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Endangered aquatic plants and fiber crafts in Solis chico river basin: Urban impact and rural development in Uruguay

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Abstract

This research examines the interactions between artisans and the use of flora, focusing on aquatic macrophytes from the Solis Chico River Basin (Yasiry) in the Uruguayan pampa biome, within the context of current human and climatic influences. Recently, the Solís Chico River which runs for 47 km until it flows into the La Plata River, had a strong deviation to the west, causing coastal and wind erosion. The study was descriptive and qualitative, conducted in a humid zone at 34º 45' 27'' S, 55º 41' 40.8'' W, using semi-structured interviews with artisans. The results revealed five species of importance to handicrafts with vegetable fiber, *Juncus effusus, Typha angustifolia var. domingensis, Cyperus rotundus, Cynara cardunculus and Butia* sp. The severe droughts in the last years (2022-2023) have made *Cyperus rotundus* more vulnerable, while floods affect *Typha angustifolia.* Eighty percent of the species cited by the artisans are on the Red List of Threatened Species, which could impact the bioeconomy of handicrafts soon. The research suggests establishing forests for handcraft use and active germplasm banks to boost populations and support environmental sustainability, as these species also serve as bioindicators within the Solis Chico River Basin.

Keywords: Environments; Aquatic macrophytes; Conservation; Bioeconomy

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC, 2023) reports that human activities have raised greenhouse gas emissions, causing global temperatures from 2011 to 2020 to rise by 1.1ºC compared to 1850–1900. Land temperatures increased by an average of 1.59ºC, while ocean temperatures rose by 0.88ºC. The report notes that in 2019, atmospheric concentrations of CO2 reached 410 ppm, which is the highest level recorded in the past 2 million years. Methane levels were at 1866 ppb and nitrous oxide at 332 ppb, both representing the highest concentrations observed in the last 800,000 years. South America is divided into seven climate change reference regions by the IPCC: NWS (Northwest), NSA (North), NES (Northeast), SAM (Monsoon), SWS (Southwest), SES (Southeast), and SSA (South). It is in the last region, southern South America (SSA) that Uruguay is located, as well as the Solís Chico River Basin (Yasiry).

The climate of Uruguay according to Koppen's classification is of the Caf type, that is, temperate, moderate, rainy and humid. In view of the latest changes or climatic anomalies experienced in Uruguay, the recent National Emergency System (Sinae) was created. According to the Statistical Yearbook 2024 (INE, 2024), the average annual rainfall in 2023 was 1,089.8 l/m2, with a minimum temperature of 12.9oC and a maximum of 23.8oC, therefore, higher temperatures and a reduction in precipitation compared to previous years, following the global profile. This research aims to document and analyze the speech and daily perspectives of artisans in the Solís Chico Basin (Yasiry) regarding local climate change and its impact on their handicraft activities.

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2. Theoretical frameworks

Thus, there is so far no research that discusses the impact of urban advancement on the environment and the riparian flora of the Solis Chico River Basin (Yassiry) and its consequences for those who depend on this aquatic flora, the artisans of vegetable fiber. But what do they think and what are the narratives about local climate change of those who daily depend on the ecosystems in the Solis Chico Basin, such as artisans for example in contexts of the last severe droughts in Uruguay?

The Solis Chico (Yasiry) Basin has been seen with greater attention since the constitutional reform of 2004 and the National Water Policy Law of 2009, where the National Water Directorate (DINAGUA) begins to promote sustainable and participatory water management, with the basins as the management unit. Thus, in 2023, the Comisión de Cuenca del Arroyo Solís Chico was created through DINAGUA. Therefore, 3 large basins are recognized, the Cuenca del Rio Uruguay, the Cuenca de la Laguna Merín and the Cuenca del Río de la Plata y Frente Maritime, the latter composed of 3 smaller basins, the Santa Lucía river basin, the Cisne lagoon basin and the Laguna del Sauce basin. The Yasiry-Solís Chico River basin is discussed in the context of Laguna del Cisne (Ministerio de Ambiente, 2024).

Environmental studies in the Cisne Lagoon (Goyenola 2017), the historical evolution of total phosphorus levels in the waters has increased since 1989. The total phosphorus concentration was around 430 and 520 μg P L-1 in the 2016 and 2017 samplings respectively, which represents values well above the limit established by Decree 253/79, which provides for a total phosphorus content (TP) < 25 μg P L-1. These data already suggest processes of eutrophication of water, which is characterized as a problem for potability and consequently for society that has in Laguna del Cisne its main source of water for drinking. The causes for the increase in phosphorus levels in water surfaces are almost always related to the most diverse anthropogenic activities, and it is in this context that the sustainable management of lagoons is urgent, including the Yasiry-Solis Chico River. This river, which has its origin in the Cuchilla Grande, runs for more than 47 kilometers until it flows into the Río de la Plata. However, its outlet to the sea was radically diverted to the west, which produced erosion on the right bank, resulting in large sand hills associated with wind erosion, with environmental and urban damage.

Thus, global climate impacts, associated with a scenario of diversion of the Yasiry-Solis Chico River, the effects of wind and water erosion, siltation of the river and processes of eutrophication of the waters, will impact, if not already impact, directly the social actors, such as artisans and artisanal fishermen who have flora (aquatic macrophytes) resources as their main sources of income. Changes in the composition of fish and zooplankton communities have already been observed in Arroyo Solís Chico, in 2021, a female carp Cyprinus carpio of 56 cm in length and 4,580 kg was captured, as well as Kellicottia bostoniensis, both exotic and invasive species, which already suggests signs of environmental disturbance, especially in relation to the community of fish and native zooplankton (Maquisá et al., 2023).

Integrating rural environments with urban expansion is a difficult equation. Research in this regard points out that integrating changes in rural land use with the inclusion of artisanal productive activities can balance sustainable urban growth with the preservation of agricultural land (Hu et al 2025), thus avoiding ripple effects, i.e., the loss of environmental conservation over time. In analogy, what would be the best strategies to equate the conservation of the Solis Chico River, specifically its aquatic macrophyte flora of interest to local artisans, in parallel with the real estate expansion over the Basin? How to make this binomial a strategy of environmental conservation in urban contexts, a new urban?

According to the National Plan for Adaptation to the Coastal Zone before Variability and Climate Change (Nap-Costas 2021) of the Uruguayan Ministry of Environment, rising sea levels and increasingly strong storms are already observed, which represent significant coastal threats not only to urban populations living on the coast of Uruguay, as well as for wetland ecosystems (humedalles). Considering, therefore, that the humid areas of Uruguay are important niches for providers ecosystem services, especially because they filter the water, as well as being spawning areas for various species of fish, any serious anthropic or climate disturbances in locus could be affected local fishermen and artisans. A more holistic approach to water resource management to achieve the Sustainable Development Goals should be preferred over segmented approaches (Momblanch 2022). This research aims to document and analyze the speech and daily perspectives of artisans in the Solís Chico Basin (Yasiry) regarding local climate change and its impact on their handicraft activities.

3. Methodology

3.1. Site studied

Uruguay has three main macro basins: the Uruguay River (113,608 km^2), Merín Lagoon (28,777 km^2), and Río de la Plata with its Maritime Front (34,016 km^2). The Solís Chico River basin forms part of the La Plata River Basin and its maritime front. It is represented by a tripartite commission consisting of civil society, users, and government representatives, established in August 2023. This commission serves as a consultative and deliberative body regarding the management of water resources in the Solís Chico River (Ministry of the Environment/Uruguay, 2024). In April 2024, we interviewed artisans using aquatic macrophytes along the Solis Chico River, at 34°45'27'' S 55°41'40.8'' W (see Figure 1).

Source: Google Earth Platform

Figure 1 Satellite view of the study area in the Solis Chico River Basin (blue marker), Department of Canelones, Uruguay

3.2. Interview protocol

This study used semi-structured interviews (Manzini 2004), allowing flexible interactions between researcher and participant within a set script. The questionnaire had the following structure: 1. Which plant species are used in handicrafts found in the Solis Chico (Yasiry) Basin? 2. Is there a predominance of one plant species over the others, that is, is any plant more aggressive than another in the colonization processes of the same area? 3. Which plant species are most sensitive to drought? 4. Which plant species are most sensitive to flooding? 5. Have any species reduced their life cycle in recent years? 6. Have you observed the effect of climate change on your handicraft activity over the last few years? 7. Free space for narratives.

4. Results

Artisans' accounts show that handicraft practices have continued for two generations, with oral knowledge transfer remaining essential today. One of the interviewees, since the age of 12, has been collecting plants on the banks of the Solis Chico River (Yasiry) and making handicrafts taught by his uncle; nowadays he is 45 years old and, therefore, for 33 years he has been extracting plants from these humid environments. This provides an opportunity to consider the significance of these environments and their flora for handicraft production, and consequently, their impact on the income of artisan families.

Considering the impact of current works such as the transposition of the course of the Solis Chico River and the erosion processes observed and documented by the Ministry of Environment of Uruguay through the technical-scientific reports of researchers (Kruk 2006; Goyenola 2011a, 2017b) associated with the effects of local and global climate change, what future will such social actors have on a 20-year scale? The socioeconomic impact on the activity of handicrafts in the Yasiry-Solis Chico River Basin is probably to be expected, since the species used by them, mostly aquatic macrophytes,

depend on this river and the reduction of water depths because silting processes could have a quantitative and qualitative impact on native aquatic macro flora present.

From an environmental biochemistry perspective, aquatic macrophytes play a role in decreasing levels of nutrients, organic matter, and microbiological pollution indicators (Diniz et al 2005). According to the same authors, the presence of aquatic macrophytes reduced ammoniacal N by 78% and Nitric N by 42%. Likewise, there was a reduction of total phosphorus (Pt) by an average of 50% and phosphate (PO4 -3) by 42% in the water depths studied. High total phosphorus levels in Uruguay's wetlands, linked to flora extraction by artisans and silting of rivers and lakes, indicate environmental, social, and economic impact some of which are already evident.

Five plant species from five botanical families are used by artisans in the Solis Chico River Basin (see Table 1). Three of these, or 80% of the sample, are listed as threatened by the IUCN, raising significant concerns about the sustainability of local handicrafts using vegetable fibers.

Table 1 Plant species used in handicrafts cited by interviewed artisans, Solis Chico River Basin, Uruguay, 2024. *LC: Least Concern category of Red List

Scientific Name	**Botanical Family**	**Common Name**	**Included in the Red List of Threatened Species (category)**
Juncus effusus L.	Juncaceae	Junco	Yes (LC)*
Typha angustifolia var. domingensis (Pers.) Griseb.	Typhaceae	Totora	Yes (LC)
Cyperus rotundus L	Ciperaceae	Cipó tiririca	Yes (LC)
Cynara cardunculus L.	Asteraceae	Cardo	No
Butia sp. (Becc) Becc.	Arecaceae	Butia	Yes (LC)

Five botanical families of plants used in handicrafts highlight these wetlands value to the plant fiber bioeconomy. All species except thistle are native, as noted by one interviewed artisan:

"These plants we use are considered pests for most people, but not for us."

This statement confirms artisans' reliance on local plants and their belief in their ongoing availability. However, river and lagoon silting decreases coastal depth, leading to large macrophyte banks (Tomáz 2002). This fact in the case of plants useful for handicrafts in the Yasiry-Solis Chico River Basin may be favorable or not, depending on which macrophytes may prevail in this relationship of aggressive colonization of wetlands, arising from silting processes.

5. Discussion

According to one of the artisan interviewees, there is a predominance of one of the plants, the reed (*Juncus effusus* L.) in river habitats, while in small streams (wetlands) there is a predominance of the totora plant (*Typha angustifolia* var. Pers. Domingensis). As for the reed, it is a rhizomatous aquatic macrophyte belonging to the Juncaceae family with stems that can reach up to 1.3 m and is present in the Pampa Biome (Irgang 1996), in coastal wetlands (humedalles).

The genus *Juncus* is a genus with a global distribution, composed of about 300 species (Brooks and Clemants 2000), being a perennial plant, densely cespitose with short rhizomes, erect stem, without leaf blades, green, smooth to imperceptibly striated. In addition to being widely used by artisans in Uruguay, known as junqueros, cutters or weavers (SNAP 2010), the reed provides an important ecosystem service, as it serves as a shelter for invertebrates, tadpoles and fingerlings, in addition to being a phytoremediation species of water and soil, that is, it cleans the environment by immobilizing toxic elements that may be present.

However, the entry of saline water into the environment of Solis Chico River Basin could reduce the population of *Juncus effusus* due to salt stress. Only a few species of *Juncus* are resistant to salinity, such as *Juncus maritimus* L and *Juncus acutus* L. (Al Hassan et al 2016). Such species present as strategies of salinity tolerance the osmotic adjustment by increasing the content of carbohydrates and proline in their tissues. Juncus effusus was introduced on the IUCN Red List of Threatened Species in 2016 (IUCN), being in the category of Least Concern (LC), considering that the next stage is already Near Threatened (NT).

Our data suggest, therefore, that *Juncus effusus*, is a bioindicator of environmental sustainability in la Cuenca Solis Chico (Yasiry), its occurrence indicates balance and its absence, environmental disturbances. Considered one of the key species for Uruguayan handicrafts, then strategies aimed at increasing the population of the species such as plantations through the collectives and cooperatives involved in the reed bioeconomy would be essential for the species not to advance on the Red List of Endangered Species, as the anthropic pressure on this resource is great.

In this context, the diversion works of the mouth of the Solis Chico River and the rise in sea level contribute significantly to the increase in anthropogenic pressure on the reed (Ju*ncus effusus* L.), which may economically compromise in the not-too-distant future the activity of small artisans in the Solis Chico Basin. Associated with this, the severe floods that are currently observed in Uruguay considered as anomalies such as that of March 20, 2024 (National Emergency System -Sinae/DINAGUA), where the Santa Lucia River rose 12 meters and the Uruguayan territory was under red alert, clearly represent the effects of global climate disturbances with local effects.

As for the totora plant, *Typha angustifolia* var. *domingensis* (Pers.) Griseb. belongs to the Typhaceae family, which has two genera, *Sparganium* and *Typha* (Matos 2020). *Typha angustifolia* appears to have been introduced from Europe to the Atlantic coast in colonial times and is found in freshwater environments and nutrient-rich brackish marshes at altitudes < 2000 m (Jepson Herbarium). They are aquatic plants occurring in humid and swampy areas, with an herbaceous, rhizomatous habit, and can reach up to 3m in height. They have a certain physiological plasticity because they support freshwater environments, as well as environments with low levels of salinity. Considering the frequent and severe floods in Uruguay and the Solis Chico Basin, associated with the narrative of artisans that this species is already sensitive to floods, then it is also another plant useful for handicrafts that already shows signs of disturbance in its natural habitat, due to the increase in salinity in estuarine environments.

Similarly to *Juncus effusus, Typha angustifolia* var. *domingensis* function as bioindicators of environmental sustainability in the Solís Chico basin, their absence would indicate environmental disturbance. Another use of *Typha angustifolia* fibers (Bidin et al 2015) is related to the pulp and paper industries. These authors analyzed five aquatic macrophytes, *Cyperus digitatus, Cyperus halpan, Cyperus rotundus, Scirpus grossus* and *Typha angustifolia* and concluded that *Typha angustifolia* (44.05 ± 0.49%) presented the highest cellulose contents than the other species, *Cyperus rotundus* (42.58 ± 1.32%) and *Scirpus grossus* (36.21 ± 2.81%) suggesting the high potential of totora (*Typha angustifolia*) for the manufacture of paper with higher tensile strength, rupture length and low moisture content compared to cellulose from tree species.

Ethnobotanical studies in southeastern Europe have pointed to the use of *Typha angustifolia* for the manufacture of barrels for brandy, pillow, doors, and beach mats in countries such as Romania, Serbia, and Turkey (Nedelcheva 2011). The totora (*Typha angustifolia*) is also on the Red List of Threatened Species in the Least Concern category, however the next category is already Near Threatened (NT). Thus, our data indicate that the time is now to increase the population of both reeds and totora through the cultivation of plants of interest to handicrafts, to ensure the sustainability of this Bioeconomic activity over time in wetlands in the Uruguayan Pampa.

As for the vine, nutsedge or swordfish (*Cyperus rotundus* L.), also mentioned by the artisans, it has been shown to be sensitive to drought, according to their perception. It is a plant of the Ciperaceae family, an upright, terrestrial and aquatic herb that can grow on clumps of aquatic vegetation. According to data from the National Institute of Agricultural Research of Uruguay (INIA) the species *Cyperus esculentus, Cyperus rotundus and Cyperus difformis* are considered pests in rice fields, but for the activity of handicrafts they are extremely important. Comparing the extracts of two herbs, one *Cyperus rotundus* and the other *Cynodan dactylon* on the growth of 3 rice varieties, was observed that the allelopathic effect of *Cyperus rotundus* was more potent in terms of inhibiting germination percentage, seedling length, number, dry mass and chlorophyll contents of 15-day-old seedlings of rice (Kavitha 2015). This species is considered, therefore, one of the most aggressive in different agricultural production systems and this is because it has an allelopathic effect, that is, inhibition on seed germination and plant development. The species entered the Red List of Threatened Species in 2017, being in the category of Least Concern, considering that the next stage is already Near Threatened; Therefore, increasing the population of this species would be an important strategy to keep the handicraft activity dependent on the tiririca vine sustainable.

The aqueous extracts of *Cyperus rotundus* showed an allelopathic effect on the inhibition of seed germination of *Brassica campestris, Brassica oleracea var. botrytis, Brassica oleracea var. capitata, Brassica oleracea* var. *italica*, *Brassica rapa* and *Raphanus sativus* (Andrade et al 2009). The allelopathic potential of the species explains its aggressiveness in the colonization processes of cultivated areas and is related to the presence of phenolic compounds such as isocurcumenol (Melo 2001). An allelopathic effect of *Cyperus rotundus* extracts was also observed in the germination of Amaranthus

spinosus at a dose of 150g/liter of water, reducing germination by 95%, demonstrating the technological potential of the species as a natural herbicide in agroecological production modes (Amrullah et al 2024).

According to the narrative of one of the artisans, it should also be observed, in view of the diversity of plants used in handicrafts, that their behavior has been shown to be different due to the recent droughts and floods in the region of the Solis Chico River.

"The nutsedge vine is more sensitive to drought, while the totora plant is more sensitive to floods."

Considering the increasingly severe droughts as pointed out by SINAE (2023), as a result of the El Niño effect, management plans to cope with water stress have been built since then, and it is also necessary to think about strategies for these plants useful to handicrafts and sensitive to drought such as *Cyperus rotundus* and not only for species produced on a large scale such as rice and soybeans. Since October 2022 the entire Uruguayan territory has been on alert for drought, this period being the longest in the last 100 years, ending in September 2023, where the months of January and February of the same year, reached the most extreme anomalies (-2.1 and -2.2) respectively (INUMET 2023).

Thus, climate change in Uruguay is already real, both due to the prolonged months of drought (2022-2023) and the intense rainfall and storms (2024), which in turn are due to global disturbances, such as global warming and increased greenhouse gases. Monitoring these species over time is necessary, especially regarding their population in these contexts of climatic disturbances.

Thistle (cardo) was another plant pointed out by artisans as important in the manufacture of fiber handicrafts. The thistle, *Cynara cardunculus* L., belonging to the Asteraceae family, is a perennial plant with large biomass production, being native to northern Europe and Africa and introduced in Uruguay in the colonial period. *C. cardunculus* it is an erect herb that grows between 60 and 150 cm, reaching up to 2 m and with root growth up to 2 m (Parsons and Cuthbertson 2001; Elzebroek and Wind 2008), with thick and rigid stems. The species has multiple uses, with its stalks and flowers being edible, it has potential for pulp and paper production, in addition to its seeds having expressive linoleic acid contents and can be used as biodiesel (Gominho et al 2018).

Such characteristics reinforce the technological potential of the cultivation of this species for unconventional uses. Thistle also showed potential for biofilm production, and its biomass is an important source of bioactive compounds, such as sesquiterpene lactone, cynaropicrin, and grosheimin in the leaves, as well as proteins extracted from seeds (Myrpoor et al 2022). Studies also showed the nutraceutical potential of extracts containing *Cynara cardunculus* restoring peripheral vascular endothelial function in adults with hepatic steatosis and early atherosclerosis (Mauroti et al 2024).

In this way, the thistle with its multiple uses is a super plant and present in humid areas under anthropogenic pressure in the Solis Chico River Basin in the Uruguayan pampa and can be used as a bioindicator of environmental sustainability. However, in disturbed or degraded areas, the thistle can be an invasive plant capable of reducing native vegetation (Marushia and Holt (2006). Thus, it is necessary to monitor the populations of thistle in the Solis Chico River, especially in degraded or deforested areas, to verify if the species (*Cynara cardunculus*) will be able to put pressure on the other species, changing the landscape.

And finally, *Butia* sp. (Becc.) Becc, this genus has 22 species and was cited by artisans as important to the activity of handicrafts with vegetable fiber. This species, which belongs to the Arecaceae family and subfamily Arecoideae (Fior 2011), also has multiple uses (food, oil, beverage, handicrafts), although the anthropogenic pressure observed on the butiais through conversion to monocultures or pastures, associated with the slow growth of individuals, already configures a population decline of the species (Soares and Witeck 2009) and Nazareno et al. (2011).

According to the Institute of Historical and Artistic Heritage of the State (IPHAE, 2023) of Rio Grande do Sul, the Proposal for Registration of the Way of Making Handicrafts with Butia Straw in the region of Torres (RS) as an intangible cultural asset of the rural community that has historically been associated with Butiais since the nineteenth century. The products made with the straw of butia leaves are diverse such as baskets, hats, bags and rugs, among others. In the Uruguayan pampa, on the other hand, there is still no such recognition, although the handicrafts are similar with the same biodiversity resource, the butia. Five species of Butia have already been on the Red List of Threatened Species since 2018, both in the vulnerable and threatened categories (IUCN) with species populations decreasing.

This scenario suggests questions to reflect on, such as, how much longer do the populations of *Butia* sp. in the Uruguayan pampa biome keep their populations stable? At what point should human intervention through butias plantations begin?

In the Solis Chico Basin (Yasiry), local artisans operate in an environment where the flora already faces varying degrees of vulnerability. Our findings contrast sharply with studies reporting that 27.3% of global mangroves benefit from urbanization in terms of extent and carbon stock, with 59.5% of these effects indirectly influenced by climate (Wei 2024).

Our data point to the urgency of developing public policies aimed at this group of artisans from the Solis Chico River basin (Yasiry), whose bioeconomy is based on the flora of aquatic macrophytes and terrestrial riparian macrophytes in these wetlands. Likewise, thinking about increasing the population of species of interest to handicrafts that are threatened through the formation of ex situ Germplasm Banks can be an alternative. The model of ex situ Germplasm Banks are spaces where species whose germplasm is threatened are cultivated to store this material against possible extinction in the future and are located outside the place of origin (ex situ) and may be within universities or research institutions (Silva et al 2007). Thus, an active ex situ germplasm bank with cultivation of Juncus effusus, *Typha angustifolia* var. *domingensis*, *Cyperus rotundus* and *Butia* sp. can be a strategy for the conservation of flora of interest to handicrafts in the face of anthropogenic urban pressure on the Solis Chico River Basin (Yasiry).

6. Conclusion

The variety of flora, especially aquatic macrophytes, is vital for artisans' livelihoods in the Solis Chico River Basin (Yassiry), highlighting the need to conserve these wetlands. Artisans note that this plant life is already affected by extended droughts and floods. Government agencies in Uruguay have confirmed these climatic anomalies, supporting the artisans' perspective. Additionally, 80% of the cited species, Juncus effusus, Typha angustifolia var. domingensis, *Cyperus rotundus* and *Butia* sp. are listed as threatened. Our data indicates that establishing forests for handcraft purposes and ex situ germplasm banks could increase these species' populations. Strengthening public policies for productive groups that rely on aquatic macrophytes in the Solis Chico River Basin (Yasiry) and including them in climate emergency plans through supportive engagement, is vital to maintaining small-scale economic activity (fiber craft chain) and ensuring their productive inclusion.

Compliance with ethical standards

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Disclosure of conflict of interest

There are no conflicts of interest to declare.

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