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MAPPING OF WEED DISTRIBUTION IN SOUTHERN KAZAKHSTAN

This study presents the results of mapping the distribution of economically important and quarantine weed species in southern Kazakhstan. Field surveys were conducted in the Almaty, Zhetysu, Zhambyl, and Turkestan regions, covering agricultural lands, roadside habitats, fallow fields, and irrigated areas. Georeferenced sampling was carried out to determine the current distribution range and infestation level of major weed species.

A total of 1,078 specimens of *Rhaponticum repens* (Russian knapweed), 1,153 specimens of *Ambrosia artemisiifolia* (common ragweed), and 1,027 specimens of *Cuscuta campestris* (field dodder) were collected and analyzed. Weed distribution mapping was performed using QGIS 3.28, while geographic coordinates were processed with the Lat Lon Tools plugin. The resulting thematic maps enabled visualization of infestation hotspots and distribution patterns across the study area.

The results showed that transportation corridors, irrigated agroecosystems, and intensively managed agricultural landscapes represent major pathways for weed dispersal. *R. repens* was primarily associated with arid and foothill environments, *C. campestris* was mainly distributed in irrigated croplands and roadside habitats, whereas *A. artemisiifolia* exhibited a fragmented but expanding distribution near urbanized and highly disturbed areas. The study demonstrates the value of GIS-based mapping as an effective tool for monitoring quarantine weeds, assessing phytosanitary risks, and supporting weed management strategies in southern Kazakhstan.

Keywords: quarantine weeds, distribution mapping, GIS, *Rhaponticum repens, Ambrosia artemisiifolia, Cuscuta campestris*, QGIS, phytosanitary monitoring.

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Қазақстанның оңтүстігіндегі арамшөптердің таралуын картаға түсіру

Осы зерттеуде Қазақстанның оңтүстік өңірлерінде таралған шаруашылық тұрғысынан маңызды және карантиндік арамшөп түрлерінің таралуын картографиялау нәтижелері ұсынылған. Далалық зерттеулер Алматы, Жетісу, Жамбыл және Түркістан облыстарының аумағында жүргізіліп, ауыл шаруашылығы алқаптарын, жол бойындағы аумақтарды, тыңайған жерлерді және суармалы егістіктерді қамтыды. Негізгі арамшөп түрлерінің қазіргі таралу аймағы мен таралу қарқындылығын нақтылау мақсатында географиялық координаттармен белгіленген үлгілер жиналды.

Зерттеу барысында *Rhaponticum repens* (жатаған кекіре) түрінің 1078 үлгісі, *Ambrosia artemisiifolia* (жусан жапырақты амброзия) түрінің 1153 үлгісі және *Cuscuta campestris* (дала арамсояуы) түрінің 1027 үлгісі жиналып, талданды. Арамшөптердің таралуын картографиялау QGIS 3.28 бағдарламалық ортасында жүзеге асырылды, ал географиялық координаттарды өңдеу үшін Lat Lon Tools плагині қолданылды. Алынған мәліметтер негізінде таралу ошақтары мен зерттелген түрлердің кеңістіктік орналасу ерекшеліктерін көрсететін тақырыптық карталар жасалды.

Зерттеу нәтижелері көлік дәліздері, суармалы агроэкожүйелер және қарқынды

C. campestris көбінесе суармалы егістіктер мен жол бойындағы учаскелерде кездескен, ал *A. artemisiifolia* урбандалған және антропогендік әсерге ұшыраған аумақтарда үзік-үзік, бірақ кеңею үрдісін көрсеткен. Зерттеу нәтижелері карантиндік арамшөптерді мониторингтеу, фитосанитариялық тәуекелдерді бағалау және оларды басқару стратегияларын әзірлеу үшін ГАЖ-негізіндегі картографиялаудың маңыздылығын дәлелдейді.

Түйін сөздер: карантиндік арамшөптер, картографиялау, ГАЖ, *Rhaponticum repens, Ambrosia artemisiifolia, Cuscuta campestris*, QGIS, фитосанитариялық мониторинг.

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**Картографирование распространения
сорных растений на юге Казахстана**

В настоящем исследовании представлены результаты картографирования распространения хозяйственно значимых и карантинных видов сорных растений на территории южного Казахстана. Полевые обследования проводились в Алматинской, Жетысуской, Жамбылской и Туркестанской областях и охватывали сельскохозяйственные угодья, придорожные территории, залежные земли и орошаемые участки. Отбор образцов с географической привязкой осуществлялся с целью уточнения современного ареала и степени распространения основных видов сорных растений.

Всего было собрано и проанализировано 1078 образцов *Rhaponticum repens* (горчак ползучий), 1153 образца *Ambrosia artemisiifolia* (амброзия полыннолистная) и 1027 образцов *Cuscuta campestris* (повилика полевая). Картографирование распространения сорных растений выполнялось с использованием программного обеспечения QGIS 3.28, а обработка географических координат осуществлялась с помощью плагина Lat Lon Tools. На основе полученных данных были созданы тематические карты распространения, позволяющие визуализировать очаги засорённости и особенности пространственного размещения исследуемых видов.

Установлено, что транспортные коридоры, орошаемые агроэкосистемы и интенсивно используемые сельскохозяйственные ландшафты являются основными путями распространения сорных растений. Вид *R. repens* был преимущественно приурочен к засушливым и предгорным территориям, *C. campestris* чаще встречалась на орошаемых сельскохозяйственных землях и вдоль автомобильных дорог, тогда как *A. artemisiifolia* характеризовалась фрагментированным, но расширяющимся распространением вблизи урбанизированных и нарушенных местообитаний. Полученные результаты подтверждают высокую эффективность ГИС-картографирования для мониторинга карантинных сорных растений, оценки фитосанитарных рисков и разработки мер по ограничению их дальнейшего распространения.

Ключевые слова: карантинные сорные растения, картографирование, ГИС, *Rhaponticum repens, Ambrosia artemisiifolia, Cuscuta campestris*, QGIS, фитосанитарный мониторинг.

Introduction

Biological invasions have long been recognized as a major ecological process shaping species distributions worldwide, with early conceptual frameworks highlighting their historical, biogeographical, and evolutionary dimensions (Di Castri, 1989; Bradley et al., 2011).

In recent decades, the ecological and economic impacts of invasive and quarantine weed species have intensified under the combined effects of climate change, land-use transformation, and increasing global connectivity. Rising temperatures, shifts in precipitation regimes, and the growing frequency of extreme climatic events enhance the establishment, persistence, and spread of invasive plants by weakening crop competitiveness and destabilizing native plant communities (Clements & DiTommaso, 2012; Kairova et al., 2025; Liu et al., 2020). At the same time, global trade, expansion of transport infrastructure, and agricultural intensification facilitate long-distance dispersal of propagules, accelerating the accumulation of alien species across regions and national borders (Early et al., 2016; Seebens et al., 2021). These interacting drivers are particularly pronounced in arid and semi-arid regions, where limited ecological resilience increases the vulnerability of agroecosystems to biological invasions.

Central Asia represents a critical hotspot for weed invasions due to its continental climate, extensive irrigated agriculture, increasing anthropogenic pressure, and long history of land disturbance. The region is characterized by highly heterogeneous environmental conditions, including arid and semi-arid ecosystems, large-scale agricultural landscapes, and extensive transport networks that facilitate the introduction and spread of alien plant species. Recent assessments indicate that invasive weeds such as *Rhaponticum repens*, *Cuscuta campestris*, and *Ambrosia artemisiifolia* are actively expanding their distributions within Kazakhstan and neighboring countries, posing increasing threats to agricultural productivity, native biodiversity, ecosystem stability, and phytosanitary security (Kochorov et al., 2025). These species are capable of forming dense populations that compete with native vegetation and cultivated crops for water, nutrients, light, and space, resulting in substantial economic losses and ecological degradation.

The invasion success of these species is largely attributed to their high ecological plasticity, broad environmental tolerance, efficient reproductive systems, persistent soil seed banks, and multiple dispersal pathways. In addition, many invasive weeds demonstrate resistance or tolerance to conventional mechanical and chemical control measures, making their management increasingly difficult once populations become established. Climate change may further accelerate invasion processes by creating favorable conditions for range expansion and increasing the likelihood of successful establishment in previously unsuitable habitats. Recent phytosanitary studies conducted in Kazakhstan have reported a continuing increase in the occurrence and distribution of quarantine weed species, emphasizing the urgent need for region-specific monitoring programs, risk assessment tools, and science-based management strategies (Kochorov et al., 2025).

From a theoretical perspective, these patterns are consistent with ecological niche theory, which emphasizes the importance of niche conservatism, environmental filtering, propagule pressure, and non-equilibrium dynamics in determining the distribution and expansion of invasive species. Understanding these mechanisms is essential for improving predictive modeling approaches and developing effective long-term strategies for invasive weed management under changing environmental conditions (Peterson et al., 2011).

Despite growing recognition of the threat posed by invasive alien species, spatially explicit and harmonized data on their current distribution in Central Asia remain limited. This information gap constrains the development of effective early-warning systems and evidence-based management strategies. Recent global syntheses have highlighted invasive species as one of the major drivers of biodiversity loss worldwide, with impacts exacerbated by climate change and insufficiently coordinated biosecurity responses (Pyšek et al., 2020; Roy et al., 2024). In response, international initiatives such as the InvasiBES project have emphasized the need to integrate ecological data, spatial analyses, and management frameworks to better understand and mitigate the impacts of invasive alien species on biodiversity and ecosystem services (Gallardo et al., 2023).

In the context of increasing pressure on agricultural systems, invasive and quarantine weeds represent not only an ecological challenge but also a significant economic constraint for crop production. Yield losses, increased management costs, and restrictions on agricultural trade associated with quarantine species underscore the need for improved surveillance and control strategies. In regions with intensive irrigation and rapidly expanding agricultural infrastructure, such as southern Kazakhstan, the risk of weed introduction and secondary spread is particularly high. Despite this, regional-scale assessments integrating field observations with GIS-based mapping remain scarce. Addressing this gap is essential for developing proactive phytosanitary measures, improving early-warning systems, and supporting evidence-based decision-making aimed at reducing the long-term impacts of invasive weeds on agroecosystem sustainability.

Advances in geospatial technologies now provide powerful tools for addressing these challenges. Geographic Information Systems (GIS), combined with georeferenced field surveys, enable the identification of invasion hotspots, dispersal pathways, and key environmental drivers of weed spread at regional and landscape scales. GIS-based approaches have proven effective for early detection, invasion risk mapping, and prioritization of control measures in agricultural and semi-natural ecosystems. Spatial information on weed distribution is particularly important for supporting non-chemical and integrated weed management strategies, which are increasingly promoted as sustainable alternatives to herbicide-based control (Pala & Mennan, 2022). In regions undergoing rapid environmental and socio-economic change, such as southern Kazakhstan, spatial analyses represent a critical decision-support tool for phytosanitary surveillance and integrated weed management under current and future climate scenarios.

Beyond documenting invasion patterns, recent studies emphasize the importance of integrating restoration and adaptive management strategies to mitigate the impacts of invasive plant species under ongoing climate change. Restoration-based approaches, including habitat rehabilitation and ecosystem resilience enhancement, are increasingly recognized as essential components of long-term invasion management (Selvakumar et al., 2026).

The objective of this study was to map the current distribution of major invasive and quarantine weed species in southern Kazakhstan using georeferenced field surveys and GIS-based mapping. Particular attention was given to species-specific occurrence patterns, infestation hotspots, and landscape features potentially associated with weed spread, with the aim of supporting phytosanitary monitoring and region-specific management strategies.

Unlike previous phytosanitary surveys in Kazakhstan, the present study provides a unified GIS-based mapping framework for three major quarantine weed species (*Rhaponticum repens, Cuscuta campestris,* and *Ambrosia artemisiifolia*) across four southern regions of Kazakhstan. The study generates one of the first published GIS-based distribution datasets for major quarantine weeds in southern Kazakhstan that may support future phytosanitary monitoring, invasion-risk assessment, and long-term surveillance programs.

Materials and methods

Study Area and Sampling

Field surveys were conducted in southern Kazakhstan, covering the Almaty, Zhetysu, Zhambyl, and Turkestan regions. Weed sampling was performed across agricultural fields, roadside habitats, fallow lands, and irrigated agroecosystems. A total of 30 georeferenced sampling sites were surveyed. Field surveys were conducted during the period of 28 April to 26 October 2025 within the active vegetation period of the target species, when plants could be reliably detected and identified under field conditions. The surveys were carried out during a single growing season. Sampling sites were selected using a targeted survey approach to represent the main habitat types and potential dispersal pathways of quarantine weeds in southern Kazakhstan. Priority was given to agricultural fields, irrigated croplands, field margins, roadside habitats, fallow lands, and areas located near transport or irrigation infrastructure. At each site, weed presence was visually confirmed, GPS coordinates were recorded, and representative plant specimens were collected for further identification. Sampling intensity varied among sites depending on local infestation density; therefore, the number of collected specimens was interpreted as an indicator of local occurrence and infestation level rather than as a standardized density estimate.

Three invasive and quarantine weed species were investigated: *Rhaponticum repens*, *Cuscuta campestris Yunck*., and *Ambrosia artemisiifolia* L.

In total, 1078 specimens of *R. repens* were collected from 13 sites, 1027 specimens of *C. campestris* from 8 sites, and 1153 specimens of *A. artemisiifolia* from 9 sites. Sampling intensity varied among locations depending on infestation density.

To ensure data consistency, all field observations were recorded following a standardized sampling protocol. Sampling sites were selected to represent major land-use types, including croplands, irrigation zones, roadside habitats, and fallow lands. At each site, weed presence was visually confirmed, and representative specimens were collected for species identification. Collected specimens were labeled and documented to link field records with spatial data.

GIS-based mapping

The geographic coordinates were recorded for each studied weed (30 points) across the study area using a Garmin Montana 750i GPS device (Kansas City, MO, USA). To map of the sampling locations based on the GPS coordinates, the Lat Lon Tools plugin (Lat Lon Tools, 2026) in the Quantum Geographic Information System (QGIS 3.28) (Gizachew et al., 2016; Khusnitdinova et al., 2024; Khusnitdinova et al., 2025; QGIS Association, 2026) was utilized (Figure 1, Table 1,2).

A similar GIS-based spatial framework has previously been applied for mapping plant pathogen distribution in natural ecosystems of Kazakhstan (Kerimbek et al., 2025). In the present study, georeferenced occurrence records obtained during field surveys were integrated into a GIS environment to visualize species distributions, identify infestation hotspots, and compare spatial patterns among regions. In addition to mapping the occurrence points, the distribution patterns were interpreted in relation to major habitat and landscape characteristics recorded during field surveys, including land-use type, irrigation influence, roadside disturbance, fallow vegetation, and agricultural management intensity.

Table1
Quarantine weed species sampling locations in the southern Kazakhstan

	Region	No. on Map	Coordinates
Rhaponticum repens (1078)	Almaty Region	1	43.5369453, 77.15861351
		2	43.46000082, 79.38916905
	Zhetysu Region	3	45.75222303, 78.43444692
	Almaty Region	4	43.39638975, 76.91333573
	Turkestan Region	5	42.33305656, 69.7138913
		6	43.22416766, 69.86472466
	Almaty Region	7	43.66500087, 76.51361352
		8	44.33861198, 75.82139133
		9	43.67638976, 76.50472463
	Zhambyl Region	10	43.83666757, 74.68222465
	Almaty Region	11	43.53666752, 77.16972463
		12	43.43500084, 78.35250239
		13	43.4350009, 78.35250241
Cuscuta campestris (1027)	Turkestan Region	14	42.33305656, 69.7138913
	Zhetysu Region	15	44.9813897, 78.34444689
		16	43.1363898, 74.62333574
	Almaty Region	17	43.2894453, 77.17833573
		18	43.28972308, 77.17833573
	Zhetysu Region	19	44.17527857, 80.12139129
		20	44.17138968, 80.08139129
	Almaty Region	21	43.60083415, 79.42805794
Ambrosia artemisiifolia (1153)	Zhetysu Region	22	44.981389704, 78.344446890
		23	44.976111926, 78.395280223
	Almaty Region	24	44.976111926, 78.395280223
		25	43.536667522, 77.170002402
		26	43.384167524, 77.164724619
		27	43.311389743, 77.373057948
		28	43.289723081, 77.178335727
		29	43.289167525, 77.178057949
		30	43.211389757, 76.712780172

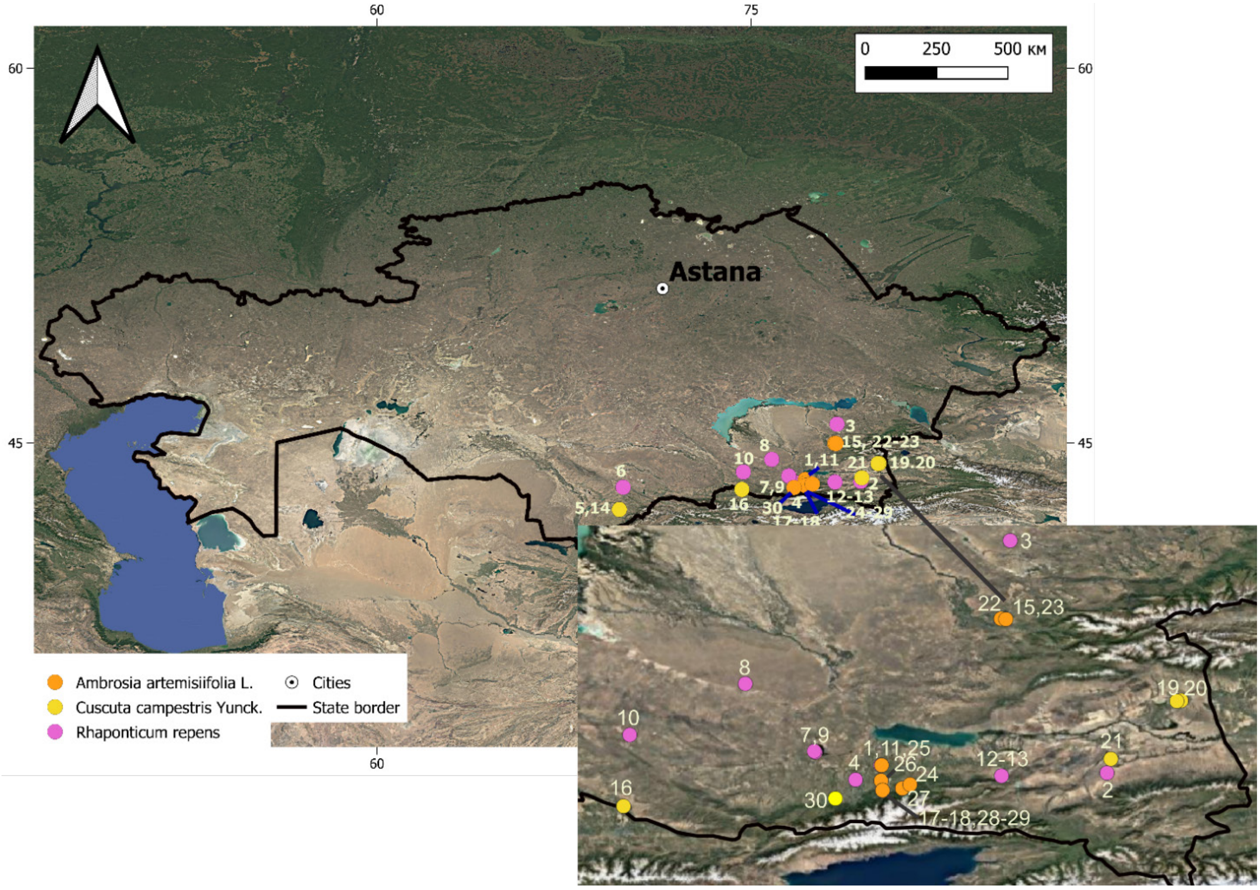
These factors were not analyzed as independent quantitative predictors in the present study; however, they were used to support ecological interpretation of the observed spatial patterns and to identify potential habitats associated with weed establishment and spread. Particular attention was paid to areas characterized by intensive agricultural activity, transportation corridors, and disturbed habitats, which are commonly recognized as important pathways facilitating the introduction and secondary dispersal of invasive plant species. The incorporation of field observations with spatial visualization also enabled the identification of potential relationships between weed occurrence and anthropogenic landscape modification.

This integrated methodological approach allowed for a consistent spatial comparison of infestation patterns among species and regions, providing a robust basis for subsequent analysis and interpretation. Furthermore, the generated distribution maps constitute an important baseline dataset for future phytosanitary monitoring, risk assessment, and long-term surveillance of invasive and quarantine weed species in southern Kazakhstan.

Table 2
Summary of occurrence records and infestation intensity of quarantine weed species in southern Kazakhstan

Species	Sites	Specimens	Mean specimens/site
R. repens	13	1078	82.9
C. campestris	8	1027	128.4
A. artemisiifolia	9	1153	128.1

Figure 1
Spatial distribution of quarantine weed species in southern Kazakhstan



Results and discussion

GIS-based mapping revealed distinct distribution patterns among the studied weed species. Species differed in geographic coverage, infestation intensity, and habitat associations across southern Kazakhstan.

Species differed considerably in terms of geographic coverage and local infestation intensity. *R. repens* occupied 43.3% of all sites surveyed (13 of 30 locations), representing the widest geographic distribution among the weeds studied. *A. artemisiifolia* accounted for the largest number of collected specimens (1153 individuals), whereas *C. campestris* showed the highest average infestation intensity per occupied site (128.4 specimens per site), indicating the formation of dense local populations despite its more restricted distribution.

Rhaponticum repens showed the broadest geographic distribution, being recorded at 13 sampling sites across arid and semi-arid landscapes of the Almaty, Zhetysu, Turkestan, and Zhambyl regions. The highest occurrence was observed in Almaty Region. This pattern may be associated with favorable climatic conditions, intensive agriculture, and high landscape connectivity; however, these factors were not quantitatively evaluated in the present study. The species' tolerance to drought, soil disturbance, and mechanical control, together with its extensive underground root system, contributes to its successful establishment and persistence in these environments (EPPO, 2026; Jacobs & Denny, 2006). Its frequent detection in agricultural and roadside habitats also indicates that repeated mechanical disturbance, movement of soil, and landscape connectivity may contribute to local persistence and secondary spread. Therefore, disturbed habitats such as field margins, fallow lands, irrigation-adjacent areas, and roadsides may serve as important reservoirs for local persistence and further spread.

The potential consequences of *R. repens* expansion are particularly relevant for agricultural landscapes of southern Kazakhstan. Dense populations of perennial rhizomatous weeds may reduce crop competitiveness by limiting access to soil moisture, nutrients, and light. In dry regions, where water availability is one of the main constraints for crop production, such competition may increase yield instability and complicate weed management. Once established, *R. repens* populations are difficult to eradicate because mechanical control alone may stimulate vegetative regrowth from remaining root fragments. This indicates that areas with repeated soil disturbance should be considered priority zones for monitoring and long-term integrated control.

Cuscuta campestris was detected at 8 sites and was primarily associated with irrigated croplands, field margins, and roadside habitats. Despite fewer sampling locations, the high number of collected specimens indicates substantial local infestation levels. This pattern suggests that *C. campestris* forms dense populations once established, particularly in irrigated agroecosystems where host availability and suitable microclimatic conditions promote rapid spread. Its close association with irrigation infrastructure and transport routes highlights the importance of anthropogenic dispersal pathways. The spread of *C. campestris* may be facilitated by several human-mediated pathways, including contaminated crop seed, movement of infested plant residues, agricultural machinery, irrigation water, and transportation networks (Parker, 2012, 2022). Non-cultivated vegetation along field margins may serve as a secondary reservoir, allowing the parasite to persist outside agricultural fields and subsequently reinvade cultivated crops. The consequences of *C. campestris* infestation can be severe, as parasitic weeds directly reduce host growth and productivity, contaminate seed material, and complicate phytosanitary control. In this context, early detection before seed formation is essential, because the accumulation of seeds in the soil may support repeated infestation in subsequent growing seasons.

Ambrosia artemisiifolia was recorded at 9 sites, mainly within the Almaty and Zhetysu regions. The species exhibited a fragmented but expanding distribution, with higher infestation levels near urbanized areas, transport corridors, and highly disturbed agroecosystems. The large number of specimens reflects active population growth and ongoing range expansion. These distribution patterns are consistent with the species' preference for disturbed habitats and its effective dispersal through agricultural machinery and road networks. Its spread is supported by high seed production, the formation of a persistent soil seed bank, and effective dispersal through transport corridors, contaminated soil, agricultural machinery, and movement of crop products (Essl et al., 2015; Lemke et al., 2019; Skálová et al., 2017).

In agroecosystems, dense populations may compete with crops during early development and increase the cost of weed control. In disturbed urban and peri-urban habitats, the species is also important because its pollen is highly allergenic and may contribute to seasonal allergic rhinitis and other respiratory symptoms in sensitive populations (EPPO, 2026; Schaffner et al., 2020). Therefore, the detection of *A. artemisiifolia* near urbanized areas and transport routes indicates a need for coordinated phytosanitary and environmental monitoring. Control measures should focus on preventing seed production, reducing disturbed bare soil patches, and monitoring roadsides and settlement-adjacent agricultural fields as potential sources of further spread.

Comparison of occurrence records revealed contrasting invasion strategies among species. *R. repens* exhibited broad regional distribution, suggesting successful long-distance establishment across multiple habitat types. In contrast, *C. campestris* demonstrated localized but dense infestations, whereas *A. artemisiifolia* displayed an intermediate pattern characterized by fragmented distribution and active expansion in disturbed habitats.

The mapped occurrence records indicate that many infestations were located in proximity to transport corridors, irrigated agricultural systems, and intensively managed landscapes. Although no formal statistical testing of environmental predictors was conducted, these patterns suggest that anthropogenic land-use features may contribute to weed establishment and spread.

The observed distribution patterns are consistent with the ecological and land-use characteristics of southern Kazakhstan, including arid climatic conditions, irrigation-dependent agriculture, and varying levels of anthropogenic disturbance. These factors create heterogeneous habitats that may facilitate weed establishment and persistence.

Recent perspectives in weed science emphasize a shift toward predictive, spatially explicit, and systems-based approaches to weed management under global change scenarios (Zimdahl & Basinger, 2024). Our findings align with recent global assessments identifying spatial monitoring, invasion forecasting, and management integration as key research priorities in modern weed science (Brainard et al., 2023).

The growing complexity of weed invasions has also contributed to the expansion of weed science as an interdisciplinary field integrating ecology, geography, and agricultural management (Shrestha et al., 2021). Similar trends in the expansion and management challenges of invasive weeds under climate change have been reported for agricultural ecosystems in other regions, highlighting the global relevance of spatially explicit monitoring approaches (Ionescu et al., 2023a, 2023b).

These findings underline the necessity of incorporating GIS-based distribution data into regional weed monitoring programs to improve early detection and management efficiency.

Conclusion

GIS-based mapping of 30 georeferenced survey locations and 3258 collected weed specimens revealed clear differences in the distribution patterns of three major quarantine weeds in southern Kazakhstan. *Rhaponticum repens* exhibited the broadest geographic distribution (13 sites), *Ambrosia artemisiifolia* produced the highest number of recorded specimens (1153), and *Cuscuta campestris* showed the highest local infestation intensity despite occurring at fewer locations.

The generated distribution maps identified several concentration zones associated with agricultural landscapes, irrigated areas, roadside habitats, and other disturbed environments. The generated maps provide a baseline framework for future integration of environmental predictors, ecological niche modelling, and invasion-risk assessments.

More broadly, the findings contribute to understanding invasion dynamics in arid and semi-arid regions of Central Asia, where agroecosystems are particularly vulnerable to biological invasions. The methodological framework applied in this study can be extended to long-term monitoring programs and additional invasive species. Future research should integrate GIS-based mapping with ecological niche modeling and climate projections to improve invasion risk forecasting and support sustainable agricultural management in Kazakhstan.

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