

MILLETS: A KEY PLAYER IN SUSTAINABLE FOOD SYSTEMS - LEVERAGING THE YEAR OF MILLETS FOR RESEARCH AND DEVELOPMENT

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Abstract

The paper provides a general picture of millets in the world, where we face global challenges such as water shortage, land degradation, climate change, etc. Millet is recognized as a climate-resilient crop that can be beneficial to our environment and diversification of our diet besides main staples such as rice, corn, and wheat.

For the recognition of these important components of millets, the United Nations declared the year 2023 as “the year of millets”, and FAO as the lead agency for celebrating the Year in collaboration with other stakeholders.

The impact of this event clearly shows in the academic publication, in a broad term, academic research on millets thanks to its health and environmental benefits has grown exponentially led by India, China, the United States, and other countries. Scopus confirms this publication trend between 2000~2023 and VOS viewer bibliometric analysis reveals a prominent cluster connecting food security, climate change, and millet with other keywords.

Although in Europe millets were planted for centuries ago, the consumption and production or even awareness of it have been relatively low, which means more research and development needs to be encouraged and the promotion of health and environmental benefits to consumers needs to be supported by the private and public sectors.

Keywords: Millet; SDG; food security; India

JEL: C18, C55, C88, O13, Q01

Introduction

Hunger or nutrient deficiency is one of the major problems faced by the developing world in achieving SDG2 (Zero Hunger) which aims to end all forms of hunger and malnutrition by 2030. More than 2 billion people are suffering from hunger ‘hidden hunger’ (micronutrient malnutrition) in the world and nearly half of them living in India (Ritchie, Reay and Higgins, 2018).

It is a global challenge to feed the growing population and tackle environment (issues such as climate change, soil and land degradation, and depletion of water resources), therefore requiring a sustainable option to produce nutritious food ensuring food and nutritional security (Sukumaran Sreekala et al., 2023).

The Food and Agriculture Organization (2013) describes food insecurity as a lack of sufficient access to safe and nutritious food. Food security encompasses not only the stable physical availability of food but also continuous access to adequate nutrition.

Food security for a nation generally implies that all individuals, at all times, have physical, social, and economic access to enough safe and nutritious food to meet their dietary needs and preferences for an active and healthy life (Food and Agriculture Organization, 1996). Any lack in these components signifies food insecurity, with greater deficiencies indicating more severe food insecurity.

In recent years, to address this issue, there have been some efforts to promote millet by the developing nations. Once a forgotten staple, for example, in India, where millet was in traditional cooking but fell out of favor over the year (Ramadurai, 2023). The government of India introduced

new policies to augment its production and consumption (Sukumaran Sreekala et al., 2023). Given the arduous situations of increase of population, climate change, and nutrition requirement, India is faced with a new direction to achieve food and nutrition security (Islam and Manaloor, 2021).

Millet is one of the strong potential crops that may promote the shift towards more plant-based diets and contribute to a solution for feeding the growing world population ensuring the world's food security and tackling climate change issues. To keep the moment going, the United Nations declared the year 2023 as “the year of millets”, and FAO as the lead agency for celebrating the Year in collaboration with other stakeholders (FAO, 2023a). This declaration is important from United Nation's Sustainable Development Goals, the 2030 Agenda for Sustainable Development perspective adopted in 2015. Figure 1 illustrates 6 out of 17 ambitious Goals related to the promotion of Millets - Zero hunger (SDG 2), Good health and well-being (SDG 3), Decent work and economic growth (SDG 8), Responsible consumption and production (SDG 12), Climate action (SDG 13), Life on land (SDG 15).

Figure 1. Millets and GDGs

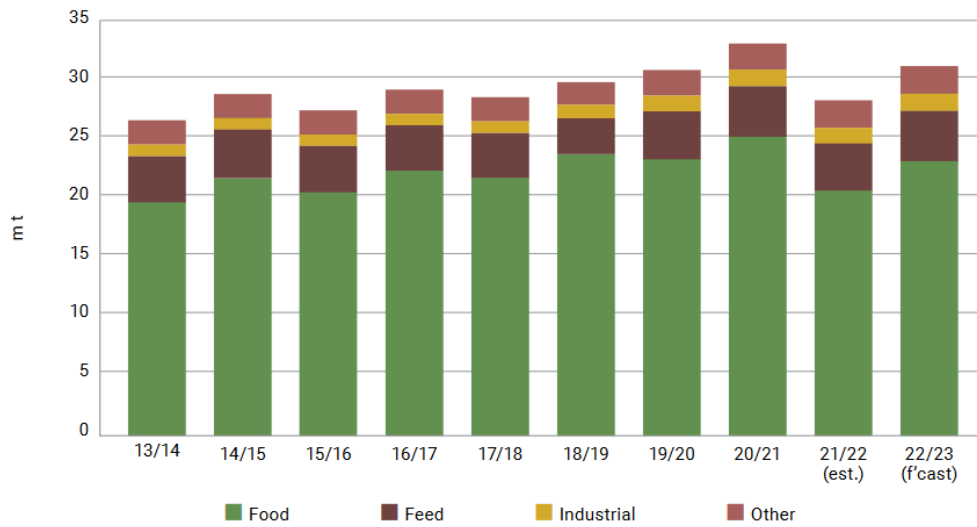


Source: FAO, 2023b (Food and Agriculture Organization of the United Nations. Reproduced with permission).

Although the Global North has just started to notice the nutritive value of millets and its invaluable role in empowering smallholder farmers, tackling climate change and food security issues, and achieving sustainable development, millets have been a stable food in India and some parts of Africa and Asia for several centuries (FAO, 2023a). For thousands of years millets were or are the main staple crops for food and animal fodder in some parts of Africa and Asia (especially in India and sub-Saharan Africa). For example, finger millet was domesticated 5000 years ago in Africa (Chamoli et al., 2018); pearl millet 4000 years ago (Taylor, 2018); foxtail millet 8000 years ago (Lu, 2002). Although Millets, being among the first domesticated crops, remain relatively unknown, their vital contributions to food security and local cultures frequently remain unacknowledged.

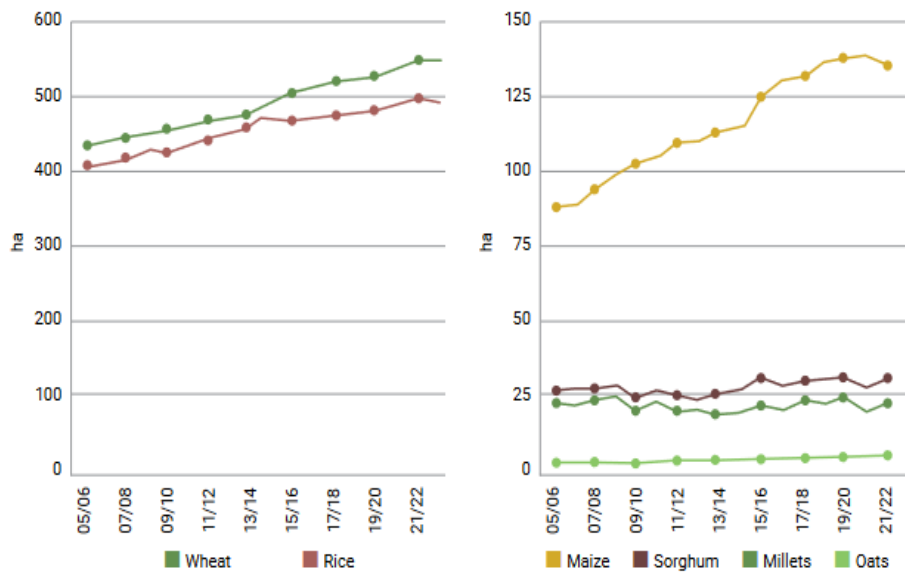
Figure 2 presents the world consumption of millets by use. Currently the annual global consumption of millets is approximately 30 million tonnes, and mostly used in sub-Saharan Africa and South Asia. And this is far below other grains like maize, rice and wheat. Figure 3 shows confirms that, illustrating the comparison of consumption by major cereals what is eaten daily by people around the world (FAO, 2023b). However, in different angle, this current number leaves more room for millets for potential growth in global human consumption.

Figure 2. World Consumption of Millets



Source: FAO, 2023b (Food and Agriculture Organization of the United Nations. Reproduced with permission).

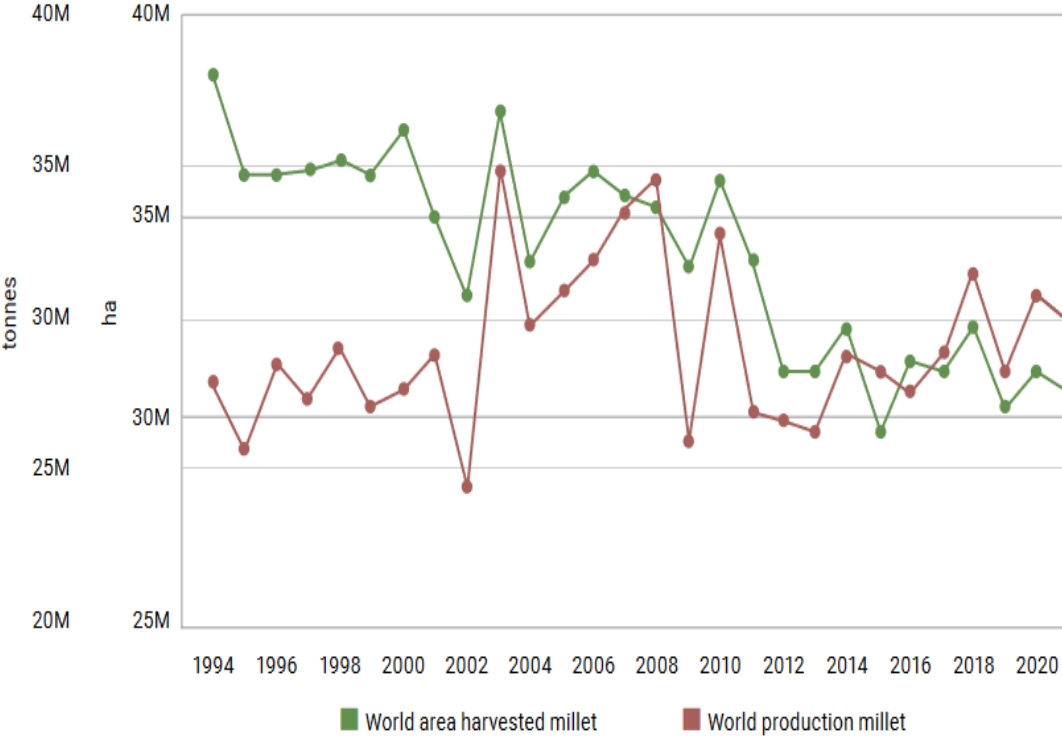
Figure 3. Comparison of world food consumption of cereals.



Source: FAO, 2023b (Food and Agriculture Organization of the United Nations. Reproduced with permission).

Figure 4 presents world area harvested millet and world production millet (1994—2020 period) and illustrates the increase in millet production despite a reduction in harvested area, indicating a slight rise in millet yields over the past decade. This presents an opportunity to leverage trade in millets to maximize the benefits of higher yields (FAO, 2023b).

Figure 4. Production and harvested area of millet, 1994 – 2021

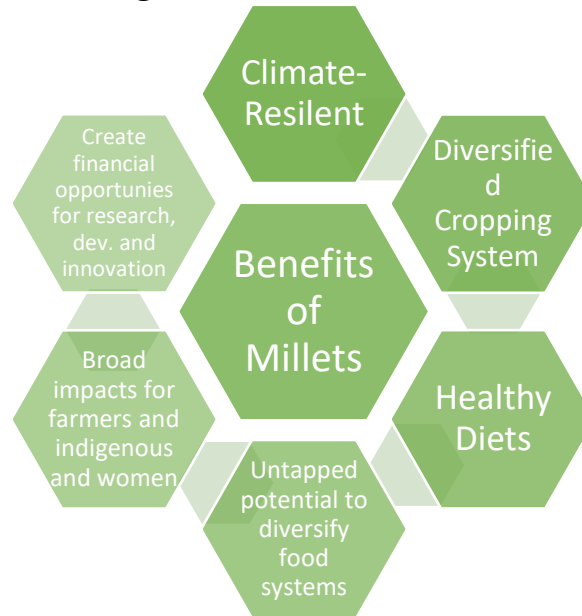


Source: FAO, 2023b (Food and Agriculture Organization of the United Nations. Reproduced with permission).

It is widely known that millets require less fertilizer and other agricultural chemical inputs such as pesticide, in contrast to mainstream cereals like rice, wheat, corn. Millets contain superior nutrients and characteristics of excellent climate resilience properties (Ceasar and Maharajan, 2022), therefore, promotion of millets is related to achieving the sustainable development goals (SDGs) set by the UN. Especially, Goal 2 states its objective as ‘to end hunger, achieve food security and improve the nutrition and promote sustainable agriculture’ (UN General Assembly, 2015).

Considering the severe hunger and malnutrition and drought prone areas in Africa, millets are attractive crop for risk avoidance strategies (Ceasar et al, 2018) which are highly tolerant to high temperatures and drought and requiring low inputs, considered the most suitable crop for climate change issue and promotion of sustainable agriculture (Saha et al.,2016; Thilakarathna & Raizada, 2015).

Figure 5. Benefits of Millets



Source: FAO 2023b, author's compilation

Figure 5 presents the benefits of millets in diagram. The benefits of millets can be broadly summarized as follows: 1) they are climate resilient, 2) they support diversified cropping systems, 3) they promote healthy diets, 4) they offer untapped potential to diversify our food systems, 5) they positively impact small-scale farmers, indigenous communities, and women, and 6) they create financial opportunities for research, development, and innovation (FAO, 2023b).

Millets have attracted researchers in Europe and America beyond the regional locations in Central Africa and South Asia, due to the rise of academic attention and their exceptional nutrient content and climate resilience properties. It was certainly not possible to see any significant literature on millets in these regions if we look two decades back, except a few places in Asia, in particular, in India (Ceasar and Maharajan, 2022).

In academic paper, there has been an increasing number of publications in recent years, and this trend is accelerated after the declaration of International Year of Millets 2023. Millet research has garnered global interest, and numerous recent articles have been published in high-impact journals (Adhikari et al., 2017).

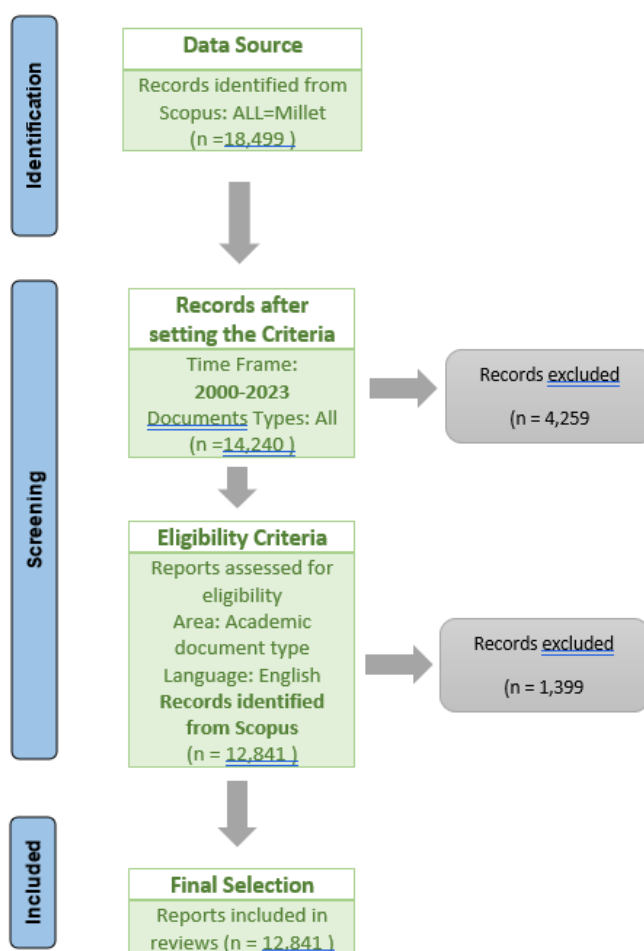
Materials and Methods

Bibliometric analysis was selected to investigate the research trend and gap in millets. The Scopus database was used for the primary bibliometric analysis because Scopus has a wide range of data (Waltman, 2016). The search term focused on millet. The following algorithm was employed. ALL = ("Millet"). Figure 6 outlines the bibliometric analysis process. Our initial search yielded 18,499 documents, which were then narrowed down to those published between 2000 and 2023 (excluding 4,259). We further refined the dataset by filtering for English-language publications, resulting in the exclusion of 1,399 documents. Ultimately, the final analysis was conducted on 12,841 documents.

In addition to this method, VOS viewer software simulation was used to show the inter-linkages of key words around millets. In other words, a co-occurrence analysis of keywords was applied. Co-occurrence analysis is a text mining technique used to identify relationships between keywords within a body of text. A specific application of this method, co-word analysis, explores how words are interconnected to construct the underlying conceptual framework of a subject matter (Callon et al., 1983). According to van Eck and Waltman (2010), this approach quantifies the frequency of keyword occurrences within documents and the co-occurrence of term pairs. The resulting co-word network visualizes the strength of these associations, mapping out the thematic landscape of a field. By examining author-assigned keywords, co-occurrence analysis delves into the core content of publications (Škare et al., 2022).

A co-word map offers a visual representation of a field's conceptual structure. Node size reflects keyword frequency, while proximity and line thickness indicate the strength of associations between concepts. This analysis aims to uncover the relationships between millet, food security, and climate change through keyword co-occurrence patterns.

Figure 6. Review process

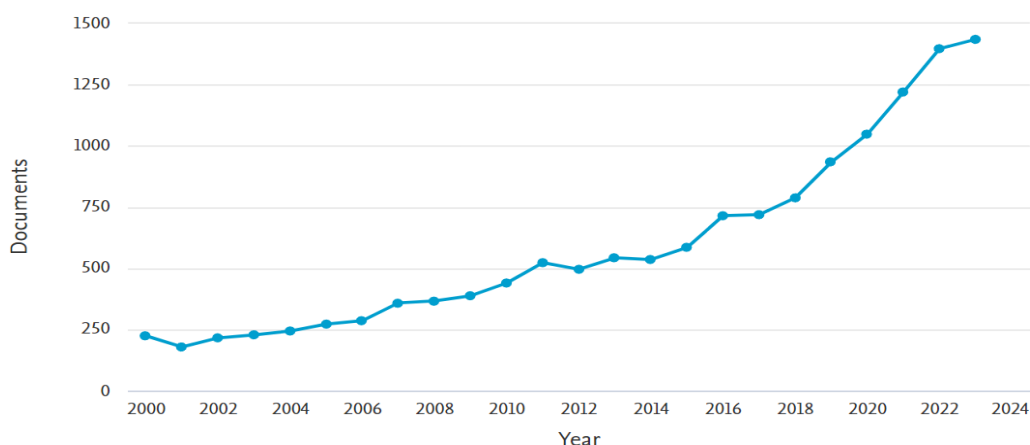


Source: Author's own elaboration from Scopus

Results

Figure 7 presents number of publications. The key word ‘Millet’ shows the total result of 12,841 documents for the period from 2000 to 2023 (document language was limited to English) to compare whether there was any meaningful increase after the declaration of millet year 2023. And as can be seen in the figure, the number of publications has steadily increased over time.

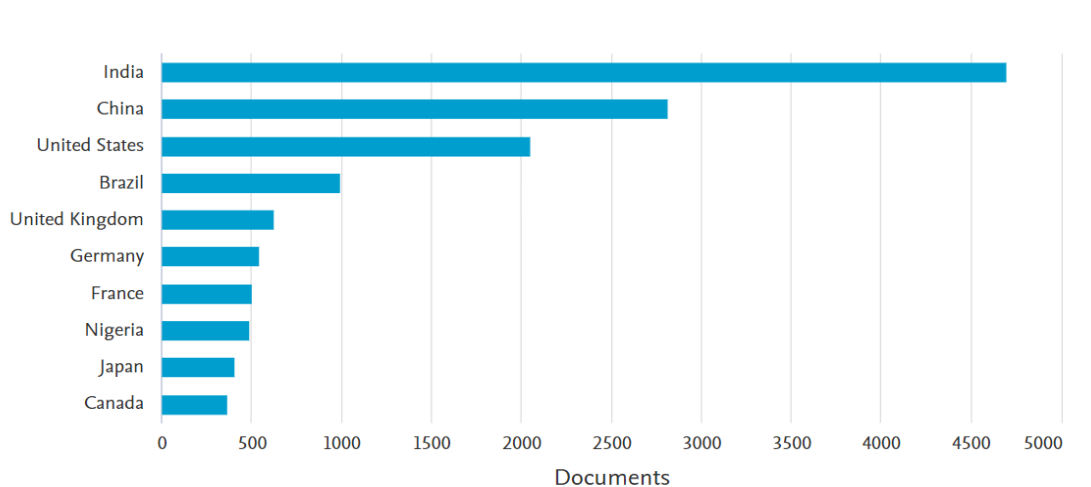
Figure 7. Millets publications on rise



Source: Scopus, accessed date: 01.08.2024

In order to see which country produced most publications in the subject, figure 8 presents the publication by country. By far, India leads the way in research in millets and followed by China, United States, and Brazil.

Figure 8. Publications by country or territory



Source: Scopus, accessed date: 01.08.2024

Figure 9 table presents top 5 authors in millets research publication quantity. Top author is Diao, X from Chinese Academy of Agricultural Sciences and 2nd ranked author is Kumar, A from India, Institute of Himalayan Bioresource Technology. All 5 authors are from either China or India.

The similar trend is noticed as well in Figure 10, which presents the top 5 most cited authors in relation to millets (from 2,000 to 2024, in English).

Figure 9. Top 5 authors in millets research publication

#	Author	Country	# published	Affiliation
1	Diao, X.	China	75	Chinese Academy of Agricultural Sciences
2	Kumar, A.	India	73	Institute of Himalayan Bioresource Technology
3	Prasad, M.	India	71	National Institute for Plant Genome Research India
4	Shetty, H.S.	India	71	Department of Biotechnology, Mysore, India
5	Feng, B.	China	70	Northwest A&F University

Source: Author's own elaboration based on Scopus, accessed date: 01.08.2024

It is noticeable that all 5 documents listed below are from natural sciences subject related, which is confirmed by the next figure the document numbers in the subject.

Figure 10. Top 5 authors (highest cited) in millets research publication

#	Author(s)	Year Published	# cited	Document Title
1	Somerville, C., Youngs, H., Taylor, C., Davis, S.C., Long, S.P	2010	1,057	Feedstocks for lignocellulosic bio-fuels
2	Schlenker, W., Lobell, D.B.	2010	921	Robust negative impacts of climate change on African agriculture
3	Schmer, M.R., Vogel, K.P., Mitchell, R.B., Perrin, R.K.	2008	887	Net energy of cellulosic ethanol from switchgrass
4	Rattan, R.K., Datta, S.P., Chhonkar, P.K., Suribabu, K., Singh, A.K.	2005	860	Long-term impact of irrigation with sewage effluents on heavy metal content in soils, crops and groundwater - A case study
5	Scharf, K.-D., Berberich, T., Ebersberger, I., Nover, L.	2012	795	The plant heat stress transcription factor (Hsf) family: Structure, function and evolution

Source: Author's own elaboration based on Scopus, accessed date: 31.08.2024

The size of the node represents the total number of keywords that appeared, and the color represents the year of publication for the keyword. The yellow color denotes the word appearing in 2020 or after and the green color represents keywords used in 2018 or after. Food security, millet, food supply and India and so on appeared after 2016. VOS Viewer bibliometric analysis shows a network of food security, climate change and millet as a big cluster to connect with other key words and this seems to be a trend in recent years that research and publications in linkage of these words have increased as the color shows. As a country, India is noticeable as the publication by country showed in figure 10, confirming that it's leading the way in publications related to climate change, food security, food supply, and millet. This suggests research linked with these topics were increased over time and the linkage was aided by the visualization of the keywords.

Conclusion

Once considered crops of the past, millets are now seen as crops of the future due to their natural tolerance to climate change. The growing interest in millets is enhanced by food and nutritional security in the world along with rice, wheat, and other stable crops, as millets are not only resilient to climate variations but also climate-smart, poised to significantly contribute to the UN's sustainable development goal of promoting sustainable agriculture. They are essential in efforts to end hunger, achieve food security, and improve nutrition, particularly among rural populations in low- and middle-income countries in Asia and Africa (Antony Ceasar and Maharajan, 2022).

Moreover, by promoting millets, smallholder farmers could earn more additional sources of revenue and bring more financial gains to rural communities and boosting economic growth for agriculture-based economies in developing countries.

In Western regions, including Europe, millets have received relatively little attention in both research and consumption compared to Asia and Africa. However, as seen in the document by year, not only document per year over the last 20 years, but also many countries in Europe such as UK., Germany, and France have developed keen interest in research in millet and total publication per year has been increasing.

VOS viewer bibliometric analysis reveals a prominent cluster connecting food security, climate change, and millet with other keywords. This suggests a growing research trend in recent years, as evidenced by the increasing number of publications linking these terms (indicated by color intensity). In relation to SDGs, this cluster trend is expected to become stronger as it is intertwined with the 2030 Agenda for Sustainable Development.

Research related millets will be enhanced in different scientific subjects and these efforts should be hand by hand with policies by public sector for promotion of health and environmental benefits of millets and therefore creating an incentive and drivers for private sector to develop more millet products based on scientific research and development.

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