Review

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Systematic review of the uses of *Cortaderia selloana* (Poaceae), an invasive plant

Revisión sistemática de los usos de *Cortaderia selloana* (Poaceae), una planta invasora

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Abstract:

Background and Aims: *Cortaderia selloana*, commonly known as Pampas Grass, manifests as an invasive plant across numerous countries with predominant studies focused on its control measures (physical, biological, and chemical approaches). Native to South America, this perennial tussock grass negatively impacts economic, environmental, and human health. This study aims to explore the diverse uses of *Cortaderia selloana* in geographical, cultural and ecological contexts, to provide insights into its applications, and to contribute to socio-economic and ecological understanding.
Methods: This study comprises a systematic literature review based on the PRISMA 2020 guidelines. The search was conducted in EBSCOhost, ScienceDirect and Web of Science using the search question "("*Cortaderia selloana*") AND ("use" OR "purpose") NOT ("control")". Two researchers independently reviewed the titles and abstracts, applying predefined inclusion and exclusion criteria and extracting data on various aspects covered in the selected studies.
Key results: A total of 88 articles were retrieved of which 16 were included in this systematic review. This study described diverse applications attributed to *Cortaderia selloana*, including wastewater treatment, composite synthesis, traditional medicine, bioremediation, biorefining, product development in the automobile industry and decoration. The utilization of this invasive species demonstrated socio-economic and environmental benefits, providing a novel perspective on transforming something harmful into a resource with various applications. Furthermore, the necessity for more research is emphasized, to enhance understanding of known applications and explore new potential uses. This study's main limitation is that it only includes peer-reviewed articles from selected databases.
Conclusions: This research provides valuable insights into the diverse uses of *Cortaderia selloana* across geographical, cultural, and ecological contexts. These findings underscore the importance of considering both the beneficial applications and the challenges posed by this invasive species in order to inform balanced and sustainable management practices.

Key words: environmental impacts, invasive species, resource management, sustainable uses.

Resumen:

Antecedentes y Objetivos: *Cortaderia selloana*, conocida como hierba de la pampa, es una planta invasora en numerosos países, con estudios predominantes centrados en sus medidas de control (enfoques físicos, biológicos y químicos). Originaria de América del Sur, esta hierba perenne tiene impactos negativos en las dimensiones económica, ambiental y de salud humana. Este estudio busca explorar los diversos usos de *Cortaderia selloana* en contextos geográficos, culturales y ecológicos, ofreciendo perspectivas sobre su utilización y contribuyendo a la comprensión socioeconómica y ambiental.
Métodos: Este estudio comprende una revisión sistemática de la literatura, siguiendo las directrices PRISMA 2020. La búsqueda se realizó en EBSCOhost, ScienceDirect y Web of Science con la consulta "("*Cortaderia selloana*") Y ("uso" O "propósito") NO ("control")". Dos investigadores revisaron de forma independiente los títulos y resúmenes, aplicando criterios de inclusión y exclusión predefinidos y extrayendo datos sobre diversos aspectos cubiertos en los estudios seleccionados.
Resultados clave: Entre los 88 artículos recuperados, 16 se incluyeron en esta revisión sistemática. El estudio identificó diversas aplicaciones atribuidas a *Cortaderia selloana*, incluido el tratamiento de aguas residuales, la síntesis de compuestos, la medicina tradicional, la biorremediación, la biorefinación, el desarrollo de productos en la industria automotriz y la decoración. La utilización de esta especie invasora demostró beneficios socioeconómicos y ambientales, ofreciendo una nueva perspectiva sobre la transformación de algo perjudicial en un recurso con diversas aplicaciones. Se enfatiza la necesidad de más investigaciones para mejorar la comprensión de las aplicaciones conocidas y explorar nuevos usos potenciales. La principal limitación es que solo incluye artículos revisados por pares de bases de datos seleccionadas.
Conclusiones: Este estudio proporciona información valiosa sobre los usos de *Cortaderia selloana* en contextos geográficos, culturales y ecológicos, subrayando la importancia de equilibrar sus aplicaciones beneficiosas con los desafíos que plantea para fundamentar prácticas de gestión equilibradas y sostenibles.

Palabras clave: especies invasoras, gestión de recursos, impacto ambiental, usos sostenibles.

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Introduction

Invasive plants are species that have been transported from their natural habitat to other locations and have rapidly and uncontrollably proliferated, eluding human control, and becoming harmful, causing negative environmental and economic impacts (PIP, 2020). There are many invasive species in Portugal, such as *Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn., which is included in the National List of Invasive Species in Portugal, according to Annex II of Decree-Law No. 92/2019 (PIP, 2023b).

Cortaderia selloana, also known as Pampas Grass, presented in figure 1, is a perennial, tussock grass native to South America, including southern Brazil, Argentina, and Uruguay (Pausas et al., 2006). It has been introduced into many regions of the world for ornamental purposes in gardens, appreciated for its showy plumes, and for practical uses such as soil amendment and windbreaks (Pausas et al., 2006). This invasive species belongs to the family Poaceae, reaching heights of 2 to 4 m and widths of 1 to 2 m (Montserrat, 2022). It has large leaves (1-3 m) with serrate margins and its inflorescence consists of several large plumose panicles, ranging from light violet to silver-white (Montserrat, 2022). These panicles produce thousands of tiny wind-dispersed seeds that facilitate its invasion (Montserrat, 2022). Flowering occurs from August to October but may occur sporadically at other times (PIP, 2023b).

The species is gynodioecious, meaning that some plants produce hermaphrodite flowers while others produce only female flowers (Connor, 1973). Hermaphrodite plants primarily act as pollen donors, resulting in low seed production, with a panicle from a female plant producing more than 50,000 seeds, while hermaphrodite plants produce an order of magnitude fewer seeds. The seeds can germinate under a wide range of environmental conditions, with improved rates under shade, sandy soils, and water availability (Montserrat, 2022). In addition to sexual reproduction, it also has asexual reproduction, that is, vegetative reproduction. The latter can occur when tillers are fragmented and are placed in contact with the soil (Almeida et al., 2024).

In its native range, Pampas Grass is common in moist soils in grassland plains, dunes, sparse shrublands and

Figure 1: *Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn. Near Madalena Beach, Vila Nova de Gaia, Porto, Portugal.

riverine habitats (Montserrat, 2022). However, the species has become invasive in many regions, encroaching on old fields, riverine areas, and marshlands worldwide, posing a threat to various ecosystems (Pausas et al., 2006). This is due to the plant's ability to tolerate various environmental conditions, such as different degrees of water availability, soil textures, drought, shading, and water salinities (Domènech and Vilà, 2008; Almeida et al., 2024). This invasiveness has raised significant conservation concerns, particularly as it encroaches on old fields, impeding restoration efforts aimed at transforming these areas back into wetlands where certain rare or endemic species thrive (Pausas et al., 2006).

This plant has significant impacts on economic, environmental, and human health levels. Economically, its invasiveness leads to dense stands that damage pastures, interfere with wooded areas, reduce road visibility, and hinder access to natural areas like riverbanks, resulting in substantial control costs (Montserrat, 2022). Environmentally, the plant affects habitats by lowering soil nitrogen levels and increasing the carbon-to-nitrogen ratio due to the low decomposition of dead leaves (Montserrat, 2022). The accumulation of dry leaves and senescent stems also increases the risk of wildfires (Montserrat, 2022). Additionally, it outcompetes native plants, causing a decline in biodiversity (Montserrat, 2022).

On the human health front, its airborne pollen can trigger allergies and its sharp leaves can cause superficial cuts (Rodríguez et al., 2021; Montserrat, 2022). It is noteworthy that this species can extend the period of grass allergies, constituting a relevant environmental health issue due to the strong impact of respiratory allergies on the human population (Rodríguez et al., 2021; Montserrat, 2022).

The control methodologies used for *Cortaderia selloana* include physical control, like hand pulling (with protective gloves), mechanical pulling, cutting and removing the rhizomes and panicle cutting; chemical control with herbicides (glyphosate is the most widely used); biological control, like grazing by cattle (successful in New Zealand); movement control (restricts against the movement of unprotected panicles across natural areas); and chemical control combined with mechanical removal (Montserrat, 2022; PIP, 2023b). Burning and foliage clipping are not effective as the plant resprouts vigorously, and any detached plants should not be left on the soil surface (Montserrat, 2022; PIP, 2023b).

Considering the high costs associated with the control of invasive species, it is useful to explore applications for the invasive species *Cortaderia selloana* (Jardine and Sanchirico, 2018). No reviews are available regarding the uses attributed to *Cortaderia selloana*. Therefore, this work systematically reviewed the uses attributed to *Cortaderia selloana* to demonstrate the potential benefits of the plant and to explore its functionality, providing insights into its utilization.

This study aims to answer the research question: What are the uses attributed to *Cortaderia selloana* across diverse geographical, cultural, and ecological contexts, and how do these applications contribute to its socio-economic and environmental significance?

Materials and Methods

Screening and study selection

This study consists of a systematic review that followed the PRISMA 2020 guidelines (Page et al., 2021). Systematic reviews, an essential tool for synthesizing existing research on a topic, can provide comprehensive and unbiased summaries of the current state of knowledge. They help to identify gaps in the literature, inform future research directions, and can address questions that individual studies may not be able to answer due to limited scope or sample size. By following a rigorous and transparent methodology, systematic reviews minimize bias and increase the reliability and reproducibility of their findings (Page et al., 2021).

The search was conducted on July 3, 2024, covering three major databases: EBSCOhost (EBSCOhost, 2024), ScienceDirect (Elsevier, 2024) and Web of Science (Clarivate, 2024). The key words "*Cortaderia selloana*", "use", "purpose", "control" were combined using Boolean Operators to formulate the search equations, which were as follows:

("*Cortaderia selloana*") AND ("use" OR "purpose") NOT ("control") in ScienceDirect

("*Cortaderia selloana*") AND ("use*" OR "purpose*") NOT ("control*") in EBSCOhost and Web of Science

Subsequently, the search results from these databases were exported to Rayyan (Ouzzani et al., 2016), a tool chosen for its capability to efficiently manage, organize, and accelerate collaborative review (Ouzzani et al., 2016). Utilizing Rayyan in an active blind mode, where the decisions and labels of one collaborator were hidden from other collaborators, two independent researchers conducted the initial screening of articles based on their titles and abstracts. The search strategy was meticulously designed to identify relevant studies that describe the uses of *Cortaderia selloana* as an invasive species observed across various countries.

The accepted name and correct author abbreviations of the studied species were confirmed through the Tropicos database (Tropicos, 2024).

Selection criteria

There was no time restriction, and the languages of the included studies were English, Portuguese, and Spanish. The inclusion criterion encompassed studies that described the uses of *Cortaderia selloana*. Conference abstracts, systematic reviews, reviews, meta-analyses, editorials, study protocols, scale design and validation studies, correspondence papers, and studies that were not within the scope of our study were excluded. The inclusion and exclusion criteria were applied by two researchers.

Data analysis

Data extraction retrieved information that was summarized in table format (Table 1), capturing essential information about each study, including author(s) and year to reference the original studies, type of study which denotes the research design (such as experimental or observational) providing context for the research methodology, and location specifying the geographic region where the study was conducted. Additionally, the table includes the use, describing the general category of use identified in the study (such as wastewater treatment or bioremediation), and the detailed use, which elaborates on the specific application or context in which *Cortaderia selloana* was utilized. Furthermore, the part of the plant used identifies the specific part (such as leaves, stems, or roots) utilized in the study, offering insight into the application of different plant components. Finally, the description of use provides a thorough explanation of how *Cortaderia selloana* was employed, including the methods employed. This table allows for a succinct yet comprehensive comparison of the various research approaches and applications involving *Cortaderia selloana*.

Results

A total of 88 articles were retrieved, of which 16 were duplicates. The resulting 72 articles were screened by title and abstract. Of these, 55 records were excluded as they did not agree with the inclusion criterion. Thus, 17 reports were analyzed by full text to check eligibility and one was excluded because of the lack of detailed use. Hence, 16 articles were included in this systematic review. The PRISMA 2020 (Page et al., 2021) screening results flowchart is shown in figure 2.

The search yielded 16 articles, with most of them (13) being experimental studies related to wastewater treatment, composite synthesis, bioremediation, biorefining and product development in the automobile industry. The remaining three articles were observational studies, providing insights into the popular medicinal use and decorative applications of *Cortaderia selloana*.

The characterization of the included studies in this systematic review is presented in table 1. They were grouped based on their uses, and the table includes information about the study type and location. Regarding the use, details such as the specific use, part of the plant used, and mode of use are provided. A notable number of studies were conducted in Iran (six), where the uses included composite synthesis and wastewater treatment. Turkey was the second country with the highest number of studies (three) focusing on water treatment and product development in the automobile industry. Portugal and Argentina each had two studies, with Argentina focusing on popular uses and Portugal on bioremediation and biorefining. Furthermore, a variety of plant parts were utilized across the diverse range of studies.

The number of articles based on uses attributed to *Cortaderia selloana* is represented in figure 3. This systematic review revealed that, up until now, several uses have

Table 1: Overview of systematic research results on the uses of *Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn. Experimental (E), Observational (O), Organic matter (OM), ammonia nitrogen (NH_4^+-N), sulfate (SO_4^{2-}), chemical oxygen demand (COD), biological oxygen demand (BOD_5), total suspended solids (TSS), orthophosphate (PO_4-P), nitrate nitrogen (NO_3^--N), total nitrogen (TN), total phosphorus (TP), lead (Pb), zinc (Zn).

Article	Study type		Location	Use	Detailed use	Part of the plant used	Description of use
	E	O					
Hernández et al., 2009		X	Argentina	Popular Medicine	Digestive, diuretic, laxative and relieves liver dysfunction	Leaves	The leaves were prepared by decoction and administered orally.
Hilgert, 2001		X	Argentina		Against parturition hemorrhage	Roots	An infusion was prepared with five flowers of *Agalinis fiebrigii* (Diels) D'Arcy/*Agalinis genistifolia* (Cham. & Schltdl.) D'Arcy in 250 ml of boiling water. This infusion was then mixed with approximately 5 cm of the root of *Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn. and consumed multiple times over a span of about two days.
					Postpartum pain		A decoction was prepared using a small handful of *Adiantum thalictroides* var. *hirsutum* (Hook. & Grev.) (or *Adiantopsis chlorophylla* (Sw.) Fée), with approximately 5 cm of *Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn. root added to the previous recipe. It was consumed cold, sweetened with honey, several times a day over a period of about 10 days.
Abhari et al., 2020	X		Iran	Synthesis of composites	Production of green nanocomposite for removing lead ions from aqueous solution through adsorption	Synflorescences	The synflorescences were sun-dried to achieve complete dehydration and pulverized. The sample was then soaked in phosphoric acid solution and filtrated. The raw material was carbonized, washed with hot distilled water and dried. This process resulted in the production of activated carbon from *Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn. which was utilized in green nanocomposites.
Afsharpour and Khomand, 2019	X		Iran		Synthesis of bio-inspired porous silicon carbides as remarkable sulfur adsorbents	Whole plant	The herbs were cleaned, immersed in water/ethanol under ultrasonic conditions, dried and placed with starch solution. After 24 hours, the mixture was carbonized at 750 °C under argon atmosphere. Magnesium powder was added based on silicon weight, and silicon carbides samples were synthesized by heating the composites at 700 °C for 6 hours under an argon atmosphere.
Khan et al., 2021	X		Iran		Reinforcement material for the manufacture of composite materials	Stems	The stems were collected, immersed in water and retted into fibers by a traditional combing process using a fine wire brush. Following this, the fibers were dried in sunlight to remove the moisture content.
Momin et al., 2022		X	India	Decoration	Wall decoration	Synflorescences	The synflorescences were left to dry (natural drying technique) on the plant itself and were harvested when fully dried.

Table 1: Continuation.

Article	Study type E	Study type O	Location	Use	Detailed use	Part of the plant used	Description of use
Costa et al., 2021	X		Portugal	Biorefining	Convert biomass from *Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn. into valuable products in a biorefinery context	Tillers	The biomass from *Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn. was collected by cutting whole tillers at the soil level from non-senescent plants. Any seeds, seed-bearing or flowering structures were discarded. All samples were stored at -80 °C until being freeze-dried. Once dry, stems were separated from leaves (including sheaths) and individual organs were ground and passed through a perforated plate screen. Some biomass underwent pre-treatment and some did not.
Parlayıcı and Pehlivan, 2021	X		Turkey	Wastewater Treatment	Remove dyes, methylene blue and malachite green, from aqueous solution	Synflorescences	*Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn. synflorescences were washed, meshed, and dried. Magnetic synflorescences were synthesized using a chemical precipitation method, and were mixed with $FeCl_3.6H_2O$ and $FeSO_4.7H_2O$ in water at pH 10. The reaction occurred at 50 °C for 1 hour with stirring. The result was filtered, washed, decanted and dried at 40 °C.
Temel et al., 2018	X		Turkey		Remove OM, NH_4^+-N and $SO4^{2-}$ from domestic wastewater	Whole plant	Planted in the corresponding unit of horizontal subsurface flow constructed wetlands.
Gholipour and Stefanakis, 2021	X		Iran		Remove OM (BOD_5, COD), TSS, PO_4-P, NH_4^+-N and NO_3^--N of hybrid constructed wetland on university dormitory wastewater	Whole plant	Planted in the perimeter of the vertical flow constructed wetland bed to enrich the biodiversity and to upgrade the landscape view of the facility. The constructed wetland was also planted with *Arundo donax* L. and *Phragmites australis* (Cav.) Steud.
Gholipour et al., 2020	X		Iran		Remove of OM (BOD_5, COD), TSS (like silica particles), TN and TP from wastewater from the glass industry	Whole plant	Planted in horizontal sub-surface flow constructed wetland filled with locally sourced natural gravel. Initially, *Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn. was cultivated in pots and then transplanted to the wetland surface.

Table 1: Continuation·

Article	Study type E	Study type O	Location	Use	Detailed use	Part of the plant used	Description of use
Saber et al., 2018	X		Iran	Wastewater Treatment	Remove sulfate from wastewater	Whole plant	*Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn. was prepared for hydroponic cultivation by rinsing with distillated water to remove soil and debris and then placed in containers filled with synthetic wastewater. The plants were maintained at 20±1 °C, with a 12-hour cycle of indirect daylight and darkness, and a relative humidity of approximately 60%. To acclimate the plants to hydroponic conditions, they were placed in containers filled with distillated water for seven days before sulfate exposure.
Xu et al., 2021	X		China		Remove NH_4^+-N, NO_3^--N, TN, TP, and COD in eutrophic water	Whole plant	*Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn. was used as an individual plant. The roots were cleaned and the stems were rolled up with a sponge and fixed onto circular foam boards with holes. Nonporous flowerpots of specified dimensions served as water containers with foam boards containing fixed plants floating on the water, creating simulated ecological floating beds. The plants underwent a two-week preculture in tap water and were subsequently treated with eutrophic water after establishing roots.
Couto et al., 2012	X		Portugal	Bioremediation	Remediation of contaminated soil with petroleum hydrocarbons contamination at a refinery	Whole plant	The plant was collected inside the refinery from an area with different contamination from that observed in the studied soil. After collection and division into smaller parts, four specimens of the plant were transplanted separately in each container without prior root washing.
Flores-Torres et al., 2021	X		Mexico		Phytostabilization of Pb and Zn in metal-polluted tailings	Root and shoots	The plant was utilized to examine the accumulation of these metals in its roots and their subsequent translocation to shoots.
Yavuz et al., 2024	X		Turkey	Product development in automobile industry	Developing vehicle brake pads	Whole plant	The collected *Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn. biomass was cleaned, dried, and portions were chopped into 2 mm pieces. These pieces were then mixed with other components such as barite, powdered novolac resin (as a binder), cashew powder (as a friction regulator), and brass powder (to dissipate heat). These mixtures were subsequently molded under specific conditions to create brake pad samples, which were then tested for tribological performance, including friction and wear characteristics.

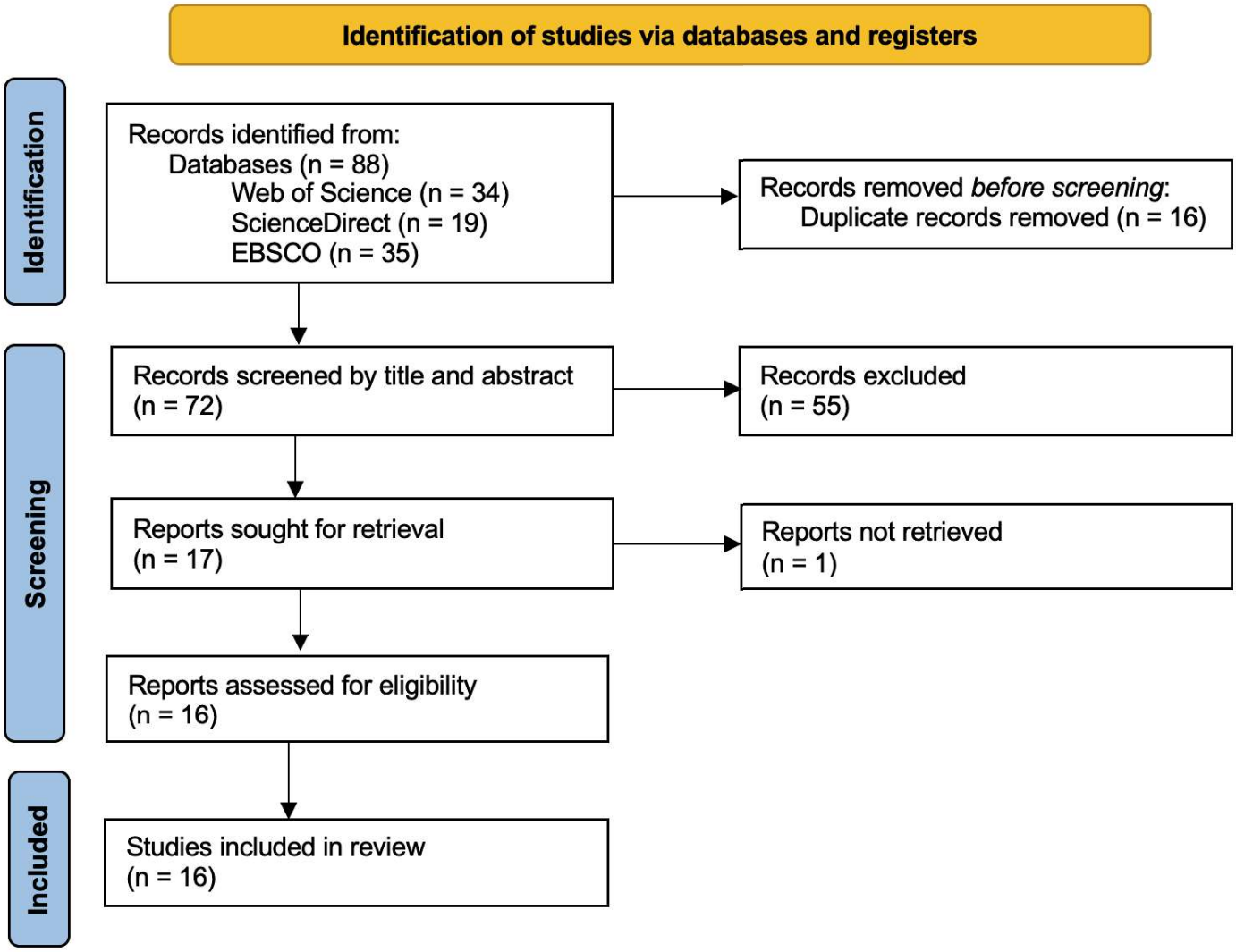

Figure 2: PRISMA 2020 flowchart detailing the study selection process for the systematic review, including identification, screening and inclusion of studies.

been attributed to this species. These include wastewater treatment, synthesis of composites, bioremediation, popular medicine, biorefining, decoration and product development in the automobile industry.

Discussion

Wastewater treatment

The most studied application was wastewater treatment, which has been conducted in Turkey, Iran, and China. All the studies on this application were experimental. Except for the research of Parlayıcı and Pehlivan (2021) where only the synflorescences were used, the entire plant was utilized. According to Parlayıcı and Pehlivan (2021), the biodegradable biosorbent, derived from the *Cortaderia selloana* synflorescence, proved to be ideal for the removal of dyes from wastewater, specifically methylene blue and malachite green.

The studies demonstrate that it was possible to remove large variety of pollutants from wastewater, including ammonia nitrogen (Temel et al., 2018; Gholipour and Stefanakis, 2021; Xu et al., 2021), nitrate nitrogen (Gholipour and Stefanakis, 2021; Xu et al., 2021), total suspended solids (Gholipour et al., 2020; Gholipour and Stefanakis, 2021) and orthophosphate (Gholipour and Stefanakis, 2021). Additionality, Xu et al. (2021) and Gholipour et al. (2020) revealed the capacity to remove total nitrogen and total phosphorus from water.

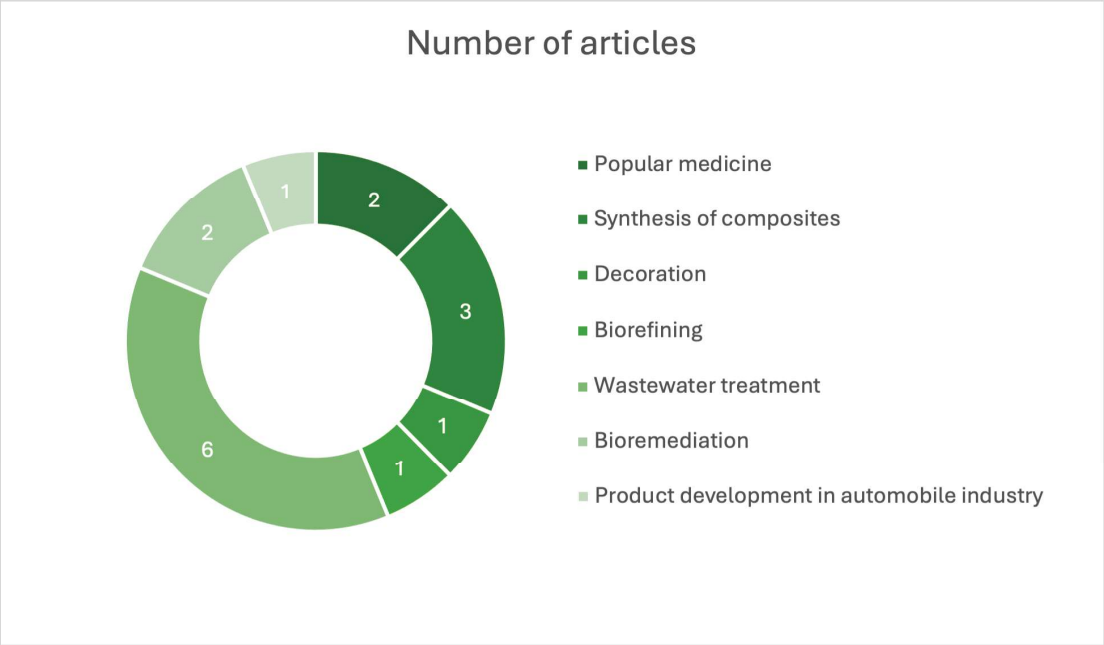

Figure 3: Graphical distribution of articles by uses of *Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn.

Organic matter, according to Temel et al. (2018), Gholipour et al. (2020), Gholipour and Stefanakis (2021) and Xu et al. (2021), was also removed from wastewater using *Cortaderia selloana*. The removal of organic matter by this species is quantified by the parameters COD (chemical oxygen demand) and BOD_5 (biological oxygen demand). In the study by Temel et al. (2018), pre-treatment was implemented, because the suspended solids entering directly into the system can cause clogging, which is the main problem of the treatment beds.

Also, Temel et al. (2018) and Saber et al. (2018) demonstrated that *Cortaderia selloana* could efficiently remove sulfate from wastewater. This was a significant finding because chronic exposure to high sulfate-waters has been described as problematic and may lead to diseases (Saber et al., 2018). Additionally, elevated sulfate concentration was described as toxic to plants (Saber et al., 2018).

Thus, the use of *Cortaderia selloana* in wastewater treatment has many advantages, such as a good and effective choice economically, environmentally, and feasibly for treating wastewater, contributing to the conservation of freshwater resources. Additionally, synflorescences are a favorable option as a biosorbent for water treatment applications requiring rapid techniques, because it is a low-cost biosorbent that can be easily obtained and separated from the aqueous solution, allowing for repeated use (Parlayıcı and Pehlivan, 2021). Moreover, Gholipour et al. (2020) showed that *Cortaderia selloana* was capable of removing silica particles, revealing the potential benefit of using this species in wastewater treatment from glass industry that produces high amount of silica particles not easy to remove. Employing this species facilitates the recycling and reuse of water, minimizing health damage due to the removal of pollutants that can harm humans.

In their research, Gholipour and Stefanakis (2021) also employed *Arundo donax* L. (Poaceae). This species, like *Cortaderia selloana*, is an invasive species in Portugal and is a large perennial grass (PIP, 2023a). *Arundo donax* has demonstrated in another study efficiency to treat various polluted waters, suggesting effectiveness in removing organic pollutants, macronutrients, microbiologic cells, and heavy metals (Zhang et al., 2021). Similarly, *Cortaderia selloana* has been found to facilitate water treatment by effectively removing various pollutants and can be used for this purpose (Zhang et al., 2021).

Synthesis of composites

The synthesis of composites constituted the second most studied application of *Cortaderia selloana*. This utility was investigated through experimental studies conducted in Iran. According to Abhari et al. (2020), the synflorescences of *Cortaderia selloana* were used to produce activated carbon, which was then employed in the synthesis of a green nanocomposite. This green nanocomposite, based on copper benzene-1,3,5-tricarboxylate (HKUST-1) and active carbon from the synflorescences, enabled the adsorption of leads ions from aqueous solutions (Abhari et al., 2020).

Khan et al. (2021) studied the properties of its stem fibers to assess their potential as a natural fiber in eco-friendly composites. These fibers were obtained by collecting the stems of *Cortaderia selloana*, retting them into fibers through a traditional combing process with a fine wire brush, followed by drying them (Khan et al., 2021). This study demonstrates the capability of *Cortaderia selloana* to be used as reinforcement material for the manufacture of composite materials (Khan et al., 2021). According to Afsharpour and Khomand (2019), *Cortaderia selloana* can be utilized in the synthesis of bio-inspired porous silicon carbides (SiC), which serve as an excellent source of silicon for SiC preparation and have proven to be highly effective sulfur adsorbents (Afsharpour and Khomand, 2019).

The composites synthetized using *Cortaderia selloana* not only afforded environmental and human health protection, but also offered a cost-effective procedure. Additionally, the green nanocomposites based on HKUST-1 and activated carbon from this species demonstrated significant potential for use as a functional material in the ink formulation of lead sensors (Abhari et al., 2020). Furthermore, the stems of *Cortaderia selloana* possessed the advantage of replacing synthetic fibers in semi-structural applications due to the desirable properties for reinforcing polymer matrices (Khan et al., 2021). Also, the porous silicon carbide synthetized with *Cortaderia selloana* allowed the removal of sulfur compounds in a model fuel, showcasing a notable advantage of this composite (Afsharpour and Khomand, 2019). This is because the release of sulfur compounds into the atmosphere is known to cause significant environmental and health problems (Afsharpour and Khomand, 2019).

Bioremediation

Cortaderia selloana, as indicated by two experimental studies, demonstrated potential for utilization in bioremediation. In Portugal, the entire plants of this species were used in the remediation of soil contaminated with petroleum hydrocarbons at a refinery (Couto et al., 2012). Consequently, this species exhibited the ability to enhance the mobility of hydrocarbons, especially of the more recalcitrant compounds, thereby promoting their degradation (Couto et al., 2012). In metal-polluted tailings in Mexico, *Cortaderia selloana* was utilized to investigate the accumulation of lead and zinc in their tissues and their translocation to shoots (Flores-Torres et al., 2021). Hence, this study highlighted a significant potential role in the phytostabilization of lead and zinc, as evidenced by metal accumulation in roots and translocation to the shoots (Flores-Torres et al., 2021).

It is noteworthy that the benefits of bioremediation of another invasive grass species have been documented by various studies. For example, a review study on the potential application of *Arundo donax* in bioremediation highlighted its ability to uptake a wide variety of heavy metals from the environment (Zhang et al., 2021). Additionally, this review study on *Arundo donax* revealed the capability for metal accumulation in its tissues, analogous to the findings presented in this review about *Cortaderia selloana* (Zhang et al., 2021).

Bioremediation involved removing or mitigating the effects of environmental pollutants that had adverse effects on the health of plants, animals, and humans (Ayilara and Babalola, 2023). Therefore, with careful control to prevent seed dispersal, *Cortaderia selloana* can contribute to the creation of a safer and more sustainable environment.

Popular medicine

Through observational studies selected, it was possible to identify the popular medicine use of *Cortaderia selloana*. This occurred in one of the native countries of the species,

Argentina, where different parts of the plant were used according to the specified purpose (Hilgert, 2001; Hernández et al., 2009). The leaves, prepared by decoction and administered orally, were used as digestive, diuretic, laxative and to relieve liver dysfunction (Hernández et al., 2009). Additionally, the roots were used against postpartum pain and parturition hemorrhage (Hilgert, 2001). However, as per this study it is necessary to make the decoction (in case of postpartum pain) or infusion (in case of preventing parturition hemorrhage) with other plants (Hilgert, 2001).

The widespread use of this species and its pharmacological activities require further investigation. It is plausible that this species, along with others from the same family, possess biological activities that could contribute to human health. For example, *Arundo donax*, traditionally used to treat conditions such as dropsy, cancer, condylomata, breast indurations, pertussis, and cystitis, and serving as an antigalactagogue, depurative, diaphoretic, diuretic, emollient, hypertensive, sudorific, and hemostatic agent, has been the subject of research to understand its biological properties (Al-Snafi, 2015). The latter research has demonstrated that *Arundo donax* exhibits antibacterial, antifungal, anthelmintic, antifeedant, and antiproliferative properties (Al-Snafi, 2015). Moreover, this species has been found to influence milk production, fattening performance, smooth muscle function, and the central nervous system (Al-Snafi, 2015). These findings underscore the potential health benefits of invasive plants and the necessity for continued research in this area.

Despite the studies being conducted in the same country, the variations in popular medicinal uses described can be associated with the different regions studied, specifically Buenos Aires and the Zenta River basin (Hilgert, 2001; Hernández et al., 2009).

Biorefining

An experimental study realized in Portugal demonstrated the possibility of using tillers of *Cortaderia selloana* as a source of biomass that could be converted into valuable products in a biorefinery context (Costa et al., 2021). Consequently, lignocellulosic biomass from high-biomass-producing by *Cortaderia selloana* could serve as a valuable material to produce a wide range of industry-relevant products (Costa et al., 2021). However, the biorefinery of plant biomass was limited by cell wall recalcitrance and to address this issue it is necessary to apply fungal pretreatments, with or without a combination with mild alkali, followed by saccharification, and pretreatment liquid fraction analysis (Costa et al., 2021). This study also demonstrated the biorefining potential of *Arundo donax* and *Phragmites australis* (Cav.) Steud., which also grows spontaneously throughout Southern Europe, including Portugal, in a manner similar to *Cortaderia selloana* (Costa et al., 2021).

The resources obtained through the biomass of *Cortaderia selloana* could contribute to the industry, create capital, and the potential added value to this spontaneous grass species could generate a financial incentive for voluntary biomass culling by landowners (Costa et al., 2021). This, in turn, could help reduce the accumulation of excessive biomass in marginal and unused lands, providing new uses for these areas and their vegetation, like other related species (Costa et al., 2021). However, it is important to recognize the risks associated with its use, and any utilization of the plant must be carefully controlled to prevent further spread and mitigate its invasive potential.

Decoration

An observational study conducted in India described the use of *Cortaderia selloana* for decoration, where the synflorescences were left to dry through natural dry technique on the plant itself, and once completely dry, they were then harvested (Momin et al., 2022).

Product development in automobile industry

A study demonstrated that brake pads developed using *Cortaderia selloana* biomass exhibited a consistent friction coefficient and low wear rate, particularly in samples containing 12% of the biomass of this plant. This suggests that *Cortaderia selloana* can be effectively used as a component in brake pads, contributing to environmentally friendly and efficient automotive products (Yavuz et al., 2024).

Limitations and future perspectives

This study allowed the systematization of the applications of *Cortaderia selloana*, characterizing them and identifying their prospective contribution to environmental sustainability and socio-economic development. However, it exhibited certain limitations that require discussion.

One of the primary limitations was the data selection strategy, which predominantly relied on titles and abstracts. While this method proved effective for initial screening, it may have resulted in the potential exclusion of pertinent articles where critical information may not have been fully reflected in their titles or abstracts.

Another limitation of this systematic review was the absence of a bias risk appraisal, which could potentially have affected the overall solidity of the conclusions drawn. However, it was not possible to find a checklist that suited the data analyzed in this study. Future research in this domain should prioritize a thorough evaluation of bias risk to enhance methodological rigor and strengthen the validity of findings presented in this review.

Additionally, *Cortaderia selloana* was understudied and the peer reviewed studies about the species were predominantly associated with invasion control. As a result, there was a lack of exploratory research on its potential uses and benefits. This limitation emphasizes the urgent need for future investigations in this field to bridge this knowledge gap and offer a more comprehensive understanding of the potentialities of this species.

Therefore, it is crucial to conduct more studies on the applications of *Cortaderia selloana*, investigating not only its known potential uses but also exploring new applications in different domains. For instance, conducting *in vitro* studies on the biological activities of this species associated with its traditional use could be particularly relevant. Furthermore, as observed, some invasive species exhibit utility, making it worthwhile to explore their uses, with the goal of deriving benefits from what is known to be harmful.

Conclusion

In conclusion, this review provides valuable insights into the potential uses of *Cortaderia selloana* across diverse geographical, cultural, and ecological contexts. These findings suggest that this species has a variety of potential applications.

It can be employed in wastewater treatment, demonstrating the capability to remove dyes, organic matter (such as chemical oxygen demand, and biological oxygen demand), ammonia nitrogen, sulfate, total suspended solids, orthophosphate, nitrate nitrogen and total nitrogen. Also, it exhibits potential in the synthesis of composites, such as green nanocomposite, bio-inspired porous silicon carbides, serving as an alternative source as reinforcement material in composite manufacturing.

Traditionally, *Cortaderia selloana* is used as digestive, diuretic, laxative and to relieve liver dysfunction, postpartum pain and parturition hemorrhage. Additionally, it shows promise in bioremediation, contributing to the remediation of soil and the phytostabilization of metals. This species has the potential to be converted into valuable products within the context of biorefineries and product development in the automobile industry. Moreover, it can be used for decoration.

Furthermore, these uses may contribute to improving economy, environment, sustainability and protecting health. However, it is important to consider the significant challenges posed by *Cortaderia selloana* as an invasive species in many countries, where it is a persistent weed requiring substantial investment for its control.

This task is both expensive and complex due to the species' ability to reproduce rapidly through both sexual and asexual means, with the latter involving fast-spreading rhizomes. Although initially introduced as ornamentals, the introduction of bisexual plants has exacerbated its spreading and reproduction alongside the originally introduced feminine plants. Given these factors, it is important to not promote its cultivation and rather explore ways to utilize *Cortaderia selloana* to mitigate the damage it causes.

Moreover, this review offers insights into its utilization instead of merely controlling this invasive species, providing some utility for a plant that causes significant damage and negative impact at various levels. Thus, by giving applicability to this plant, it is possible to transform

something that causes environmental, economic, and human health damage into products that bring benefits to these domains.

Nevertheless, this review also highlights the necessity for further research studies to better recognize the application of *Cortaderia selloana*. Therefore, it is important to conduct future research on the applications of the studied species, focusing on the known uses, conduct *in vitro* studies to investigate activities associated with traditional medicine and exploring new applications.

Author contributions

JT, MS and AC conceived and designed the study. JT and MS contributed to data acquisition. JT performed the analysis and interpretation of data. JT wrote the manuscript with the help of MS. All authors contributed to the review and approval of the final manuscript.

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