



Article

Desertification trends and prospects for its prevention: research findings with a focus on agricultural seeder technologies.

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Abstract: Desertification and a lack of fertile land are two of today's most critical challenges, requiring rapid response. These difficulties provide enormous challenges to global agricultural productivity, as the quality of conventional pastures deteriorates, emphasizing the vital need to investigate alternate choices. This study not only looks into the possible benefits of seeders and drills in agriculture, but also how automation could boost output in arid places. A bibliometric analysis of research papers on seeding units and drills published in the Web of Science Core Collection database between 2013 and 2024 was carried out using a variety of analytical tools such as Office Excel, Mapchart.net, and VOS Viewer. The literature corpus consisted of 981 publications, of which approximately 90% were peer-reviewed scientific articles. In the current context, it is essential to prioritize investments in research and development initiatives, with a particular emphasis on fostering international collaborative partnerships. Global efforts to promote the adoption of seeders and metering devices are promising strategies for enhancing agricultural productivity and addressing the challenges posed by drought conditions.

To analyze global research trends, scientific collaboration, and technological developments related to seeders and seed drills in agriculture, with particular attention to their role in improving agricultural productivity and supporting sustainable farming in arid and desertification-prone regions.

A bibliometric analysis was conducted using publications indexed in the Web of Science Core Collection database from 2013 to 2024. The study examined 981 publications related to seeding units and seed drills. Data processing and visualization were performed using Office Excel, MapChart.net, and VOSviewer to evaluate publication dynamics, geographic distribution, collaboration networks, and research trends.

The analysis showed a steady increase in scientific interest in seeders and drilling technologies over the studied period. Approximately 90% of the analyzed publications were peer-reviewed scientific articles. The results demonstrated growing international collaboration and highlighted the importance of automation and precision seeding technologies for improving agricultural efficiency, especially under drought and limited fertile land conditions. Research activity was concentrated in countries actively investing in agricultural innovation and sustainable land management.

Seeders and metering devices play an important role in enhancing agricultural productivity and supporting sustainable agriculture in arid regions. The findings emphasize the need for continued investment in research and development, as well as stronger international scientific cooperation. The adoption of advanced seeding technologies and automation can contribute to mitigating the negative effects of desertification and improving global food production systems.

Keyword: desertification, sowing unit, seeder, bibliometric, agriculture.

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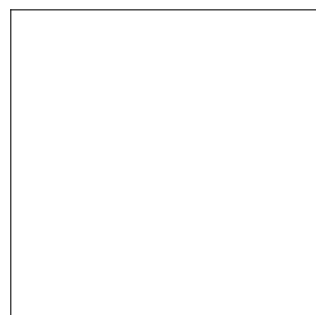
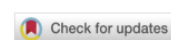
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Introduction

The term "desertification" is often overused. It refers to a form of land degradation that occurs in arid, semi-arid, and dry sub-humid regions, leading to a persistent decline in land productivity. Desertification is typically driven by a combination of natural processes and human activities.

Natural factors, such as prolonged droughts and extreme weather events, exacerbate desertification. Desertification leads to the loss of arable land, reduced crop yields, and can contribute to food insecurity, displacement of communities, and biodiversity loss. Efforts to mitigate desertification often involve a combination of sustainable land management practices, reforestation, and policies aimed at protecting and restoring affected areas [1].

A sowing unit is a crucial component of agricultural machinery, specifically designed for planting or sowing agricultural crops [2]. It forms an integral part of seeders, which are utilized to efficiently sow seeds in the field. The primary functions of a seed meter include: Seed Placement – This function ensures that seeds are positioned at the correct depth and spacing, which is essential for optimal crop growth and yield [3]. This is critical for optimal crop growth and yield [4]. Seed Metering – This component accurately meters the seeds, ensuring that the correct quantity is sown. This contributes to maintaining a consistent plant density, which is vital for crop uniformity and health. This helps maintain a constant plant density [5]. Seed Delivery – The seed meter is responsible for transporting seeds from the seed hopper to the soil, often using mechanisms such as belts, rollers, or pneumatic systems [1]. Soil Preparation – Some seed meters incorporate built-in features for soil preparation, such as furrow openers or compactors, which prepare the soil for optimal planting conditions [5].

A seeder is a type of agricultural equipment used for sowing seeds into the soil [6]. It plays a critical role in modern agriculture by automating and optimizing the planting process. Different types of seeders are designed to meet specific planting conditions and crop requirements [1]. Below are some common types of seeders and their functions: Spreading Seeders – These seeders spread seeds over a large area, either manually or using machinery [7]. They are commonly used for planting grass seed, cover crops, or small grains [8]. Row Seeders – These seeders plant seeds in rows and are equipped with furrow openers that create channels in the soil [9]. Precision Seeders – These seeders place seeds at precise depths and intervals, ensuring accurate seed distribution. They are often employed for crops such as corn, soybeans, and cotton [10]. Pneumatic Seeders – These seeders use air flow to transport seeds from a hopper to the seeding mechanism [3]. Plate Seeders – These seeders use a rotating plate with holes to meter and place seeds into the soil [11].

Bibliometric review articles are widely regarded as one of the most popular types of scientific article reviews [12]. These reviews are employed across various research fields such as grain stored, land use, groundwater, agriculture mechanization. This bibliometric analysis highlights the growing research on desertification, emphasizing the role of forage crops and mechanized seeders in improving agricultural productivity and food security. It concludes that machine seeding of forage crops is more effective than manual methods in combating desertification in arid and semi-arid regions .

Materials and Methods

The global repository on desertification, seeders, sowing units, and their derivatives was analyzed using the Web of Science Core Collection database for the period from 2013 to 2024. Initially, a search was conducted with "desertification" as a keyword within the article title, abstract, and keywords, resulting in the identification of 981 published documents during the specified timeframe. Subsequently, on April 24, 2024, the following filters were applied as part of the retrieval strategy: TITLE ("desertification" AND "seeder" AND "sowing unit") AND PUBYEAR > 2013 AND PUBYEAR < 2024 AND (LIMIT-TO (SUBJAREA, "Environmental Science" OR "Agricultural Engineering" OR "Engineering" OR "Plant Science")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (PUBSTAGE, "Final")) (see Fig 1). After applying these filters, a total of 981 papers were recorded, which were then converted into CSV and RIS file formats. The bibliometric analysis was performed using VOSviewer software, version 1.6.18, and included bibliographic coupling, thematic analysis, co-authorship networks, co-occurrence analysis, citation patterns, and co-citation analysis.

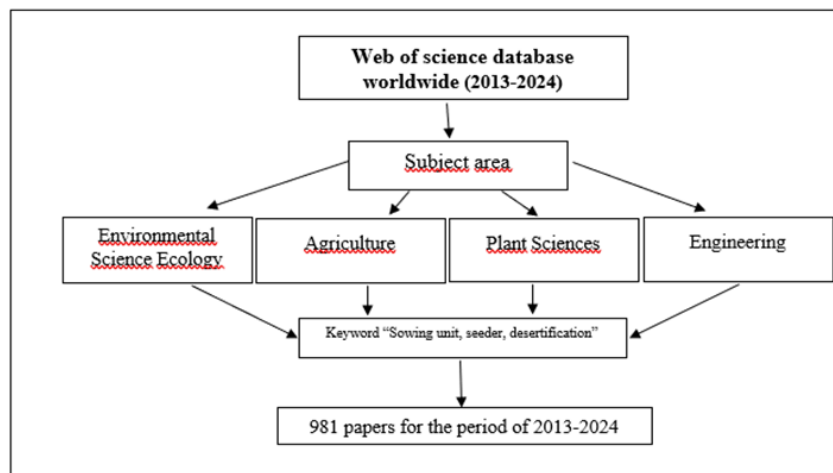


Figure 1. Flowchart of the methodology

Results

To assess the progress of sowing units and seeders in agriculture, annual publication and citation trends were analyzed, as depicted in Figure 2. Research on seeders and sowing units has been published in 93 countries globally. The data shows a general upward trend in publications, increasing from 67 papers in 2000 to 29 papers in 2024, with a slight decline observed between 2021 and 2023. This trend suggests that researchers are increasingly focusing on sowing units and seeders within the agricultural sector.

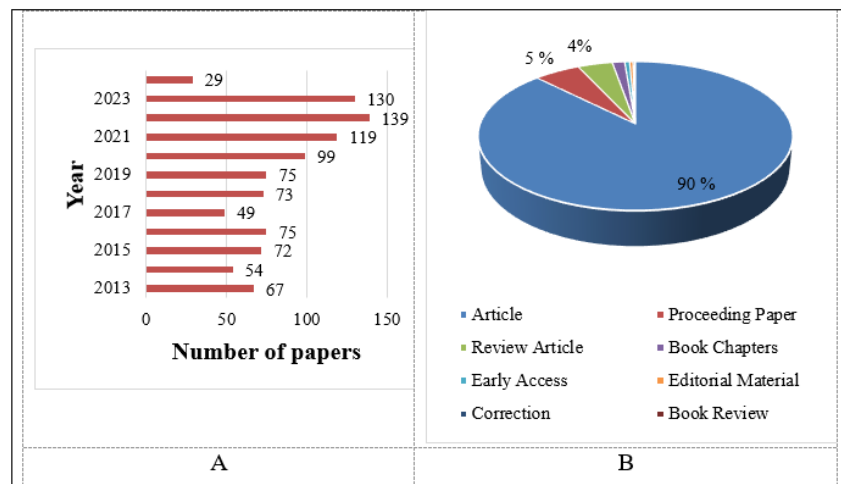


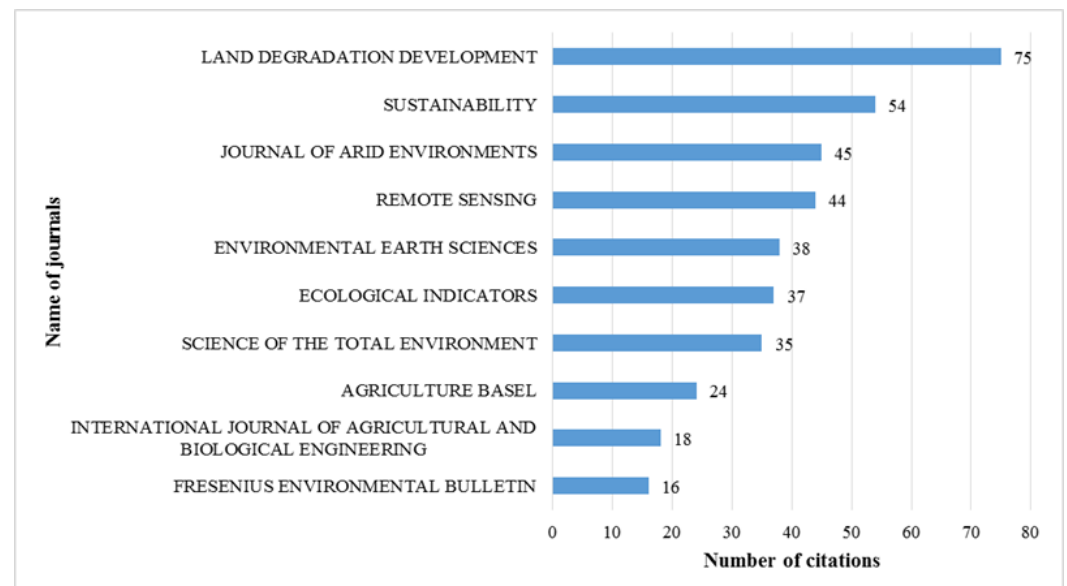
Figure 2. Number of papers on sowing units and seeders by year of publication worldwide (A), Types of publications on sowing units and seeders worldwide (B)

Moreover, the analysis indicates that among the 981 documents reviewed, the majority 883 papers (approximately 90%) were original research articles. This was followed by 56 conference proceedings and 42 review articles. Additionally, only about 1% of the documents fell into other categories, including book chapters (15), early access articles (6), editorials (4), corrections (2), and a single book review (1) (Figure 2). Top number of publications and top cited journals on sowing units and seeders The analysis focuses on the country of publication and the impact factor of the top 10 journals (Table 1). Among these journals, three were published in Switzerland and the Netherlands, three in the United States and Germany, two in China, and one in the United Kingdom. The average impact factor of the journals with the highest number of publications was 4.82. Remote Sensing of Environment had the highest impact factor among the selected journals, while Land Degradation Development accounted for the largest number of publications in this research domain.

Table 1. Distribution of research output in the most prolific journals by country and impact factor

Journal	TNP (%)	Publishing country
Land degradation development	7.645%	United Kingdom
Sustainability	5.505%	Switzerland
Journal of arid environments	4.587%	United States
Remote sensing of environment	4.485%	United States
Environmental earth sciences	3.874%	Germany
Ecological indicators	3.772%	Netherlands
Science of the total environment	3.568%	Netherlands
Agriculture basel (Agriculture)	2.446%	Switzerland
International journal of agricultural and biological engineering	1.835%	China
Fresenius environmental bulletin	1.631%	Germany
Total:	39.3%	

While some journals published a relatively modest number of papers on sowing units and seeders, they nonetheless accumulated a high number of citations between 2013 and 2020. To identify these journals, we first sorted the source titles alphabetically in the Excel dataset containing 2,016 records. We then calculated the total citation count for each journal. This process resulted in an updated list of journals with high citation impact in the field. The 10 most cited journals were selected and are presented in Table 1. Collectively, these journals account for approximately 46.7% of all citations (54,048 in total) related to sowing units and seeders. Notably, the top-ranked journal based on both number of publications (75 documents) and total citations emerged as the leading source in this field (Tables 1). Six journals Land degradation development, Sustainability, Journal of Arid Environments, Remote Sensing, Environmental Earth Sciences and Ecological Indicators are highlighted in Figure 3 as the most cited journals in agricultural research specifically related to seeders and sowing units.

**Figure 3.** Top cited journals in research on sowing units and seeders

Publications by keywords on sowing units and seeders In this section, a bibliometric analysis was conducted to investigate the evolution of research on sowing units and seeders, utilizing keyword co-occurrence analysis through VOS Viewer. For this study, the raw bibliographic data was imported into VOS Viewer, and a map of keyword co-occurrences was constructed (Figure 4). The analysis

revealed 30 distinct keywords that were grouped into four thematic clusters: Cluster 1 (11 items), Cluster 2 (7 items), Cluster 3 (7 items), Cluster 4 (5 items). This keyword co-occurrence analysis provides valuable insight into the dynamic nature of research on sowing units and seeders, illustrating the increasing emphasis on sustainability and technological innovation in recent years.

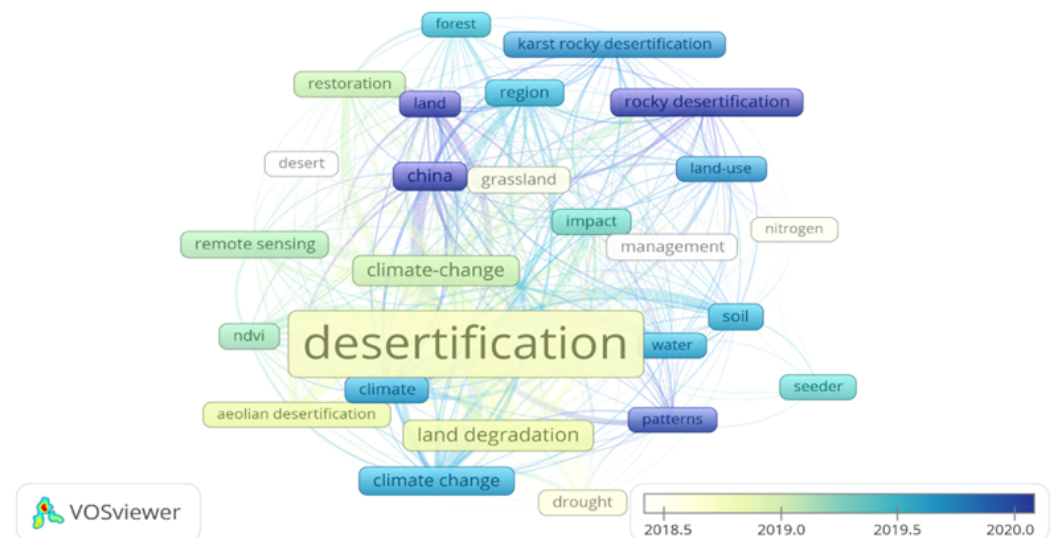


Figure 4. Keyword co-occurrences analysis based on Web of science data using VOS viewer

International collaboration plays a pivotal role in advancing scientific research, particularly in the field of sowing units and seeders. To analyze this, a co-authorship network of countries was visualized using VOS Viewer (version 1.6.18), based on data from the Web of Science database. The visualization reveals the global collaboration patterns among 92 countries, organized into 9 distinct clusters, encompassing 55 items, 110 links, and a total link strength of 219 (Figure 5). The clusters identified through this analysis show the geographical distribution and collaboration dynamics of research in this domain. Specifically: Cluster 1 contains 10 countries, Cluster 2 includes 8 countries, followed by clusters 3 and 4, each with 7 countries. Cluster 5 contains 6 countries, while Clusters 6 and 7 include 5 countries each. Cluster 8 has 4 countries, and Cluster 9 contains the smallest group, with 3 countries. This co-authorship analysis emphasizes the increasingly global nature of research on sowing units and seeders, with countries engaging in international collaborations to advance knowledge and innovation in this critical area of agricultural engineering.

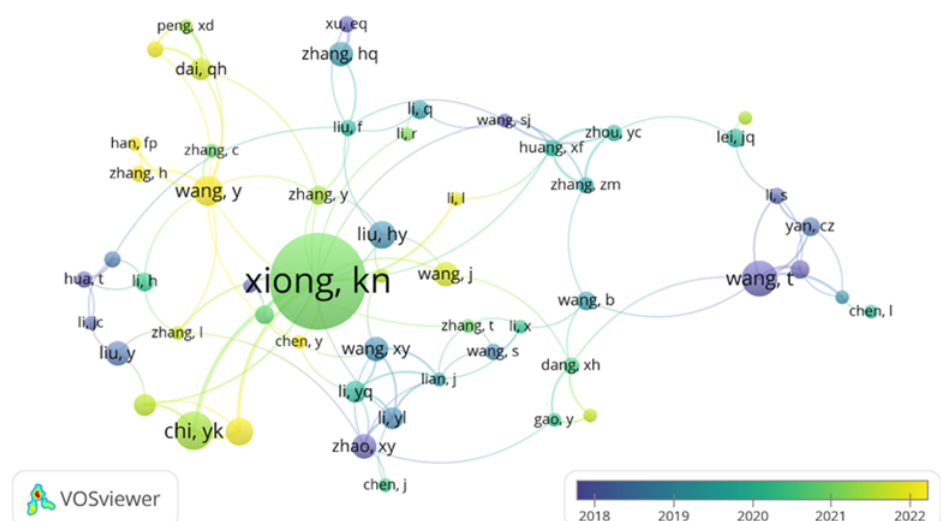


Figure 5. Structure map of countries co-authorships on seeder and its derivatives

Discussion

This study, while comprehensive, does present several limitations that should be considered when interpreting the results and conclusions. (1) Single Database Selection: One of the primary limitations of this study is the reliance on a single database, the Web of Science Core Collection, for gathering bibliometric data. While the Web of Science is a robust and widely recognized source, it only represents a portion of the global scientific literature. By excluding articles from other major databases, such as Scopus or Google Scholar, this study may have missed relevant publications, particularly those from sources not indexed by the Web of Science. Additionally, the process of combining data from multiple databases was avoided due to potential formatting and compatibility issues with the visualization software. The findings of this study demonstrate that research on sowing units and seeders is becoming increasingly relevant to the broader challenges of land degradation, desertification, and sustainable agricultural development. Although desertification is primarily recognized as an environmental and land-management problem, its prevention and mitigation also require appropriate technological solutions for restoring degraded areas. In this context, efficient seeding technologies can play an important role by enabling the establishment of vegetation in arid and semi-arid environments where conventional agricultural practices are often constrained by limited water availability, poor soil conditions, and low land productivity. The distribution of publications among leading scientific journals further confirms the interdisciplinary character of this research area. The presence of studies in journals associated with environmental science, land degradation, remote sensing, and agricultural engineering indicates that seeding technologies are increasingly considered as part of a broader system of sustainable land management rather than as isolated agricultural machinery components. The relatively high average impact factor of the leading journals identified in this study (4.82) also suggests that research related to land degradation and agricultural technologies has attracted substantial scientific attention. In particular, the prominence of Land Degradation Development is consistent with the close relationship between land restoration and the development of technologies capable of establishing vegetation on degraded land. Meanwhile, the strong representation of environmental research highlights the importance of integrating technological approaches with environmental monitoring and assessment. The keyword co-occurrence analysis provides additional evidence of this interdisciplinary development. The identification of 30 keywords distributed across four thematic clusters indicates that research on sowing units and seeders encompasses several interconnected scientific directions. The increasing emphasis on sustainability and technological innovation suggests a transition from conventional mechanical sowing toward more efficient and environmentally responsive technologies. This development is particularly relevant to desertification control, where the success of vegetation restoration depends not only on seed quality and species selection but also on the ability to place seeds effectively under difficult environmental conditions. In arid environments, inappropriate seed placement or non-uniform seed distribution may reduce establishment rates and consequently limit the effectiveness of restoration programs. The international co-authorship analysis provides another important finding. The identification of 92 countries organized into nine collaboration clusters, with 55 items, 110 links, and a total link strength of 219, demonstrates a relatively broad international research network. Such collaboration is particularly valuable for desertification research because land degradation is a transboundary and geographically diverse problem. International research partnerships can facilitate the exchange of experimental data, engineering solutions, ecological knowledge, and field-testing methodologies. They may also accelerate the adaptation of seeding technologies to different soil-climatic conditions and support the development of standardized approaches for evaluating their performance. Taken together, the results suggest that the future development of seeder technologies should move toward more specialized, precise, and sustainable systems. Conventional seeders are generally designed for relatively uniform and free-flowing agricultural seeds, whereas restoration of degraded desert and semi-desert areas may require machinery capable of handling irregular seed mixtures and difficult sowing conditions. Therefore, future engineering research should increasingly consider seed physical-mechanical properties, metering accuracy, seed distribution uniformity, sowing depth, field speed, soil conditions, and the interaction between the working mechanism and seed material. The integration of automation and precision-control technologies may further improve sowing accuracy and reduce unnecessary seed losses, which is particularly important where seed availability and es-

tablishment conditions are limited. From the perspective of desertification prevention, these findings indicate that agricultural engineering should be considered an important component of integrated land-restoration strategies. Effective restoration cannot rely exclusively on ecological measures; it also requires practical technologies capable of implementing restoration practices efficiently over large areas. Seeder technologies can contribute to this process by improving the mechanization of desert forage plant establishment and facilitating the restoration of vegetation cover. Increased vegetation establishment can, in turn, contribute to soil stabilization, reduction of wind erosion, and improvement of the productive potential of degraded pasturelands.

Conclusions

This paper provides an in-depth bibliometric review of research on seeders and sowing implements, based on an analysis of 981 bibliographic records. The study reveals that seeding methods have become widely used in agricultural research, delivering significant improvements in sowing efficiency and crop yields. Over the past decade, research on sowing units and seeders has steadily advanced, with a noticeable surge in activity beginning in 2021. These advancements are evident across various crop types, including vegetable seeders, cotton seeders, and desert forage seeders. The analysis of published sources identified "Land Degradation Development" as one of the leading journals in the field, originating from the United Kingdom. A keyword analysis further confirmed that concepts such as sowing units, seeders, and desertification dominate the research landscape. Notably, researchers Xiong K., Salvati L., and Chi Y.K. have emerged as some of the most prolific contributors to this field. Geographically, China, the USA, and Italy stand out as the leading countries in terms of both the number of publications and total citations in seeder-related research. Overall, this bibliometric analysis not only reflects the current global research landscape on seeders and sowing units but also signals the emerging trends that will likely shape the future of agricultural research. The increasing interest in automation, AI, and intelligent control systems opens up new avenues for research, offering opportunities for innovation in seeding technologies that could have far-reaching implications for global food security and sustainable agriculture. Overall, the findings demonstrate a clear connection between the evolution of seeder research and the growing need for sustainable responses to land degradation and desertification. The increasing scientific attention to sustainability, technological innovation, and international collaboration indicates that seeding technologies have significant potential to support vegetation establishment in degraded areas. Future research should focus on the development of specialized seed metering and sowing mechanisms, automation, precision seeding, and adaptation to the physical-mechanical properties of desert forage seeds. Such developments could strengthen the role of agricultural engineering in practical desertification prevention and contribute to more sustainable restoration of degraded drylands.

Authors' contribution

Conceptualization and methodology, E.T.Farmonov.; software, validation; formal analysis, research, resources, data collection, writing preparation of the original draft, Sh.X.Mirzaeva.; writing review and editing, visualization, Sh.X.Mirzaeva.; supervision, E.T.Farmonov. All authors have read and approved the published version of the manuscript.

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Ethics approval

The authors declare no conflicts of interest.

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