concentration of phosphates showed values above 0.01 mg L^{-1} in almost every pond with the exception of the farm PAR (1.33 mg L^{-1}) Table 2. In fact, the owner tries to not supply their animals of water from this watering pond because they are worried about possible diseases (e.g., diarrhea). Regarding fecal coliforms, used as indicators of water pollution provoked by animal excreta, values were relatively low except in the farm PAR (conventional rangeland) where some of its ponds recorded values above 6000 cfu mL^{-1} . Excessive values in nitrates have been also observed by the owner of the farm VAL (conventional grassland supplied by water from a nearby reservoir distributed by irrigation canals) but we have no analytical data to confirm it yet.

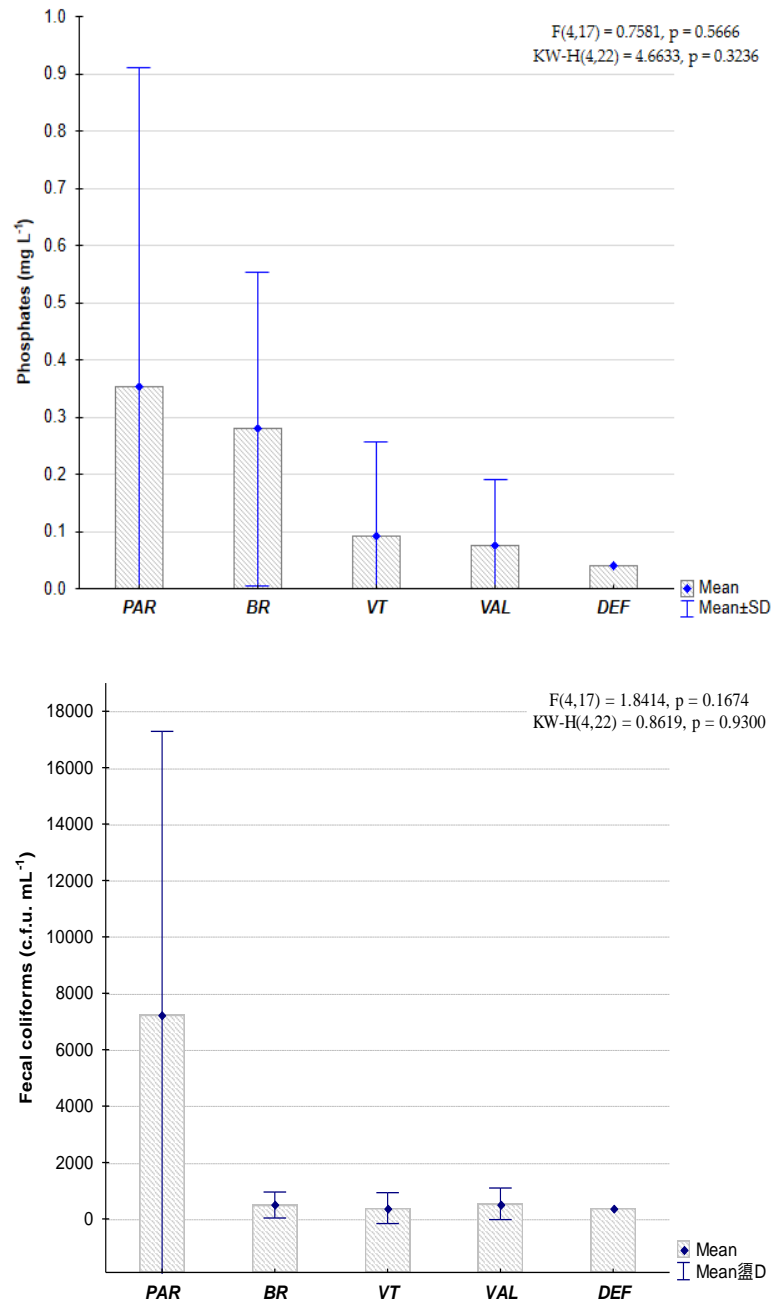


Figure 3. Mean values by farm of the concentrations of phosphates and fecal coliforms in water.

Table 2 shows some descriptive statistics of water quality parameters by farm. Values of phosphates ranged from 0.01 mg L^{-1} to 1.33 mg L^{-1} (observed in the farm PAR) and of fecal coliforms from 10 cfu mL^{-1} to $21,000 \text{ c.f.u. mL}^{-1}$ (also detected in a watering pond of the farm PAR). In addition, high data variability was also found.

Table 2. Main descriptive statistics of the parameters of water quality by farm.

Farm ¹	Parameter	N	Mean	Median	Min	Max	SD
PAR	Phosphates (mg L ⁻¹)	5	0.35	0.07	0.01	1.33	0.56
	Fecal coliforms (cfu mL ⁻¹)	5	7236	100	10	2,1000	10,053
BR	Phosphates (mg L ⁻¹)	6	0.28	0.21	0.01	0.75	0.27
	Fecal coliforms (cfu mL ⁻¹)	6	493	455	60	1300	460
VT	Phosphates (mg L ⁻¹)	6	0.09	0.04	0.01	0.29	0.11
	Fecal coliforms (cfu mL ⁻¹)	6	535	365	80	1600	559
VAL	Phosphates (mg L ⁻¹)	4	0.09	0.01	0.01	0.34	0.17
	Fecal coliforms (cfu mL ⁻¹)	4	383	145	40	1200	549
DEF	Phosphates (mg L ⁻¹)	1	0.04	0.04	0.04	0.04	-
	Fecal coliforms (cfu mL ⁻¹)	1	380	380	380	380	-

¹ We have used acronyms because some farmers have preferred to keep anonymous.

3.2. Arroyo de la Luz

The questionnaire survey in the municipality of Arroyo de la Luz reported some interesting findings: (I) widespread dissatisfaction with water quality for human consumption, (II) remarkable ignorance about the current agroecological initiative of the huerta arroyana and its historical importance as a provider of vegetables, (III) about 40% of local people believe Arroyo de la Luz has a single reservoir, that from water is consumed at home (Reservoir Molano), and (IV) widespread recognition of the importance of local water for human consumption, fishing, natural richness, species protection, and cultural legacy.

By using a Likert scale ranging from 1 (the worst mark) to 7 (the best mark) local citizens scored water quality for human consumption (tap water) with a mark of 2.8 out of 7.0. Only 18 out of 109 (16.5%) respondents admitted to drinking tap water but 13 out of them (11.9%) only if water is previously filtered. The rest of the people recognized they usually buy water bottles in the supermarket or go to natural water sources to stocking up. A total amount of 96 out of 109 (88.1%) respondents justified the bad quality of water for human consumption because it had bad taste and smell, brown color in summer, and some of them even stated water is polluted. Nevertheless, only 25 of them (22.9%) claimed having seen official data or having been informed by staff of the council. The degree of satisfaction with the service (managed by the local council) is 2.3 out of 7.0 in spite of the fact that only 25% of people pay monthly a bill above 50 EUR.

Regarding the historical importance of water management in the municipality only 78 out of 109 (71.6%) respondents recognized to know what the agroecological initiative huerta arroyana means and only 64 of them (58.7%) knew about its historical importance as a provider of vegetables in important markets such as Cáceres city. This ignorance about local water and its importance was also observed in the question about the number of reservoirs/watering ponds local people know. A total amount of 48 out of 109 (44.0%) stated they only knew 1 reservoir that is used for human consumption (Reservoir Molano). It means other activities such as wool laundry, power generation, irrigation agriculture, and fishing are being progressively forgotten.

Figure 4 shows the degree of importance given by local people to the different water uses. The highest marks were obtained by environmental purposes such as natural richness and species protection. It can be logical since Arroyo de la Luz has some protected areas belonging to the European Union Natura 2000 Network (Special Conservation Areas of Petit I (ES4320065) [20] and Lancho (ES4320064) [20] Reservoirs). Human consumption was scored with a mark of 5.0 out of 7.0. It means local people know to have enough water for them in spite of its presumably quality is really important. Fishing of species such as tench (*Tinca tinca*), a practice with a centennial tradition in the region, was scored with a mark of 4.6 out of 7.0. A similar mark (4.3) was obtained by the cultural legacy.

The lowest mark was reached by bathing activities such as swimming. It can be due to the proliferation of public and private swimming pools in the municipality since 1990.

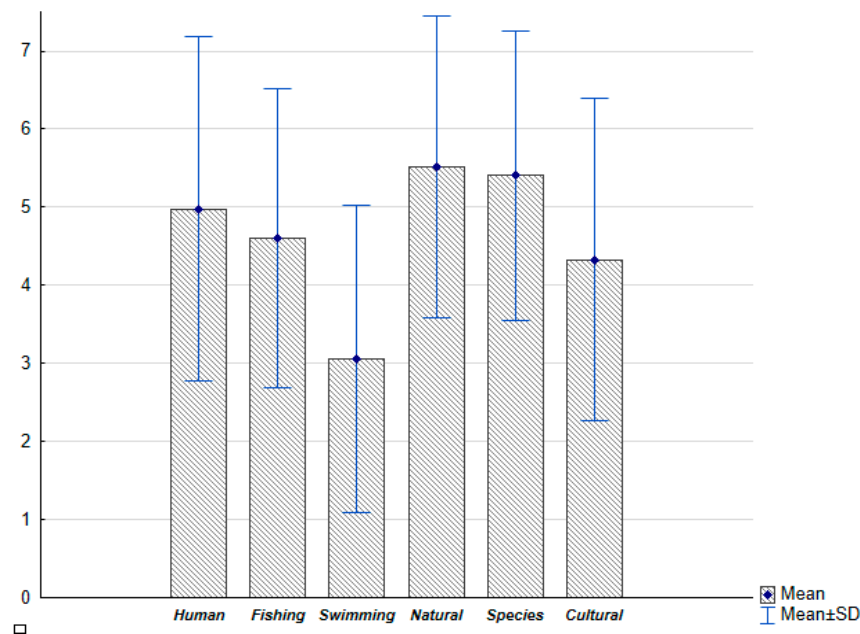


Figure 4. Degree of importance of different water uses scored by local people (N = 109).

3.3. Valdepajares de Tajo

As can be viewed previously on Figure 3, the farm Valdepajares de Tajo (VT) did not show evidence of chemical and/or microbiological pollution since its values of phosphates and fecal coliforms were quite low (Table 2). In addition, the farm has a storage capacity of 5 Hm³ of water (estimated from the relationships between pond surface and volume found by Marín Comitre et al. [11]) and the annual necessities of its livestock animals are less than 0.4 Hm³ (calculated from Luke [21]). So, neither water shortage is a problem for this farm. Therefore, this excess of water of relatively good quality is being a key issue to attract wildlife such as aquatic birds, hunting animals, and endangered species such as black storks (*Ciconia nigra*) and Iberian lynx (*Lynx pardinus*). Lynx feces have been observed inside the farm.

According to the words expressed by Carmen Perona (representing the staff of the farm Valdepajares de Tajo) the main problem the farm is now facing is the unintended arrival of invasive species such as *Azolla filiculoides* (Figure 5). The origin of this plague has been probably the transportation of this plant on a bird leg. This aquatic plant has occupied the total surface of some ponds in spring and it has avoided the entrance of sunlight and oxygen and consequently reduced the possibilities of surviving several aquatic species due to eutrophication processes. Another added problem related to this species is they can be reproduced by sporeling and fragmentation. So, it makes really difficult the viability of any eradication plan.

Another problem identified by Carmen Perona is the presence of non-native species of fishes such as *Gambusia holbrooki*, introduced in previous centuries to reduce the amount of malaria-transmitting mosquitoes (a worrying problem of human health until the 20th century). The voracity of these fishes is leading to the reduction of biodiversity of every pond. They arrived to this farm as a consequence of extreme rainfall events that allowed the connectivity with water bodies located upstream (outside of the boundaries of the protected site). The presence of other invasive species such as *Trachemys scripta scripta* (yellow eared terrapin) has been also reported (Figure 6). This species is particularly worrying because its reproduction capacity is three times higher than that of the autochthonous species of terrapins such as leper and European terrapins (*Mauremys leprosa* and *Emys orbicularis*) [22].



Figure 5. Water surface of one of the watering ponds of the farm in spring. Author: Carmen Perona.



Figure 6. Individual of yellow eared terrapin observed on the farm. Author: Jesús Barrena González.

The decision of leaving this watering ponds system as a naturalized system (its main input is rainfall) has been controversial because of its pros and cons. The smallest ponds reduce significantly its water content in summer and it means the death of some ictiofauna. Nevertheless, it is really positive for the community of amphibians (the most endangered due to climate change) because they can continue their chain of reproduction since their fry can be raised safely [23]. In fact, 13 different species of amphibians have been quantified in Valdepajares de Tajo (personal communication). The changes

in water level, therefore, ensure the life cycles of a greater number of species. Nonetheless, Carmen Perona expressed to us her worries about changes in water level and its alleged effects. The fluctuations in water depth of every watering pond are more evident each year since she began working in the farm (2015). The rainfall events are progressively generating a predominance of surface runoff processes instead of favoring water infiltration processes and the stabilization of the water table.

Other questions discussed during the interview was the role played by the livestock since it was reduced considerably in number 20 years ago in order to promote the recovery of native Mediterranean vegetation in the eastern half of the farm (locally known as the forest). Nowadays, grazing is becoming more important in land management (Table 1) but some uncertainties still persist. The increase in the number of livestock heads (from 0 sheep in 2010 to 120 sheep in 2020) or being the refuge of hunting animals within a context of increasing pressure on water could alter the microbiological balance of the watering ponds. In other words, fecal coliforms could increase, as well as the transmission of diseases between hunting and domestic animals.

Finally, two problems not detected yet in the farm but they can be problematic to artificial wetlands in the regional context were also mentioned and discussed: legal or illegal pumping of subsoil water and the widespread use of fertilizers and pesticides in the irrigation agriculture that can reduce significantly the number of invertebrates of the watering ponds, basal layer of the food chain of these ecosystems. As an alternative, Carmen Perona has proposed the implementation of new strategies such as key line design and mulching system-based cropping in order to optimize water resources.

3.4. Brazilian Faxinals

In spite of faxinal farmers (faxinalenses) having enough water for livestock consumption and self-consumption agriculture since humid subtropical climate is regularly rainy (annual rainfall ≈ 1500 mm), they also design watering ponds to profit from surface water particularly in those farms in which water does not pass in the form of an ephemeral or permanent stream and/or river. Livestock animals usually drink directly from these sources: ephemeral or permanent water courses and/or watering ponds (Figure 7). Nevertheless, these forms of storing water are not frequent in this part of Brazil and are more common in the northeast where climate conditions are drier.



Figure 7. Illustrative picture of a permanent stream used for livestock consumption in a faxinal farm of the municipality of Prudentópolis. Author: Valdemir Antoneli.

The watering ponds of faxinals, also called water contention areas, can be different in size and typology. From the smallest to the biggest size we distinguished between banhados, charcos, and lagoas. Banhados are generally created by the animals taking profit from the accumulation of water due to irregularities of the terrain and contact with the water table (size < 10 m²). This form of ponds is also created by wild boars (*Sus scrofa*) in Extremadura (Spain). Charcos could correspond to the watering ponds analyzed in Extremenian rangelands (size: 100–1000 m²). In fact, they are called charcas in Spanish. Finally, lagoas are usually used to irrigate tobacco and other irrigation crops (size > 1000 m²). In addition, other ponds called açude (weir) used for irrigation crops in places where it is not possible to pump up water from the river also exist (large size).

The main problems identified in these watering ponds have been, on one hand, the removal of riparian vegetation due to animal trampling and defoliation and, on the other hand, water pollution in form of turbidity (suspended sediments) and livestock microorganisms that can reach the main rivers when the rainfall intensity promotes surface runoff. In fact, animal paths that usually go from the paddock to the watering ponds enhance the connectivity of water and sediments and promote significant soil erosion. In agricultural areas (mostly dedicated to tobacco leaves production) the presence of watering ponds is more frequent. Nevertheless, they are designed only to store water during the harvest period (irrigation) not for the whole year. These water bodies are not usually polluted but they encourage indirectly the dissemination of fertilizers and pesticides used for intensive agriculture.

3.5. The Wilaya of Ouargla

The use of (surface and subsurface) water in the Algerian wilaya of Ouargla has a double purpose: irrigation agriculture and fish farming. The main crops are potatoes (*Solanum tuberosum*) and watermelons (*Citrullus lanatus*) as well as palm trees (*Phoenix dactylifera*) to pick up dates. Nevertheless, most of irrigated areas (irrigation perimeters) used water from the subsoil aquifers. It is provoking serious problems of salinization that is a common problem in all of Algeria and not only in Ouargla.

The watering ponds (in which rainfall water is stored) were firstly designed for irrigating nearby agriculture fields but they are being mainly transformed for fish farming although some of them are only used for agriculture. The main reason behind this decision is that Ouargla is located far away from the sea and fish have become a valuable resource in the daily diet of the inhabitants. This transformation has been supported by the Algerian government in order to guarantee the food sovereignty and self-sufficiency for the region.

Fish farming activities are also provoking problems of different types. One of them is that the water reaches high temperatures (due to climate change these temperatures will be presumably higher in the future) in summer and many fish die. Water pollution is also another problem identified so far. The origin of polluters is often agriculture (fertilizers and pesticides) and badly treated domestic wastes of settlements located nearby. Regarding fish farming, no problems have identified so far linked to the feeding of fish or with the introduction of non-native species.

The problem of high water temperatures is being currently solved by the design of a circuit composed of some pools used to decrease water temperature. These pools are very basic in their designs. They are normally cube-shaped with a surface area of 2 × 2 m and a depth of 3 m to reduce evaporation and heating. In a near future, perhaps water could be only refrigerated using industrial coolers that they will need energy and this system will stop being sustainable or eco-friendly.

4. Discussion

We have identified, broadly speaking, four significant problems in watering ponds designed for different purposes: water shortage and pollution, invasion of non-native species, and soil erosion, among many others such as low quality of tap water and lack of indigenous knowledge regarding water management.

Water shortage was already reported by Pulido Fernández and Schnabel [24] in 2010 in a similar study made from a telephone questionnaire survey. In this period of 10 years between both studies,

the percentage of farmers with problems of water scarcity for livestock consumption due to lack of infrastructures has decreased but it is still a pending task, particularly now when the effects of climate change will be more remarkable. The lack of economic profitability and the increasing worry of farmers for the quality of water that their livestock animals drink seem to be the reasons that many farms do not make a significant investment in the design of new watering ponds or the rebuilding of the existing ones. Another possible reason behind this fact is that watering ponds can be considered a hotspot of disease transmission (e.g., tuberculosis) between domestic and wild animals [25].

The problem of water shortage is a general issue in all of Spain as well as in many other Mediterranean countries. In other words, water scarcity is becoming a serious threat not only for cropping or providing drinking water for animals, but also for human consumption [26]. Water desalination seems to be a possible solution in geographical areas located near the sea [27]. Even so, within cities, some authors [28] have proposed the use of rainwater harvesting systems as an alternative to supply water for uses that require water of low quality (e.g., washing machines). The use of groundwater is probably the most extended strategy for reducing the negative impact of surface water shortage, but it cannot be sustainable in every context [29].

The pollution of water bodies by polluters of agricultural origin is a widespread and commonly-known fact [30]. In the case of Extremadura, this problem is not something particularly worrying in rangelands. It was only observed in some farms that share the same hydrological basin that some areas dedicated to the intensive agriculture. This latter is located in some regional areas where rangelands are not a common feature. The microbiological pollution caused by animal excreta seems to be much more worrying since the reduction of the animal stocking rate could be the most effective solution. In case the storage capacity of watering ponds decrease (something likely in future climatic scenarios), Extremenian rangelands will only be sustainable if the number of heads is too low or water resources start to be managed in a different way: i.e., creation of a network of healthy water points, deeper ponds to reduce evaporation, pumping up from the ponds to portable drinkers to avoid accumulation of excreta, recovery of traditional practices such as transhumance or transterminance, etc.

Regarding livestock husbandry, intensive farming is considered the main source of polluters to water bodies since great amount of wastes (manure and slurry) must be managed in their farms. In addition, they reach the water courses via fertilization in agricultural areas [31]. Within an extensive farming system, animal excreta do not seem to be a serious global threat since the concentration of polluters is only remarkable in water bodies located inside the farms. Nevertheless, farmers and authorities should pay more attention because pathogens and antibiotics can accumulate in the meat (presumably of high quality) that citizens eat [32].

The maximum values of fecal coliforms (≈ 7000 cfu mL⁻¹) and phosphates (1.33 mg L⁻¹) observed in some ponds are much higher than those suggested by the regulations in force. For instance, the Spanish Royal Decree 140/2003 and the EU Directive 98/83/CE on water quality for human consumption indicate water must not have any concentration of fecal coliforms. In the case of phosphates, the US EPA Gold Book [33] suggests a maximum value of 0.025 mg L⁻¹ for reservoirs. Nevertheless, these maximum values have been only observed in a reduced number of ponds being values within the limits proposed by the regulations the dominant in the most of watering ponds although fecal coliforms were detected in almost all cases.

The invasion of exotic aquatic plants is a serious problem that affects every water body of the whole territory of Extremadura region. The most worrying is the presence of water hyacinth (*Eichhornia crassipes*) and Mexican lily pad (*Nymphaea Mexicana*) in the Guadiana River (water used for irrigating crops of the agricultural belt of the region). Their origin was a person who threw it into the river after having used them as a decorative element in his garden [34]. In the case of smaller water bodies such as watering ponds, the presence of *Azolla filiculoides* introduced by birds on their legs is being to be a serious problem since it compromises the survivorship of many amphibians species. A problem related to the invasion of this kind of aquatic plants have been already reported in other remote areas such as the Caspian Sea [35], in Europe [36] and specifically in Mediterranean temporary

wetlands [37]. Nevertheless, the efficiency of *Azolla filiculoides* in phytoremediation to recover polluted water bodies has been also confirmed [38–40], as well as an alternative to remediate problems of salinization [41].

Other source of polluters that should be considered, at least in the wilaya of Ouargla (Algeria), is the untreated domestic residuals. Urban settlements are usually located near both agricultural fields and also watering ponds for fishing farming. There is not a strong network of wastewater treatment plants yet, and these residues consequently arrive to watering ponds altering their chemical and microbiological balance [42]. The efficiency of wastewater treatment plants has been already assessed in neighbor semi-arid areas such as Egypt [43], but it still lacks consistent works carried out in Algeria to properly understand the magnitude of the problem since the convenience of integrating fishing farming and agriculture has positively assessed [14].

Untreated wastewater is one of the main environmental problems caused by the rapid growth of population, particularly in the developing countries [44]. In the United States and the European Union, regulations on wastewater treatment are strict [45,46] and it does not seem to be the main source of polluters to the water courses [47]. Nevertheless, significant efforts should be still made to reduce the reaching of fertilizers and pesticides from agriculture to water courses and bodies [48].

In the specific case of the Brazilian faxinals, the alteration of riparian vegetation seems to be the driver that leads to soil erosion and an increase in the turbidity of the main rivers. This fact has been deeply studied by the interviewee (Prof. Valdemir Antoneli) and his team, although most of their works have been published in Portuguese [49]. The riparian restoration trying to introduce native species of flora and fauna could be a good strategy to reduce the effects of this problem of systems based on communal lands. In fact, Flesch and Esquer [50] have reported quite positive results from their experience in private and communal lands in NW Mexico.

Changes in riparian vegetation due to fluctuation of water level have been already reported also in Mediterranean areas [51]. In fact, Richardson et al. [52] detected problems of degradations (as Antoneli et al. [49] in Brazil) accompanied by alien plant invasion (similar to the problems detected in some of our study areas). These alterations in the riparian vegetation mean also degradation in the ecological networks of the riparian ecosystem [53].

Finally, the generalized refusal of drinking tap water by local people is a fact that has been already detected in other similar work carried out in the Extremenian municipality of Arroyo de San Serván [54]. It must suppose a deception for stakeholders and decision makers because local councils invest a lot of money to ensure the arrival of water of quality to the tap of every home. Another concern is how the traditional water use is being lost or at least little recognized by the younger generations. Perhaps it can be explained by the overall context of the Extremadura region embedded in a serious problem of depopulation, ageing, and emigration of young people [55].

5. Conclusions

This multi-case study has served to identify some problems in watering ponds designed for several purposes in different climatic and socioeconomic contexts: shortage, pollution, invasive species, and soil erosion, among many others. We have detected water shortage in transitional climatic areas such as the Spanish region of Extremadura. In addition, livestock have been identified as another source of polluters (in Spain and in Brazil) and the creation of artificial wetlands is a door of entrance for invasive species. This actually hides more serious problems related to land management that are putting at risk the sustainability of land-water system of long tradition in many cases. Water shortage is a consequence of the lack of infrastructures of many farms and it could be worse if climate conditions become more arid. Water pollution and the invasion of exotic species are induced by conflicts between land and water use and management. In the Extremenian rangelands and in the Algerian fishing farming ponds nearby agricultural activities seem to be the source of many polluters. In addition, wild fauna are introducing new diseases and invasive species as well as increasing the pressure on water for drinking. Finally, we have also observed a disconnection between local people and the

recognition of their natural resources as well as a disregard for tap water despite the efforts made by the administrations to guarantee its potability.

Supplementary Materials: The following are available online at <http://www.mdpi.com/2076-3298/7/9/63/s1>, S1: Rangeland farmers' questionnaire, S2: Arroyo de la Luz citizens' questionnaire.

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