



# Desertification dynamics and future directions: results of a study with a focus on agricultural seeding technology.

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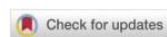
**Abstract:** Desertification and land degradation are among the major environmental and agricultural challenges affecting the productivity and sustainability of dryland ecosystems. The degradation of pasturelands and the decline in soil fertility highlight the need for effective technologies for restoring degraded areas and improving the establishment of forage vegetation. This study analyzes the development and research trends related to agricultural seeding technologies, with particular emphasis on seeders, sowing units, and metering devices applicable to arid and semi-arid environments. A bibliometric analysis of scientific publications indexed in the Web of Science Core Collection was conducted for the period 2013–2024 using Microsoft Excel, MapChart, and VOSviewer. A total of 981 publications were identified, approximately 90% of which were peer-reviewed research articles. The analysis examined publication trends, geographical distribution, scientific collaboration, research topics, and keyword relationships to identify major directions and emerging areas of research. The results indicate growing scientific interest in the application of advanced seeding technologies, precision metering systems, and automation for improving seed placement and agricultural productivity under water-limited conditions. The findings also demonstrate the importance of strengthening research and development and promoting international scientific collaboration in this field. The further development and adoption of efficient seeding and metering technologies may contribute to the restoration of degraded lands, improved forage establishment, and more sustainable agricultural production in arid and semi-arid regions.

**Keyword:** desertification; land degradation; seeding technology; agricultural seeder; sowing unit; seed metering; forage plants; arid regions; semi-arid regions; bibliometric analysis.

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## Introduction

Desertification is frequently used in a broad context and refers to a specific form of land degradation occurring in arid, semi-arid, and dry sub-humid regions, resulting in a long-term decline in land productivity. This process is generally caused by the combined effects of natural phenomena and anthropogenic activities. Environmental factors, including prolonged droughts and increasingly frequent extreme climatic events, can further intensify the progression of desertification. As a consequence, desertification may result in the deterioration of agricultural land, declining crop productivity, food insecurity, displacement of local communities, and the loss of biodiversity. Addressing these challenges requires an integrated approach involving sustainable land-use management, afforestation and reforestation measures, and effective policies focused on the conservation, rehabilitation, and restoration of degraded 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 [6]. 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 [7].

A seeder is a type of agricultural equipment used for sowing seeds into the soil [8]. 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 [9]. 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 [10]. They are commonly used for planting grass seed, cover crops, or small grains [11]. Row Seeders – These seeders plant seeds in rows and are equipped with furrow openers that create channels in the soil [12]. 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 [13]. Pneumatic Seeders – These seeders use air flow to transport seeds from a hopper to the seeding mechanism [14]. Plate Seeders – These seeders use a rotating plate with holes to meter and place seeds into the soil [15].

Review articles are widely regarded as one of the most popular types of scientific article reviews [16]. Result of our reviews have been increasingly applied in diverse areas of scientific research, including grain storage, land-use management, groundwater resources, and agricultural mechanization. The present bibliometric study provides an overview of the expanding body of research on desertification, with particular attention to the contribution of forage crops and mechanized seeding technologies to sustainable agricultural development and food security. The findings indicate that the use of mechanized seeders for forage crop establishment can provide greater efficiency, uniformity, and operational productivity compared with conventional manual sowing practices. Therefore, the application of mechanized forage seeding technologies represents a promising approach for supporting the rehabilitation of degraded lands and mitigating the impacts of desertification in arid and semi-arid regions.

## Materials and methods

The scientific literature concerning desertification and agricultural seeding technologies, including seeders, sowing units, and related equipment, was systematically examined using the Web of Science Core Collection database. The bibliometric investigation covered publications from 2013 to 2024. As an initial step, the term “desertification” was used to identify relevant publications based on their titles, abstracts, and keywords. This preliminary search yielded 981 documents within the selected period.

To refine the dataset and ensure its relevance to the research objectives, a structured retrieval strategy was applied on April 24, 2024. The search query was defined as follows: TITLE (“desertification” AND “seeder” AND “sowing unit”) AND PUBYEAR > 2013 AND PUBYEAR < 2024. The results were further restricted to the subject areas of Environmental Science, Agricultural Engineering, Engineering, and Plant Science. Only publications written in English and classified as final-stage documents were included in the analysis (Fig. 1). Following the application of the specified criteria, 981 publications were obtained and exported in CSV and RIS formats for subsequent analysis.

The resulting bibliographic dataset was processed using VOSviewer software version 1.6.18. The analysis incorporated several bibliometric techniques, including bibliographic coupling, thematic analysis, co-authorship analysis, keyword co-occurrence, citation analysis, and co-citation analysis. These methods were employed to identify major research trends, thematic relationships, scientific collaboration patterns, and the development of research directions related to desertification and agricultural seeding technologies.

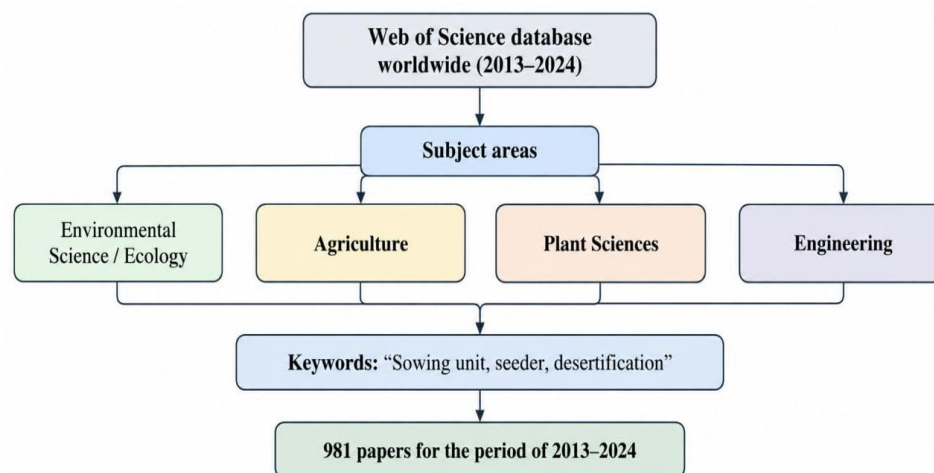


Figure 1. Flowchart of the methodology

### 3 Results & Discussion

#### 3.1. Published papers on sowing units and seeders

To examine the development and research dynamics of agricultural sowing units and seeders, the annual trends in scientific publications and citations were analyzed, as presented in Figure 2. The findings indicate that studies related to sowing units and seeders have been conducted and published across 93 countries worldwide. Overall, the publication trend demonstrates an increase in research activity, rising from 67 publications in 2000 to 29 publications in 2024, although a temporary decline was observed during the 2021–2023 period. This pattern reflects the sustained scientific interest in the development and application of sowing units and seeders as important technologies for improving agricultural sowing processes.

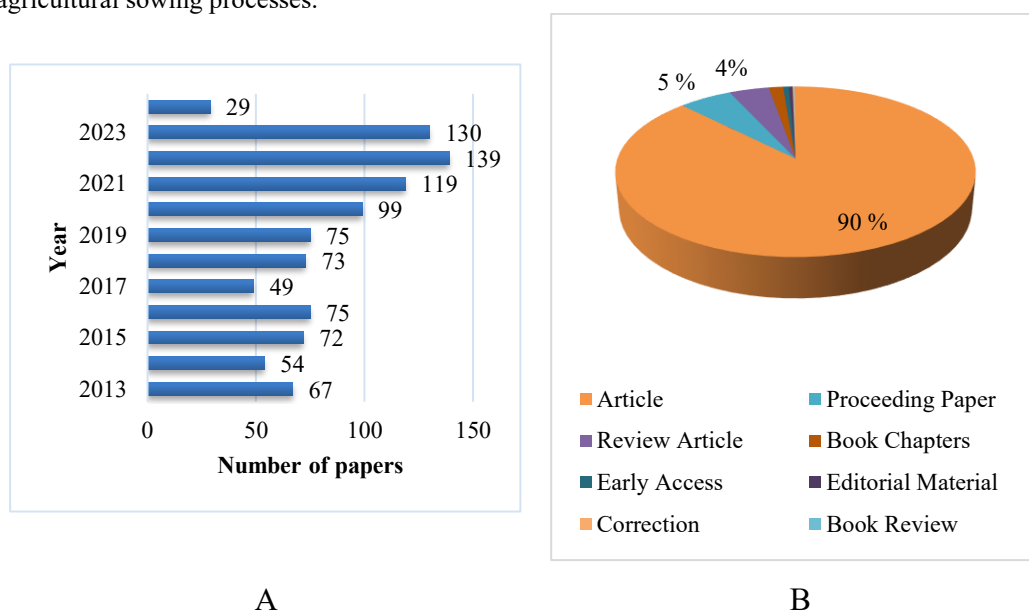


Figure 2. Number of papers on sowing units and seeders by year of publication worldwide (A), Types of publications on sowing units and seeders worldwide (B)

Furthermore, the document-type analysis revealed that the 981 publications included in the dataset were predominantly original research articles, accounting for 883 papers, or approximately 90% of the total. Conference proceedings represented the second-largest category, with 56 publications, followed by review articles, which accounted for 42 documents. The remaining publications, representing approximately 1% of the dataset, comprised various document types, including 15 book chapters, 6 early-access articles, 4 editorials, 2 corrections, and 1 book review, as illustrated in Figure 2.

#### 3.2 Top number of publications and top cited journals on sowing units and seeders

Table 1 presents an analysis of the leading journals publishing research on sowing units and seeders, considering both their publication output and impact factor, as well as their countries of

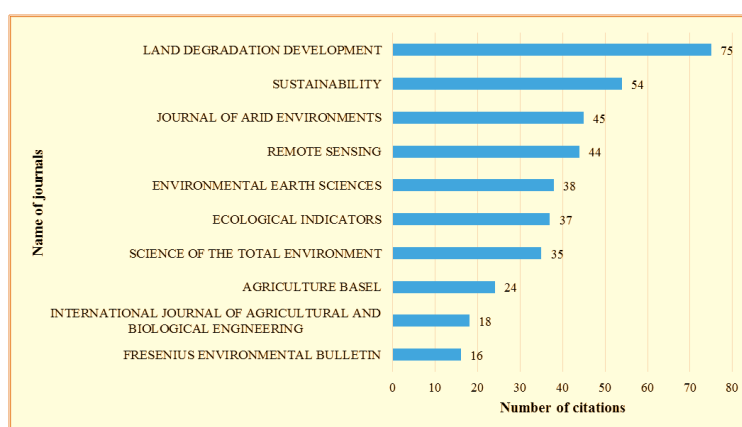
publication. The selected journals represent several countries, including Switzerland, the Netherlands, the United States, Germany, China, and the United Kingdom. Among the journals analysed, those published in Switzerland and the Netherlands accounted for three journals, while three were associated with the United States and Germany, two with China, and one with the United Kingdom. The mean impact factor of the top-ranked journals was 4.82. Among the journals considered, Remote Sensing of Environment recorded the highest impact factor, whereas Land Degradation & Development had the highest publication output within the research field.

**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%**

Although several journals contributed a relatively small number of publications on sowing units and seeders, they demonstrated considerable citation impact during the study period. To determine the journals with the greatest citation influence, the source titles in the Excel dataset containing 2,016 records were first organized alphabetically. The total number of citations was then calculated for each journal, allowing the sources with the highest citation performance to be identified. Based on these results, the ten most frequently cited journals were selected and are presented in Table 1. Together, the ten leading journals accounted for approximately 46.7% of the total 54,048 citations recorded for research on sowing units and seeders. In particular, the journal with 75 published documents ranked first in terms of both publication output and overall citation count, indicating its prominent role in this research area (Table 1). Furthermore, six journals Land Degradation & Development, Sustainability, Journal of Arid Environments, Remote Sensing, Environmental Earth Sciences, and Ecological Indicators were identified as particularly influential sources and are highlighted in Figure 3. Their citation performance demonstrates their significant contribution to agricultural research focused on sowing technologies, seeders, and sowing units.



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

### 3.3 Publications by keywords on sowing units and seeders

To examine the development and thematic structure of research on sowing units and seeders, a keyword co-occurrence analysis was performed using VOSviewer. The bibliographic records obtained for the study were imported into the software, and a co-occurrence network was generated based on the identified keywords, as shown in Figure 4. The analysis identified 30 keywords with sufficient relevance and frequency, which were subsequently organized into four thematic clusters. Cluster 1 comprised 11 items, while Clusters 2 and 3 each contained 7 items, and Cluster 4 consisted of 5 items. The resulting network illustrates the relationships among the major research topics and reveals the main thematic directions within the field of sowing units and seeder technologies.



metering drum with adjustable rotational speed, a dosing system incorporating a cone-shaped working element, and a drive mechanism for regulating the operating parameters. The hopper was designed with inclined walls to facilitate the movement of seed material toward the lower part of the metering system. The inclination angle of the walls was selected based on preliminary investigations of the physical and mechanical properties of the Izen seed heap. The experimental installation for sowing Izen seeds was manufactured by JSC “BMKB-Agromash” based on the results of the author's research (Fig. 6). The proposed design and its technical parameters were implemented according to the results of theoretical and experimental investigations. The manufactured installation provided the necessary conditions for evaluating the operational stability and sowing performance of the developed seed metering mechanism.



Figure 6. General view of the experimental machine prototype. 1-hopper; 2-shaft (on which a conical working element is mounted); 3-drum; 4-seed delivery tube; 5-variable transformer; 6-distribution panel; 7-belt conveyor

## Discussion

### 4.1 General discussion of the bibliometric paper on sowing units and seeders

Through a scientometric analysis, we were able to track trends and assess the contributions of various research papers and institutions over the past decade. The bibliometric analysis demonstrated a marked increase in publications on sowing units and seeders from 2013 to 2024, with the most significant research output occurring in the past five years. The research can be divided into three distinct phases: an introductory period (2013-2016), a period of slight growth (2017-2020), and a period of stable growth (2021-2024).

**Introductory Period (2013-2016):** During this period, the initial studies focused primarily on the environmental challenges faced by agriculture, with researchers exploring the relationship between sowing practices and land degradation. This phase laid the groundwork for the exploration of how improved sowing units could mitigate desertification and other environmental issues.

**Slight Growth Period (2017-2020):** In this phase, research gained traction as the connection between agricultural machinery, such as seeders, and environmental sustainability began to gain more recognition. Scholars explored various aspects of sowing technology, focusing on improving efficiency, reducing resource consumption, and optimizing seed placement to address issues like soil erosion and water conservation.

**Stable Growth Period (2021-2024):** By the most recent phase, the interest in sowing units and seeders had reached a steady growth trajectory. Researchers in this period focused on refining technologies, with a particular emphasis on developing more efficient, low-maintenance, and environmentally friendly seeders. Furthermore, there was a growing trend of interdisciplinary research that combined engineering, agricultural science, and environmental studies to improve the overall sustainability of agricultural practices.

One of the key findings of this analysis is the dominance of China in the field of sowing unit and seeder research. The country leads in terms of the number of publications, citations, authors, co-authors, and research funding. The National Natural Science Foundation of China (NSFC), with its substantial contribution to funding, has played a pivotal role in advancing this field. This dominance can be attributed to China's strong academic infrastructure, including numerous renowned research institutions and universities that focus on agricultural engineering and

environmental science.

China's leading position in sowing unit and seeder research is not surprising given the country's ongoing efforts to address agricultural productivity and environmental challenges. With vast arid and semi-arid regions, China has been particularly focused on improving seeding technologies to combat desertification and increase crop yields. The role of national funding agencies such as the NSFC in supporting this research is a critical factor in the continued advancement of these technologies.

In addition, the bibliometric analysis of sowing units and seeders reveals a growing global focus on sustainable agricultural practices. The data underscores the importance of continued research and development in this area, particularly in the context of environmental challenges such as desertification and climate change. As this field continues to evolve, it is crucial that global collaboration, along with targeted funding and institutional support, remains central to achieving advancements that will contribute to food security and environmental sustainability.

#### *4.2. Discussion of the development of sowing unit and seeder over three periods*

Period 1: 2013–2016. The first period, spanning from 2013 to 2016, was characterized by a relatively low number of scientific works focusing on the development of sowing units and seeders. However, this period was crucial in setting the foundation for subsequent advancements in the field. The studies published during this time were primarily concerned with understanding the environmental challenges faced by agriculture, particularly in arid and semi-arid regions affected by desertification. The first notable publication from this period, "Mitigation and Adaptation Investments for Desertification and Climate Change: An Assessment of the Socioeconomic Return", highlighted the impact of climate change on desertification. This paper emphasized that climate change would exacerbate the already-existing challenges of desertification, affecting vast areas of the world. It marked the early recognition of the need for sustainable agricultural practices, including efficient sowing techniques, to mitigate desertification.

Another important article from this period, "Plant-Soil Interactions in Mediterranean Forest and Shrublands: Impacts of Climatic Change", discussed the specific challenges of the Mediterranean climate. The study examined how the scarcity of soil nutrients and water affects plant growth, leading to a direct impact on soil structure and fertility. These interactions between plant growth and soil properties are critical for the development of effective sowing units and seeders, as they must be adapted to optimize seed placement and soil conservation in such harsh conditions.

The analysis of this problem laid the groundwork for improving the design and performance of pneumatic seeders, emphasizing the importance of optimizing the flow distribution system for better seed placement and minimized waste. In summary, the first period (2013–2016) focused on addressing the fundamental environmental issues that impact agriculture, particularly desertification, climate change, and water scarcity. Early studies also introduced the concept of optimizing sowing technology to adapt to these challenges, marking the first steps toward the development of more efficient and sustainable seeding systems. However, the number of publications was relatively low during this period, reflecting the nascent stage of research in this field.

Period 2: 2017–2020. The second period, from 2017 to 2020, witnessed a significant increase in publications focusing on the development and optimization of sowing units and seeders. During this period, scientific efforts expanded to address more practical and specific challenges related to desertification, seeder mechanisms, and precision farming. Several studies highlighted the importance of improving seeders to combat desertification, enhance sowing efficiency, and ensure the sustainable use of agricultural land. The first key paper from this period, "Detecting Sustainability of Desertification Reversion: Vegetation Trend Analysis in Part of the Agro-Pastoral Transitional Zone in Inner Mongolia, China", focused on desertification in China. This study was pivotal in examining vegetation dynamics, a crucial aspect of global environmental change. The research specifically discussed desertification in the Khorkin Sandy Land during the late 1990s and the trends in vegetation recovery, which is critical for monitoring the spatiotemporal variability of desertification on a regional and global scale. The findings highlighted the role of vegetation dynamics in combating desertification, indirectly pointing to the need for more effective sowing units that could promote vegetation growth and sustainable land management.

Another important paper, Desertification: China Provides a Solution to a Global Challenge, explored the broader issue of desertification as a major environmental challenge. It emphasized the serious threats desertification poses to environmental security and sustainable development. The paper proposed a four-pronged strategy to combat desertification, offering solutions that could be applicable worldwide. This study helped set the context for agricultural technologies, such as advanced seeders, to address desertification by enhancing soil fertility and promoting reforestation efforts through efficient sowing techniques.

A significant technical contribution came from Virtual Simulation Analysis and Verification of Seed-Filling Mechanism for Dipper Hill-Drop Precision Direct Rice Seeder, which introduced a new approach for improving the seed-filling ability of precision rice seeders.

Similarly, the paper *Test on Effect of the Operating Speed of Maize-Soybean Interplanting Seeders on Performance of Seeder-Metering Devices*, delved into the impact of operating speed on the performance of seeder-metering devices. The authors discussed the importance of maintaining optimal metering performance across varying operating speeds in multifunctional seeders.

Period 3: 2021–2024. The third period, spanning from 2021 to 2024, highlights the continued evolution of sowing unit and seeder technology, with a particular focus on sustainable practices, advanced technological solutions, and addressing environmental challenges such as desertification. This period shows significant strides in both the development of new seeding mechanisms and the exploration of their broader environmental impacts. Several studies have been pivotal in advancing the field of seeding, addressing challenges related to soil health, desertification, and precision agriculture. "Comparative analysis of soil bacteria assemblages across land-use types in a given karst landscape in southwest China", focuses on understanding the impact of land use types on soil microbial communities. Although not directly related to seeders, this study provides important insights into how land management practices, including sowing techniques, can influence soil health. The findings from this research are crucial for understanding how different land uses, such as crop fields versus forests, interact with soil microorganisms and how these interactions can affect the long-term productivity of agricultural lands.

"Path analysis model to identify and analyse the causes of aeolian desertification in Mu Us Sandy Land, China" (Feng et al., 2021), addresses desertification in northern China, particularly the relationship between human activities and desertification processes. This study used spatial data from 1975 to 2015 to map the extent of desertification in the Mu Us Sandy Land. While the paper primarily discusses desertification, the findings underscore the importance of using effective sowing technologies, such as no-till or minimal disturbance seeders, to combat land degradation. The study highlights the urgent need for improved seeding practices that can help restore and maintain vegetation in desertified areas.

"Development and first results of a no-till pneumatic seeder for maize precise sowing in Huang-Huai-Hai Plain of China" (H. Li et al., 2021), presents the development of a no-till pneumatic seeder specifically designed for maize sowing in the Huang-Huai-Hai Plain of China.

"Driving factors and prediction of rock desertification of non-tillage lands in a karst basin, southwest China" (Huang et al., 2021), examines rock desertification and its driving factors in a karst basin in southwest China. Using artificial neural networks (ANN), the authors identified key environmental factors contributing to desertification in uncultivated lands. This paper highlights the broader environmental context in which seeders operate. It underlines the need for technologies that can adapt to varying land conditions, including rocky or degraded soils, to enhance the effectiveness of sowing units in diverse environments.

"The possible role of *Ziziphus lotus* as an ecosystem engineer in semiarid landscapes" (Constantinou et al., 2021), discusses the role of *Ziziphus lotus* in improving soil health and promoting vegetation growth in semiarid regions. This article, although more focused on ecological restoration, illustrates the potential for seeders to be used in the restoration of semiarid landscapes. *Ziziphus lotus*, as an ecosystem engineer, improves soil fertility and structure, which is vital when using seeders in environments that face water scarcity and soil erosion.

"Brief review of minimum or no-till seeders in China" (Jiang et al., 2021), provides a comprehensive review of no-till and minimum tillage technologies in China. This article focuses on the importance of reducing soil degradation due to wind and water erosion by implementing no-till seeding systems. The review highlights different technologies and working components of no-till seeders, making it a key reference for understanding the technological advancements in this area. By reducing soil disturbance, no-till seeders help conserve soil moisture, improve soil health, and reduce the energy required for sowing.

"Evaluation of seeding unit equipped with shock absorber suspension on corn and sunflower" (Liu et al., 2021), investigates the performance of seeding units equipped with shock absorber suspensions, particularly for corn and sunflower sowing. The study emphasizes the importance of seed placement accuracy in relation to seed germination and final yield. The findings suggest that shock absorber technology can significantly improve the uniformity of seed depth and distance between seeds, especially under challenging soil conditions. This advancement is crucial for ensuring that sowing units can perform well across different soil types and environmental conditions, ensuring high-quality yields.

The third period saw continued innovation in sowing technologies, particularly focused on precision sowing, no-till practices, and addressing the challenges posed by desertification and soil degradation. The studies published during this period reflect a clear shift toward integrating advanced technologies, such as artificial intelligence, virtual simulation, and no-till systems, to enhance sowing efficiency while maintaining or improving environmental sustainability. This period also marks a growing recognition of the importance of integrating ecological factors, such as soil health and vegetation dynamics, into the design and application of seeders.

Furthermore, the use of shock absorbers, pneumatic systems, and minimal soil disturbance in seeding units suggests a trend toward more efficient, adaptable, and environmentally conscious agricultural practices. These developments are crucial for meeting the global challenges of

sustainable agriculture, particularly in regions facing land degradation, desertification, and resource scarcity. The advancements in seeding technology during this period are laying the groundwork for more resilient agricultural practices that can support food security and environmental health in the coming decades.

**Table 2.** List of publications on sowing unit and seeder during 3 periods

| 1-period: 2013-2016 |                                                                                                                                                          |      |                                                                                                                            |                                        |            |
|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|------|----------------------------------------------------------------------------------------------------------------------------|----------------------------------------|------------|
| Nº                  | Article title                                                                                                                                            | Year | Authours                                                                                                                   | Doi                                    | Country    |
| 1                   | Mitigation and adaptation investments for desertification and climate change: an assessment of the socioeconomic return                                  | 2013 | Ximena Salinas, Carla; Mendieta, Jon                                                                                       | 10.1007/s11027-012-9380-8              | USA        |
| 2                   | Plant-soil interactions in Mediterranean forest and shrublands: impacts of climatic change                                                               | 2013 | Sardans, J.; Penuelas, J.                                                                                                  | 10.1007/s11104-013-1591-6              | Spain      |
| 3                   | Air-seeds flow analysis in a distributor head of an air drill seeder                                                                                     | 2013 | Bourges, G.; Medina, M.                                                                                                    | 10.17660/ActaHor tic.2013.1008.34      | Argentina  |
| 2-period: 2017-2020 |                                                                                                                                                          |      |                                                                                                                            |                                        |            |
| 1                   | Detecting sustainability of desertification reversion: vegetation trend analysis in part of the agro-pastoral transitional zone in inner Mongolia, China | 2017 | Lian, Jie; Zhao, Xueyong; Li, Xin; Zhang, Tonghui; Wang, Shaokun; Luo, Yongqing; Zhu, Yangchun; Feng, Jing                 | 10.3390/su9020211                      | China      |
| 2                   | Desertification: China provides a solution to a global challenge                                                                                         | 2017 | Bao, Yingshuang; Cheng, Leilei; Bao, Yanfeng; Yang, Liu; Jiang, Lina; Long, Chao; Kong, Zhe; Peng, Peng; Xiao, Jun; Lu, Qi | 10.15302/J-FASE-2017187                | China      |
| 3                   | Virtual simulation analysis and verification of seed-filling mechanism for dipper hill-drop precision direct rice seeder                                 | 2017 | Wang Jinwu; Zhou Wenqi; Tian Liquan; Li Shuwei; Zhang Zhao                                                                 | 10.25165/j.ijabe.20171006.2981         | China      |
| 4                   | Test on effect of the operating speed of maize-soybean interplanting seeders on performance of seeder-metering devices                                   | 2017 | An, Xue; Wang, Sheng; Duan, Hongyan; Yang, Chen; Yu, Yongchang                                                             | 10.1016/j.proeng.2017.01.153           | China      |
| 5                   | Dynamic performance of a no-till seeding assembly                                                                                                        | 2017 | Sharipov, Galibjon M.; Paraforos, Dimitris S.; Pulatov, Alim S.; Griepentrog, Hans W.                                      | 10.1016/j.biosystemseng.2017.03.016    | Uzbekistan |
| 3-period: 2021-2024 |                                                                                                                                                          |      |                                                                                                                            |                                        |            |
| 1                   | Comparative analysis of soil bacteria assemblages across land-use types in a given karst landscape in southwest China                                    | 2021 | Li, Qiang; Yang, Hui; Song, Ang                                                                                            | 10.15244/pjoes/130678                  | China      |
| 2                   | Path analysis model to identify and analyse the causes of aeolian desertification in Mu Us Sandy Land, China                                             | 2021 | Feng, Kun; Wang, Tao; Liu, Shulin; Yan, Changzhen; Kang, Wenping; Chen, Xiang; Guo, Zichen                                 | 10.1016/j.ecolind.2021.107386          | China      |
| 3                   | Development and first results of a no-till pneumatic seeder for maize precise sowing in huang-huai-hai plain of China                                    | 2021 | Li, Hui; Liu, Hu; Zhou, Jilei; Wei, Guojian; Shi, Song; Zhang, Xiangcai; Zhang, Rongfang; Zhu, Huibin; He, Tengfei         | 10.3390/agriculture11101023            | China      |
| 4                   | Driving factors and prediction of rock desertification of non-tillage lands in a karst basin, southwest China                                            | 2021 | Huang, Xianfei; Zhang, Zhenming; Zhou, Yunchao; Wang, Xingfu; Zhang, Jiachun; Zhou, Xinwei                                 | 10.15244/pjoes/130403                  | China      |
| 5                   | The possible role of Ziziphus lotus as an ecosystem engineer in semiarid landscapes                                                                      | 2021 | Constantinou, Elena; Sarris, Dimitrios; Vogiatzakis, Ioannis N.                                                            | 10.1016/j.jaridenv.2021.104614         | Greece     |
| 6                   | Brief review of minimum or no-till seeders in China                                                                                                      | 2021 | Jiang, Shan; Wang, Qingjie; Zhong, Guangyuan; Tong, Zhenwei; Wang, Xiuhong; Xu, Jing                                       | 10.3390/agriengineering3030039         | China      |
| 7                   | Evaluation of seeding unit equipped with shock absorber suspension on corn and sunflower                                                                 | 2021 | Liu, Kaihua; Zanchin, Alessandro; Sozzi, Marco; Gasparini, Franco; Benetti, Marco; Sartori, Luigi                          | 10.1109/MetroAgriFor52389.2021.9628859 | Italy      |

#### 4.3 Limitations

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.

#### Conclusion

This study presents a comprehensive bibliometric assessment of the global research landscape

concerning agricultural seeders and sowing units, drawing on 981 bibliographic records. The findings demonstrate a sustained expansion of scientific interest in seeding technologies and their role in improving sowing performance, crop establishment, and agricultural productivity. Research activity has developed considerably over the last decade, with a particularly notable increase observed from 2021 onward. This growing body of research covers a wide range of applications, including vegetable, cotton, and desert forage seeders. The analysis of scientific sources indicates that *Land Degradation & Development*, published in the United Kingdom, represents one of the prominent journals contributing to this research area. The keyword co-occurrence analysis further highlights the central role of terms such as sowing units, seeders, and desertification, reflecting the major thematic directions of current research. Among the most productive researchers identified in the analyzed dataset were Xiong K., Salvati L., and Chi Y.K., demonstrating their notable contribution to the development of this scientific field. At the country level, China, the United States, and Italy showed particularly strong research performance, both in terms of publication output and citation impact. Taken together, the results provide an overview of the evolution, major research themes, leading contributors, and geographical distribution of studies related to seeders and sowing units. The observed research trends also indicate a transition toward increasingly advanced and intelligent seeding technologies. In particular, the integration of automation, artificial intelligence, sensor-based systems, and intelligent control technologies represents a promising direction for future research. Further development in these areas may contribute to more precise, efficient, and sustainable sowing operations, while supporting agricultural productivity, environmental sustainability, and long-term global food security.

### Future trends

Future research on sowing units and seeders could focus on several emerging and impactful areas, particularly the development of automated systems, innovations in seeding technologies, artificial intelligence (AI), and intelligent control mechanisms. As agricultural technology continues to evolve, these areas are likely to play a critical role in enhancing the efficiency, precision, and sustainability of seeding operations. Automation can improve the overall performance of seeders, making them more adaptable to various soil types, crop varieties, and environmental conditions. The integration of AI into seeder design could enable real-time adjustments to seed placement, depth, and spacing, enhancing crop yield and minimizing waste.

### Authors' contribution

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

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### Conflicts of interest

The authors declare no conflicts of interest.

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