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Research trend and conceptualization of low-carbon agricultural systems for food security in Brazil and Africa: a systematic and bibliometric analysis

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Abstract
Brazilian research institutes have remarkable contributions in promoting food security in Africa through collaborative-knowledge transfer. However, there is lack of information on publications, research production and emerging trends on low-carbon agricultural systems (LoCAS) and food (in)security within and between Brazil and Africa. This work is aimed at mapping the research collaborations, thematic evolution, and publication trends on LoCAS and food security in Brazil and Africa by using a systematic and bibliometric analysis. This is the first time different bibliometric methods (such as VOSviewer, Flourish studio, Bibliometrix and Biblioshiny models in Rstudio) were simultaneously used to investigate the research impacts on LoCAS and food security in the regions. Data were extracted from the Web of Science databases by using the relevant search terms and strings. From the dataset, information relating to LoCAS was extracted and collated from the regions by identifying seven LoCAS and estimated the number of articles reflected on each. A qualified 687 articles, which had annual scientific growth rate of 13.1%, involving 2,839 authors who applied 2,519 keywords and had 10.2% international collaborations was observed. Brazil (22.4%), and South Africa (14.3%) had the highest number of publications. Number of LoCAS increased with corresponding authors countries' research relevance. Thirty-six core benefits of LoCAS were identified. Authors' scientific production showed, de Oliveira Silva and Pereira (Brazil), and Thierfelder (Zimbabwe) as the most impactful authors. Published studies reflecting on food (in)security increased by 75% while those for LoCAS increased by 67%. The hybrid bibliometric approach helped to close the knowledge gap on Brazil-African research trajectory on LoCAS and food security, and the roles of countries, authors, institutions, and publishing journals. This knowledge could support in making future agricultural policies to enhance food security, and climate change resilience, especially in Africa where there have been low research and publications on the topic.

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1 Introduction

Low-carbon agricultural systems (LoCAS) covered various farming practices that improve food security and enhance carbon sequestration in agricultural soils [1–4]. LoCAS encompassed different agricultural systems including carbon farming, climate-smart agriculture, conservation agriculture, and integrated agricultural systems (e.g., integrated crop-livestock, and integrated crop-livestock-forestry). LoCAS can be defined as a sustainable farming or agricultural activity that sequesters carbon in the soil without jeopardizing the improvement of soil, other environmental indicators, and food security [5–7].

Agricultural system accounts for a significant amount of greenhouse gases (GHG) released into the environment. Farming systems that decrease carbon stocks or increase CO_2 emissions often lead to poor soil, consequently low food production [8–11]. The agricultural system is not only critical for achieving food security, but it is also responsible for carbon sources and sinks. When properly and sustainably adopted, agriculture has the capability to guarantee food security, increase biological N-fixation, reduce inorganic wastes, and sequester hundreds of billions of tons of carbon [1, 12, 13]. For example, it is reported in South America that from 2016 to 2050 the LoCAS has the potential of sequestering terrestrial carbon to an estimated amount of 8.24 Pg C [1]. The authors also stated that the annual C balance estimates from 2016 to 2020, 2021 to 2035, and 2036 to 2050 were 0.08, 0.25, and 0.28 Pg C, respectively, which are equivalent to balancing 7.5, 22.2 and 25.2% of the global annual GHG emissions by land use and land use change for each period [1]. Relatively, the emission balance for LoCAS is fixed at 31.0% by restoring degraded pastures, 25.6% by integrated agricultural systems (IAS), 24.3% by conservation agriculture especially, no-till, 12.8% by cultivated commercial forest and afforestation, 4.2% by biological N fixation and 2.0% by recycling the industrial organic wastes [1].

Several studies have established that farmers can increase food productivity and enhance the amount of carbon stored in agricultural soils under LoCAS strategies [14–16]. Moreso, farmers can control non-CO_2 GHG emission by promoting intensive crop-livestock system which protects soil health and provides more food [5, 17]. Meanwhile, for effective LoCAS, suitable policies are crucial to achieve success in the system [18–20]. LoCAS has both short-and-long term values over other agricultural systems (such as the conventional or monocropping systems). For example, by promoting C-stocks and reducing C-emissions, LoCAS has the potential for mitigating climate change, boosting soil health, improving food security, and enriching farmers´ income and livelihoods [14–16, 21, 22].

These potential of LoCAS have made it a promising farming system to reckon with irrespective of farmer's geographical location, and economic status because it is economical and climate change resilience. LoCAS has been globally recommended for obtaining increase in food productivity especially in the tropical regions where there are exacerbated poor soils, harsh weather, high poverty, and large population that need more food [6, 8, 13, 23, 24]. It is on this context that the Brazilian government through its agricultural and research institutions established sustainable agricultural agendas (e.g., the ABC plan, and the RenovaBio program) that helped to promote Brazil as one of the top countries in global food production [19, 20]. To extend its south-south cooperation in support of Africa which has peculiar demographic, agroecological and climatic conditions, Brazil has been pioneering the transfer of its food production systems to Africa. This has been successful through the establishment of programs and sharing of knowledge via research collaborations and publications [25–27].

In as much as the role of the Brazilian government through its research institutes in promoting food security in Africa has been remarkable, there is little or no studies available. The dearth of publications focusing on the LoCAS and activities in Brazil and Africa is a concern. Therefore, this work is aimed at mapping the intra-and-inter research impacts, collaborations, thematic evolution, and publication trends on LoCAS and food (in)security in Brazil and Africa by using a systematic and bibliometric analysis. The work also identified the challenges and benefits of LoCAS and their disparities between the regions.

In various fields of scientific knowledge, the evolution of science can be understood based on systematic and bibliometric studies. On several topics, these studies were performed to comprehend the research thematic evolution and reveal emerging trends in different scientific fields by examining the contributions of countries, regions, researchers, journals, and institutions in a field of science [28, 29]. In the context of LoCAS and food (in)security in Brazil and Africa, there are no bibliometric studies, because this is the first time a study is conducted on this topic and comparing the two regions simultaneously. However, systematic and bibliometric approaches have been applied to analyze LoCAS and agrifood production systems in Brazil [30, 31], Africa [32, 33], and world-wide [34–36] yet, none either integrated Brazil and Africa, or applied multiple scientometric analysis.

In recent years, modern systems of information provide databases and analysis tools (e.g., Web of Science (WoS), Scopus, Google Scholar, and bibliometrix, VOSviewer, Citespace, and Flourish studio) that can present a better outlook of the scientific evolution and performance of countries and researchers in a particular field of knowledge [37].

This study presents a bibliometric analysis of the scientific research on LoCAS and food (in)security in Brazil and Africa based on papers published in journals indexed in the WoS database between 2015 and 2024. The main objectives of this study are to: (i) evaluate the chronological trends and contributions to scientific research on the topic by considering regional and country scales; (ii) identify the main research institutions in the two regions and their collaborations; (iii) identify the keywords, their occurrences, and map their thematic evolution and network visualization; (iv) identify the trends in research fields within LoCAS and (v) highlight the environmental, social, and economic benefits and challenges of LoCAS.

The study will promote the intellectual exchange among the Brazilian-African scholars who work on agricultural food production chains. By unveiling the research trends, the paper might contribute to increasing the number of studies and publications on LoCAS and food security thereby enhancing the adoption of LoCAS. This might consequently increase food availability and sustainable development, particularly in Africa where more research and publications are in high demand to improve food security.

2 Materials and methods

2.1 Data collection

In support of a comprehensive review on LoCAS and food (in)security in Brazil and Africa, information on the thematic evolution and research trajectory were incorporated by performing a scientific diagnostic on the concepts. The Web of Science (WoS) and Scopus are the most applied databases by the research community for data extractions and bibliometric analyses [38–40]. In this study, all databases from the Web of Science®—Clarivate Analytics platform (https://webofknowledge.com/) were used. It is a database popular for scientific citations, collaboration network mapping, and bibliographical coupling data are orderly presented and stored [41], which satisfactorily validated the adoption of the WoS database in this case. The credibility of the analyzed result significantly depends on the search string method [40]. Thus, a productive search structure was designed considering the database features after selecting the database to be applied. The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) were adopted for the research methodology (Fig. 1). These systematic and bibliometric analysis were applied to contribute to closing the gap in knowledge on the research trends on LoCAS in the regions by revealing the keywords, major institutions and countries, top authors, and the chronological trend. This is because scientific studies promote LoCAS and improve food security between the regions. Many studies have reported the significant role of research, development and publications on the global achievement of food security [42–45]. According to CGIAR [46], a 1% increase in agricultural publication, research and development increases the knowledge on food systems, which has a likelihood of leading to a 0.155 increase in agricultural productivity. Another study reported that a 1% increase in the number of publications causes an increase in agriculture and economic growth in the range between 0.324 and 0.465% [45]. Similarly, Coe and Helpman [47] established that investment in agricultural research and development (R&D) is the key driver of productivity because R&D produce new knowledge and achieve technological breakthroughs. Studies have also stated that agricultural research and extension are two key policy tools that governments employ to promote agricultural growth and transformation [44]. It was on these notes that on 15th August 2024, we lunched search terms on WoS to unveil the trends in research and publication on LoCAS and food security by applying the following string: "low-carbon agricultural system (Topic) OR low-carbon agriculture (Topic) OR low-carbon farming (Topic) OR carbon farming (Topic) OR climate-smart farming (Topic) OR climate-smart agriculture (Topic) OR integrated crop-livestock (Topic) OR integrated crop-livestock forestry (Topic) OR integrated agricultural systems (Topic)" AND "food security (Topic) OR food insecurity (Topic)". The initial search had no time span, but it was discovered that years before 2015 had relatively low publications, thus, the search was narrowed between 2015 and 2024. The result was further refined by applying additional inclusion and exclusion criteria (Table 1) such as selecting only Brazil and the African countries. The dataset was further screened by restricting to only English documents, and key subject areas that related to the study objective, specifically, agriculture, food production technology, and environmental sciences ecology. Only publications in English language were included as also applied

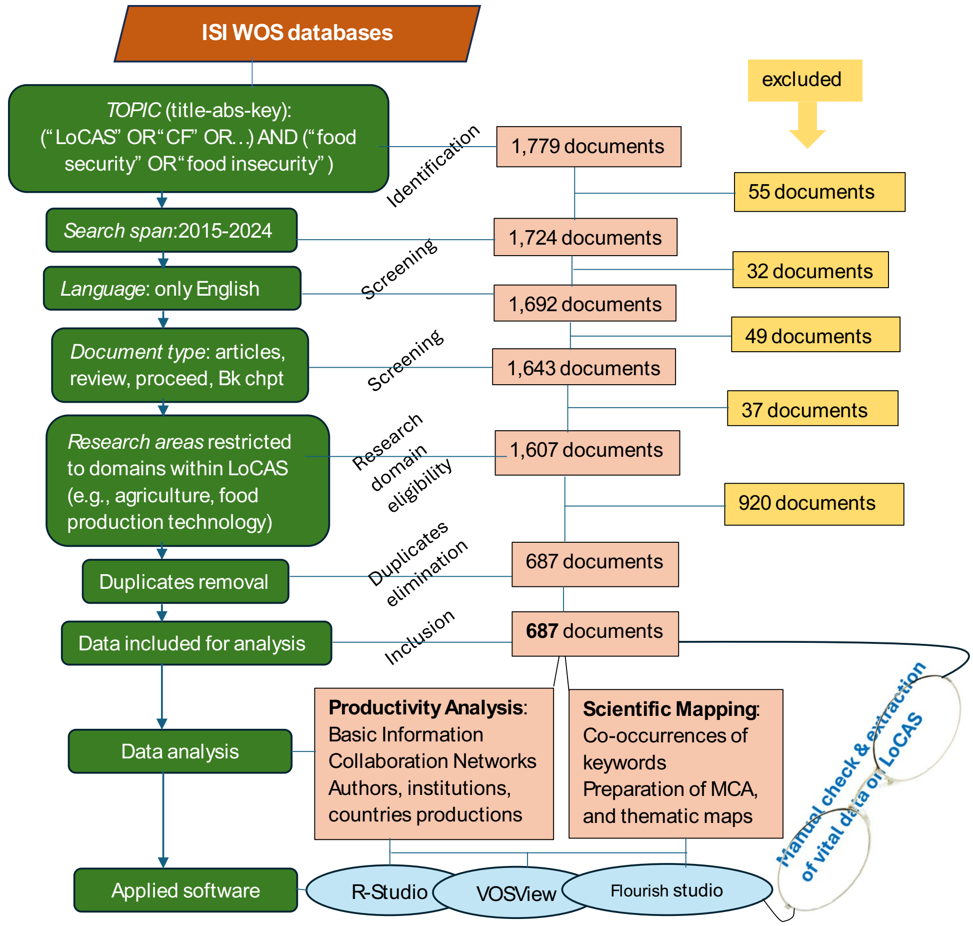


Fig. 1 PRISMA methodological flow framework for selecting articles from Web of Science (WOS). *LoCAS* represents low-carbon agricultural system, *CF* represents carbon farming; proceed represents proceedings, *Bk chpt* represents book chapters, MCA represents multiple component analysis

in a previous study by Di Letizia et al. [48], and this was because there was no available translator(s) to translate other languages, in this scenario from Portuguese to English. And since much information including LoCAS need to be extracted from the papers and there might also be many other different languages published in Africa, thus English became the major language of consideration. Also, for a paper to be selected it must cover at least two of the low-carbon agricultural systems (LoCAS) (*as defined in the next section: that is,* Sect. 2.2).

Before downloading the results, the record contents were adjusted to include the essential and relevant information namely author, title, source, citation counts, abstract, keywords, affiliation, document type, research areas, published year, and cited references. Subsequently, the results derived were exported via the plain text and bibtext

Table 1 Eligibility criteria for the selection of reviewed literature

Inclusion criteria	Exclusion criteria
▪ Qualitative and quantitative analysis	▪ Mere descriptive or theoretical
▪ Proof of empirical study	▪ No evidence of empirical research
▪ Period: 2015–2024	▪ Before 2015
▪ English language	▪ Other languages outside English
▪ Articles that focused on either the impacts of LoCAS on food security, or the nexus between them	▪ Articles relating to issues outside the relationships between LoCAS on food security
▪ Research articles, review articles, proceedings and book chapters	▪ Grey literatures: Early Access or Editorial Material or Book Review or Correction or Letter or Meeting Abstract
▪ Key subject areas: agriculture, food production technology, and environmental sciences ecology ▪ Only Brazil, and African countries	▪ Outside these key subject areas that related to the study objective, specifically, agriculture, food production technology, and environmental sciences ecology ▪ Outside Brazil and Africa

files. These were saved and applied in the bibliometric analysis using VOSViewer [49], Bibliometrix [50], and Flourish studio [51]. In-depth data analysis was done via Biblioshiny with support from Power BI, Biblio-Analytics, and an online Flourish studio visualization platform (https://flourish.studio/). Biblioshiny provides an interactive and user-friendly interface for conducting bibliometric analysis using the functionalities supplied by the Bibliometrix package in R-studio. Further, analytical techniques and tools such as MS Excel, MS Access, and Notepad were employed to further analyze the results and produce comparative values. In VOSViewer, Flourish studio, and biblioshiny of Bibliometrix various types of analysis were performed. These included co-occurrences, bibliographic coupling, network analysis, overlay visualization, collaboration mapping and citations, as well as thematic evolution analysis and MCA of the keywords.

2.2 Data organization, processing, and analysis

After the data collection, the main studies that covered the different low-carbon agricultural systems (LoCAS) in our dataset were identified. These were classified based on the previous studies in the regions [1, 2, 5, 7, 8, 11, 12, 52–59]. They were identified by examining the entire sections of the articles to extract the information on LoCAS. Seven LoCAS were identified in the dataset, namely, integrated crop-livestock-forest (ICLF), restoration of degraded pastureland to promote livestock intensification (RDPLi), conservation agriculture (CA), and plantations of commercial forests and forestation (PCFF). Others were activities promoting biological N fixation (BNF), practices involving the treatment and recycling of industrial and animal wastes (IAW), and other integrated agricultural systems (o-IAS). The ICLF involves the growing of crops, animals, and trees simultaneously on the same land, and this promotes soil health, food security, and income [1, 54]. The RDPLi aimed at improving the pastures livestock production by increasing soil fertility and forage quality and carrying capacity through acidity management and efficient use of NPK fertilizers [9, 59]. The CA practices consisted of no-or-minimum till, cover cropping, organic amendments, and crop/animal diversification including crop(or grazing) rotation and intercropping [5, 17, 18, 22]. PCFF involved the creation of land area of cultivated high yielding forest species for wood-oriented purposes such as furniture, construction, as well as for non-wood purposes including biodiversity, recreation, carbon capture, food and medicine [1, 8, 14]. The BNF encompasses biological N fixation practices through bio catalytic conversion of atmospheric N_2 to ammonium via a symbiotic dinitrogen-fixing bacteria and plants (e.g., legumes: beans, cowpea, soybean, etc.) [52, 57]. The IAW is the aspect of carbon farming system that relates to circular (bio)economy strategies which considers animal production for generating energy and for composting aimed at replacing or fortifying the mineral fertilizer [1, 10, 23]. Agroforestry, integrated cropping systems, integrated crop-livestock, and improved fallow were classified as other IAS (o-IAS) [4, 16, 19]. Further, to quantify the benefits and challenges of these LoCAS, stakeholders and experts on the field including some of the selected papers authors were interviewed virtually. Ten participants from Brazil, and 20 participants from five African countries covering the 5 regions of the continent. The selected African countries were Nigeria, Ethiopia, Egypt, Congo DRC, and South Africa, and 4 participants were interviewed from each of the countries. In addition to having a uniform representation of each of the African regions, these countries were selected because they either (i) have the highest human population, or (ii) higher number of papers on the topic, or (iii) larger landmass, agricultural systems, and farming activities. From our dataset (i.e., the reviewed papers), 36 benefits and ten challenges of LoCAS adoption were identified as listed in Supplementary Tables 1 and 2 respectively. To validate, quantify, and scrutinize the LoCAS, responses from the selected 30 expert participants were collected and analyzed. The identified challenges and benefits of LoCAS were presented to each of the respondents, and they were asked to rank each based on the impact in their countries. The impacts were to be ranked between 5 and 1 where 5 = very significant impact, 4 = significant impact, 3 = unsure/uncertain of impact level, 2 = insignificant impact, and 1 = very insignificant impact. The average values on each item from each region (Brazil and Africa) were used for the analysis.

Finally, the variables examined were: (a) number of publications per year; (b) number of publications per institution; (c) main journals and publication trends on the topic; (d) most used keywords; (e) scientific collaboration among countries and institutions; (f) most impactful authors, their respective countries, (g) the LoCAS covered by authors, (h) the trend in the number of papers covering LoCAS and food (in)security, and (i) identification and assessment of the benefits and challenges of LoCAS adoptions in Brazil and Africa.

3 Results and discussion

3.1 Research data and the chronological publication trend on LoCAS and food security in Brazil and Africa

The summary of the analyzed dataset revealed that 687 documents spanning between 2015 and 2024, had an annual scientific growth rate of 13.1% (Table 2). It encompassed 2,839 authors who applied 2,519 keywords and had 10.2% collaboration with international authors.

While the number of papers increased in recent years, citations per year and per article were higher in the earlier periods (Fig. 2). 2019 and 2020 had a very low number of papers which were more than thrice lower than the number recorded in 2022 and 2023. In exception of 2019 and 2020, there was a continuous increase in the number of published documents over the years, and this could be attributed to more adoption of LoCAS and stakeholders' efforts to increase food production [60, 61]. The remarkable decline in both the number of papers and mean citations in 2019 and 2020 might be explained by the Covid-19 epidemics that affected research and publications in various fields [62].

3.2 Collaborations, countries, institutions and sources

Brazil had 22.4%, South Africa (14.3%), and Nigeria and Ethiopia had approximately 12.8% each for the total number of publications (Fig. 3A). Twenty of African countries had at least 4 cited documents out of the 30 African countries that had publications on the topic (Fig. 3B).

Brazil had more collaborations with some African countries (e.g., South Africa, Nigeria, Ghana, Morocco, Uganda, and Mozambique) than the others. This could be attributed to two main reasons: (i) these are the richer and more populated African countries. Thus, they have more research institutions and fundings to collaborate [63, 64]. (ii) The Brazilian government and the research institutions such as the Brazil's Low-Carbon Agriculture (ABC), Brazilian Agricultural Research Corporation (EMBRAPA), the São Paulo Research Foundation (FAPESP) have more agricultural development projects in these countries [65–68].

Fifty research institutions in Africa showing six clusters, and 35 institutions in Brazil forming five clusters were involved in the publication and co-authorship on the research topic (Fig. 4). For Africa, the red cluster had mainly the north African institutions, the yellow cluster had the south Africa institutions, the purple cluster had basically the east African institutions. On the other hand, the light blue, blue, and green clusters had a mixture of institutions across the regions such as the west African institutions (e.g., Univ of Ibadan, Federal Univ of Technology Akure, Univ of Ghana, Kenyatta Univ, and Makerere Univ). South Africa (24%) had the highest number of the institutions in Africa. This could be because South African is among the top developed country in Africa and its research institutions rank higher than most other institutions in Africa [69], and availability of funds is also a factor [63, 64].

For Brazil, University of São Paulo, and Federal University of Vicosa had the highest number of articles with 49 and 30 respectively. This agrees to the fact that São Paulo State is the richest and most populous Brazilian State and releases the highest amount for research fundings especially in agriculture University of São Paulo pioneered by the São Paulo

Table 2 Description of the main information about the dataset used for the study

Description MAIN INFORMATION ABOUT DATA	Results	Description AUTHORS	Results
Timespan	2015:2024	Authors	2839
Sources (Journals)	192	Authors of single-authored docs	76
Documents	687	AUTHORS COLLABORATION	
Annual Growth Rate %	13.1	Single-authored documents	107
Document Average Age	5.4	Co-Authors per document	4.04
Average citations per document	11.36	International co-authorships %	10.2
References	37248	DOCUMENT TYPES	
DOCUMENT CONTENTS		article	627
Keywords Plus (ID)	1654	article; review	57
Author's Keywords (DE)	2519	article; book chapter	2
		article; proceedings paper	1

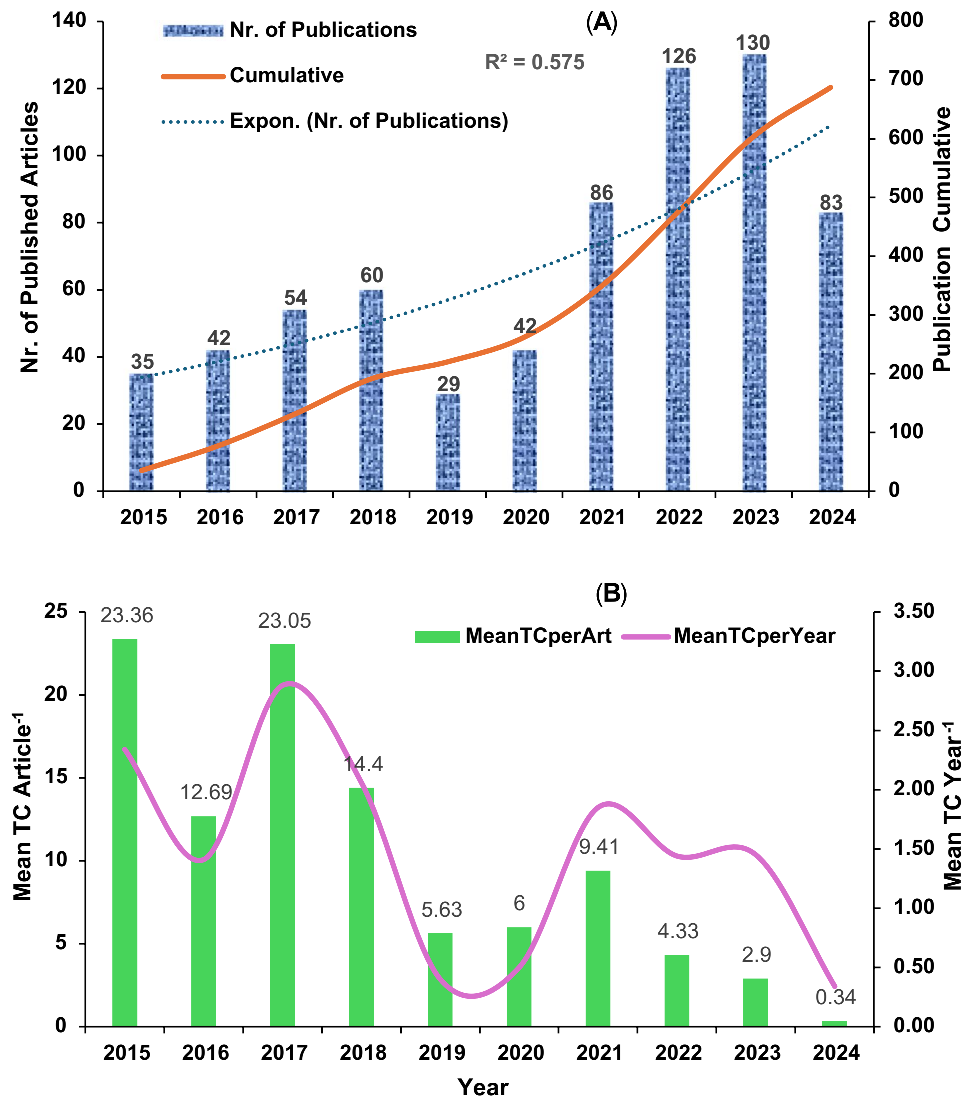


Fig. 2 (**A**) Publication chronological trend (**B**) mean total citation per year and per article on the research topic between 2015 and 2024 (N = 687). MeanTCperArt represents Mean total citation per article; MeanTCperYear represents Mean total citation per year

Research Foundation-FAPESP [66, 67]. In São Paulo State, according to de Brito Cruz [65], FAPESP has been developing an important strategy for creating opportunities for research collaboration for researchers in the state, and has maintained cooperation agreements with research funding agencies, higher educational and research institutions to keep promoting research innovations and publications.

In terms of publication chronology, it was observed that the top research institutions in Africa had most of their studies between 2015 and 2020, while the top institutions in Brazil such as the University of São Paulo, Federal university of São Paulo, and the Brazilian Agricultural Research Corporation (EMBRAPA) had most studies in recent years (i.e., between 2021 and 2024) (Fig. 5).

3.3 Authors, collaborations, and the low-carbon agricultural systems (LoCAS)

Corresponding authors' collaborations were more than 80% single country publication (SCP) than multiple country publication (MCP) (Fig. 6). This is contrast to the study by Carammia [70] where MCP was observed to have increased by at least 95% over the SCP. These differences in our findings might be explained by the variations in the research fields. In agreement with this study, Ozdemir and Isik [71] reported higher SCP than MCP in an agricultural related study.

Seven different LoCAS were identified in the dataset and the number of LoCAS increased with corresponding authors countries' research relevance. Unlike Benin, Senegal, Namibia, and Mali which focused on only two LoCAS, Brazilian covered all the seven LoCAS (e.g., ICLF, RDPLi, CA, PCFF, BNF, IAW, and o-IAS). This is a prove that Brazil is among the top

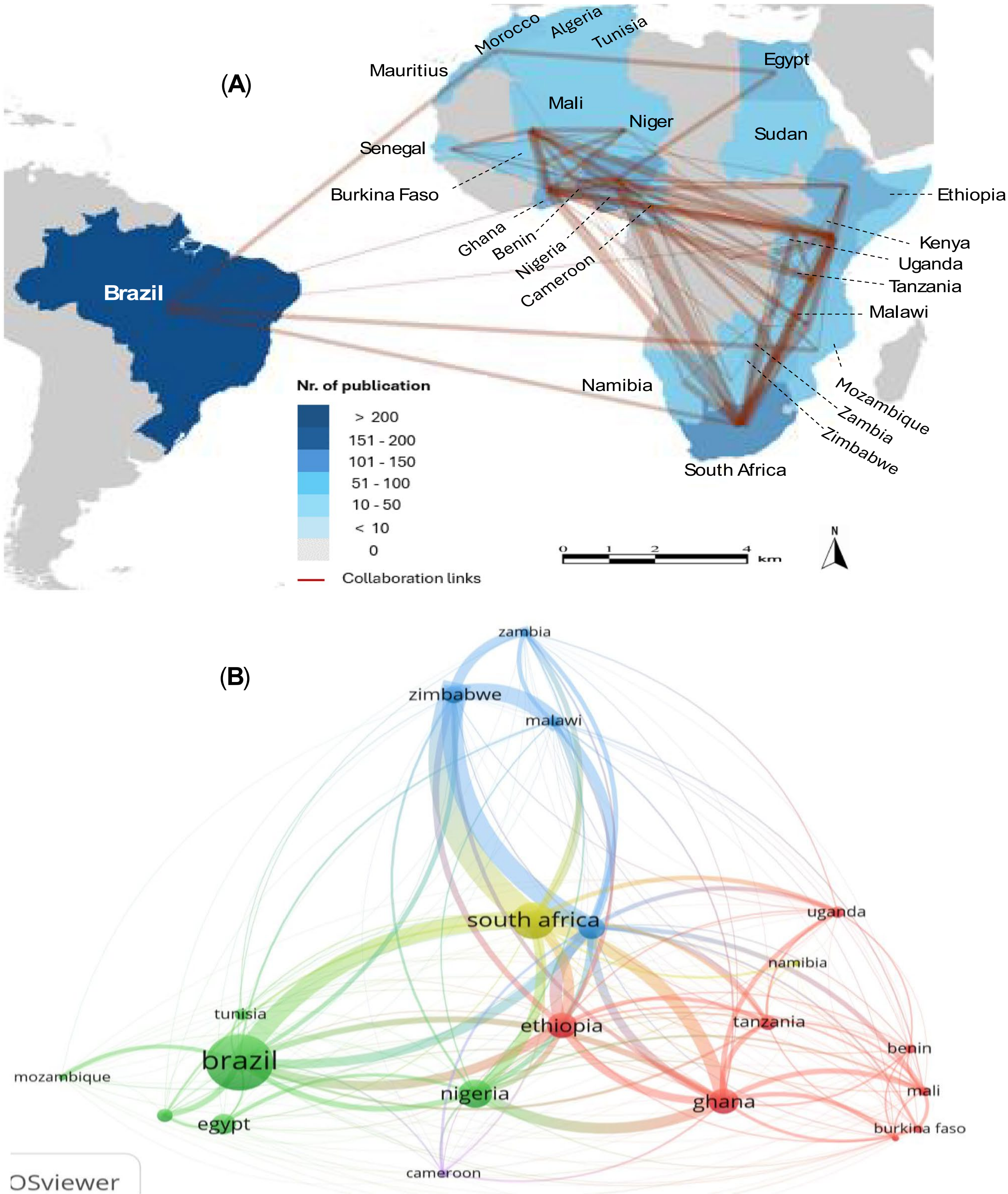


Fig. 3 Publication distributions and collaboration networks on the research on LoCAS and food security in Africa and Brazil (**A**) number of publications (**B**) top African countries that have at least 4 cited documents. Note for b: The ball or bubble size shows the total number of cited articles, the line thickness shows the linkage's strength, and the color shows the cluster

agricultural food and energy producer and exporter globally [1, 19, 20, 72–74]. In Brazil, agriculture has been intensified and diversified to cover different LoCAS, aimed at increasing C-sequestration and food productivity without compromising the environmental safety. Brazil is among the first and top countries which prioritized the agricultural sector to meet their nationally determined contributions (NDCs) to the climate change mitigation agreement [1, 75].

In addition to recording the highest number of articles and total citations per year, de Oliveira Silva and Pereira (Brazil) and Thierfelder (Zimbabwe, CIMMYT Africa) contributed to scientific production on the research topic in all the years of investigation, as well as had studies covering most of the LoCAS (Fig. 7). In addition to de Oliveira Silva who is from the University of São Paulo (USP, Brazil), other authors who had good research coverage on the LoCAS were Cherubin (USP), Pellegrino Cerri (USP), de Carvalho (EMBRAPA, Brazil), Malaquias (EMBRAPA, Brazil) and Marchao (EMBRAPA, Brazil). These high-ranking authors are from top research institutions in Brazil and Africa where agricultural research and development are well funded by the São Paulo State research Foundation (FAPESP), EMBRAPA, and CIMMYT [65–67]. A recent study has revealed that between 2012 and 2021 EMBRAPA published in the top 10% journals on agriculture, globally [68]. EMBRAPA and FAPESP are key promoters of agricultural research in Brazil, exercising a decisive role in segments of the agricultural research and production chains [76–78].

Studies in Brazil covered a greater number of the LoCAS than those found in the Africa studies, and the commonly adopted crops were maize, soybean, and cowpea (Table 3). The common forage and tree species were *Brachiaria* and *eucalyptus spp*, while the livestock were cattle, goats and sheep. This could be because these species are adaptable to the tropical environment in Brazil and Africa as they bloom with high productivity [58, 79]. Different *eucalyptus spp* including *E. urophylla, E. grandis, E. tereticornis, E. resinífera*, and *E. pellita* were hybridized for higher productions and adaptation to the tropical environmental conditions [58].

3.4 Sources impacts

In addition to having the highest impact factor (IF), Science of the Total Environment was remarkable by ranking top in the list of journals with the highest total citation (899), the highest metric indices, the highest number of paper as well as increasing publication trend for both LoCAS and food (in)security (Table 4). Further, it was observed that published studies reflecting on food (in)security increased by 75% while those relating to LoCAS increased by 67% (Table 4). These are strong indications that satisfying the nutritional-growing needs of the growing population through sustainable agricultural systems is a crucial issue in Brazil and Africa. The findings might not be a surprise because the countries in these regions are developing and have rapidly increasing populations with high records of impoverishment [80, 81] due to poor soil quality and unsustainable farm practices [82–84]. All journals which have early publication years recorded an increase in studies for both LoCAS and food (in) security except Land. The rising cost of publishing in Land for most researchers in these poor countries might have contributed to the decrease in LoCAS publications, and a constant trend in food (in)security published articles [85].

3.5 Keywords network analysis and thematic evolution

There were 2518 keywords out of which 117 keywords met the threshold of 5 occurrences, and these formed three different clusters (Fig. 8). The red cluster had the various agricultural and agronomic management practices namely, low-carbon farming, carbon farming, cover cropping, crop diversification, no-tillage, industrial and animal wastes management which helped to improve carbon sequestration, microbial biomass, soil quality, crop growth and yield. Similarly, the blue cluster encompassed crop-livestock forest, low-carbon agriculture system, climate-smart agriculture, climate change, smallholder farmers, degraded pasture, and sub-Saharan Africa.

Though, the green cluster also had some agricultural and agronomic management practices (e.g., biological N fixation, forestation, mixed cropping, crop rotation, conservation agriculture, and organic amendment), it contained the products of the LoCAS such as food, food security, dietary diversity, recycling, nutrition, sustainable development, income, livelihood, food insecurity, and malnutrition.

The green cluster also reflected the dominant study locations including Brazil, South Africa, Nigeria, and Ethiopia. Many studies have established that a well-managed agricultural system such as LoCAS is viable for food security, dietary diversity, improved income and livelihood, and sustainable development, while a poor farming system leads to food insecurity and malnutrition [2, 5, 7, 10, 16, 18, 21, 21, 22, 22, 23]. For instance, the LoCAS under the ABC Plan in Brazil has been established as a potentially significant farming system for the achievement of environmental,

Fig. 4 Co-authorship network of the top universities and institutions related to LoCAS and food security research in (**A**) Africa and (**B**) Brazil, obtained from WoS database from 2015 to 2024. Note: The threshold value = 5, applied for published articles resulting in 50 and 35 institutions for Africa and Brazil respectively. The ball or bubble size shows the total number of articles, the line thickness shows the citation linkage's strength, and the color shows the cluster ▸

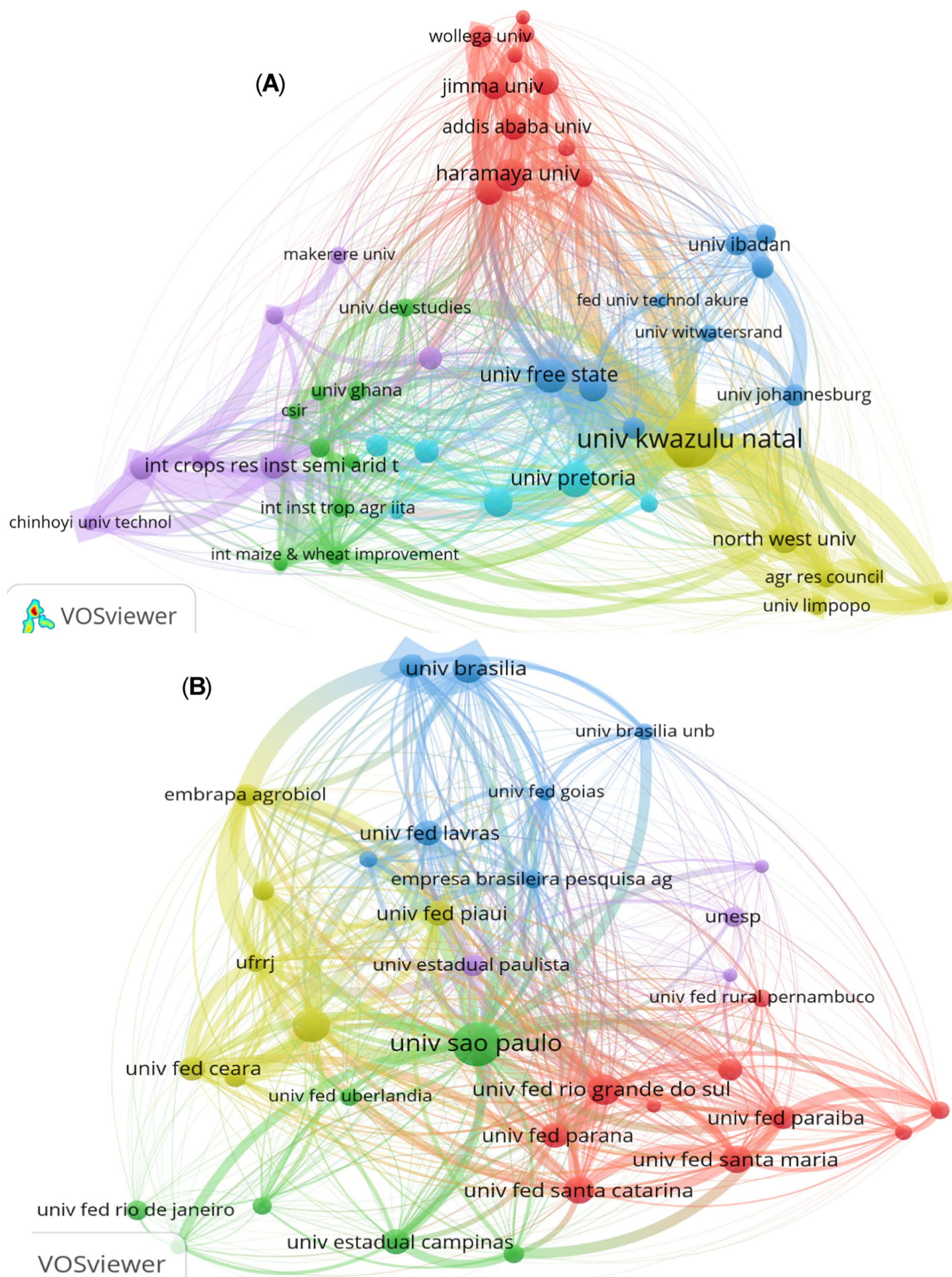
social and economic sustainability [1, 20]. It has also been known as the strong lever for food security, and projection of Brazil among the top countries famous for food and bioenergy production and exporter [19, 86].

Figure 9 indicates the trend in thematic areas and chronological evolution on LoCAS-food security research considering authors' keywords and keywords plus. (Fig. 9A) are representative indicators for the content and scientific concepts portrayed in papers and can encapsulate the paper's content with greater depth and variety [87, 88]. On the other hand, authors' keywords (Fig. 9B) tend to be constrained in depth as they contain a large list of terms that authors consider as the most appropriate to depict the content of their paper [89]. The chronological evolution showed that the adopted authors' and keywords plus in Fig. 8 were reflect of the keywords in the three clusters of the VOSviewer network visualization analysis (see Fig. 8), and they increased over time. The authors used more keywords between 2018 and 2022, and fewer between 2015 and 2017, and 2023–2024 (Fig. 9B). LoCAS and practices (e.g., carbon farming, conservation agriculture, no-till, crop rotation, and climate-smart agriculture) appeared in both the authors' keywords and keywords plus but food security/insecurity tend to be used more frequently. This could be explained by the fact that there are different terminologies for LoCAS, authors might have other synonymous terms to be used but food security or insecurity are commonly used as they rarely have exactly similar or alternative words.

3.6 The LoCAS benefits, and comparison with traditional agricultural systems

Synthesis from the studies in our dataset revealed many environmental, social, and economic benefits of LoCAS as shown in Fig. 10. Conservation agriculture, ICLF, and o-IAS provided the most benefits, accounting for more than 65% of the benefits of all the LoCAS. Considering regions, environmental benefit (especially, increase in carbon stocks), and socioeconomic benefit (precisely, food security) tend to have the highest mean values (Table 5). Disparities were also observed in the benefits of LoCAS between the regions, and structural, socio-economic, or policy-related factors are the strong architects of these disparities. For example, when compared with Africa, Brazil has better agricultural structure, funding and policies that have strong bearing on agricultural transformation for environmental safety, climate change mitigation, and food security. Both the institutional frameworks [such as Brazilian Agricultural Research Corporation (EMBRAPA), São Paulo Research Foundation (FAPESP), and other Brazilian research institutions (e.g., MAPA)], and the established policies and programs [such as, the Low-Carbon Agriculture Plan, termed ABC Plan, The Brazilian National Policy on Climate Change (BPNMC), and the RenovaBio program which is a federal biofuel policy that certifies producers to receive C credits (CBIOs)] contribute substantially to the success of LoCAS in Brazil than as obtainable in Africa. The identified benefits of LoCAS were food security, nutrient-use efficiency, increased soil-C stocks, time and resources savings from no-till, climate change resilience, and improved microbial and biodiversity [1, 4, 6, 10, 14, 16, 17, 59]. For example, Sá et al. [1] reported that, the adoption of LoCAS could annually increase crop and meat production till 2050 in Brazil. Similarly, recent study in Brazil affirmed the benefits of LoCAS as a pesticide-free farming system, very promising in the improvement of productivity and soil health [17]. On the same hand, in Nigeria (Africa), Olajire et al. [6] concluded that integrated approach to indigenous climate change adaptation strategies, as required in LoCAS, could ameliorate negative effects of future climate change on food security in the region.

In comparison with the conventional agricultural systems, LoCAS has enormous potential for increasing food security by enhancing soil health and soil organic carbon stocks, consequently decreasing CO_2 emissions (Fig. 11). Crop-livestock integration synergies and by-product recycling have also been found as major factors of agroecological transition food security among smallholder farmers in Burkina Faso [10]. The potential of LoCAS in promoting the microbiomes and microorganisms which are critical to many ecological processes in agroecosystem (such as nutrient cycling, N_2 fixation) were highlighted in a study by Mohanty and Swain [90], and Vanlauwe et al. [57]. In addition to carbon sequestration, the implementation of LoCAS has been known as promising for food security, livelihoods sustainability, soil security, ecosystem services and biodiversity enrichment, as well as climate change resilience [1, 2, 5, 11, 14, 16, 21, 27, 54].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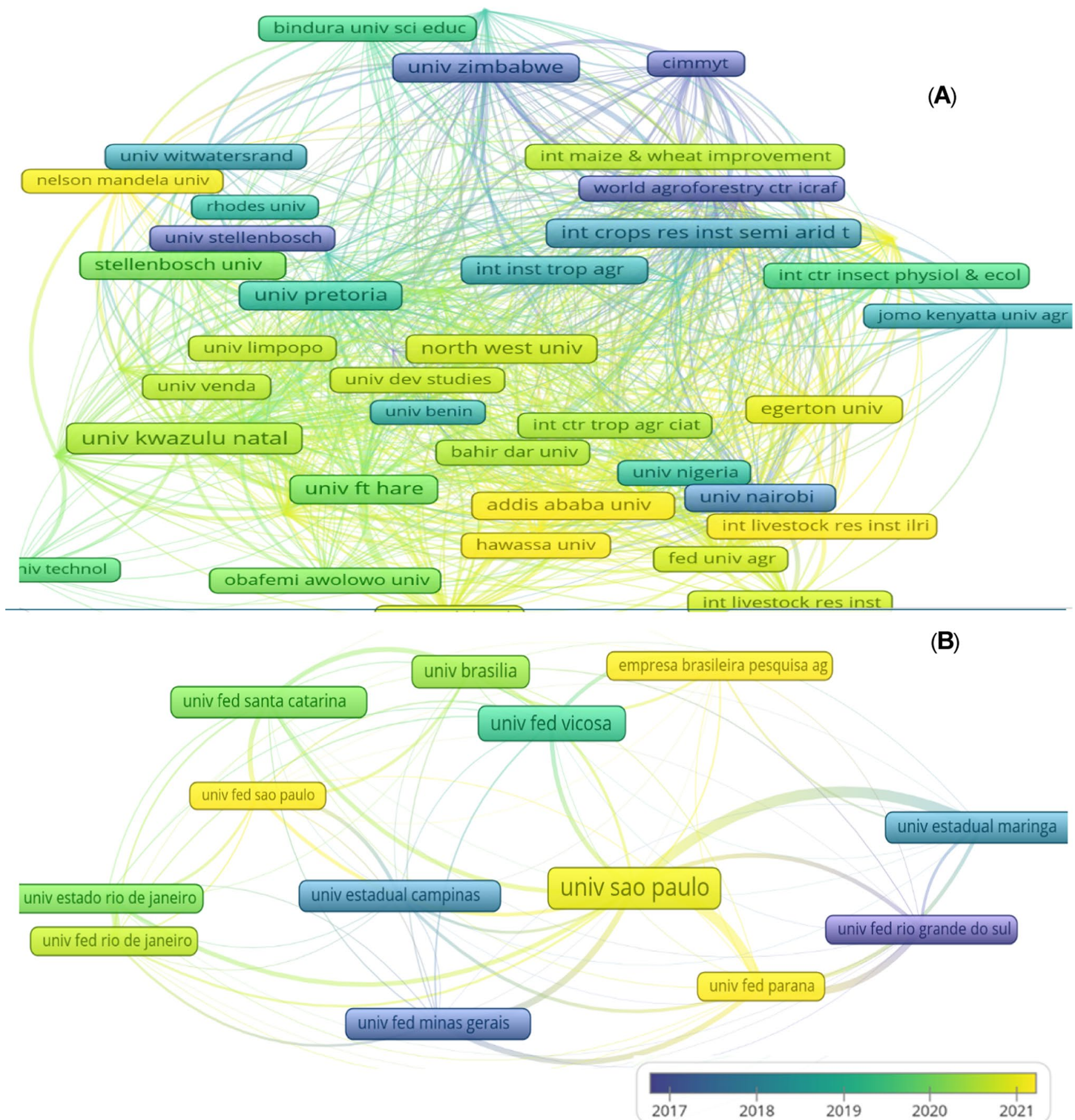
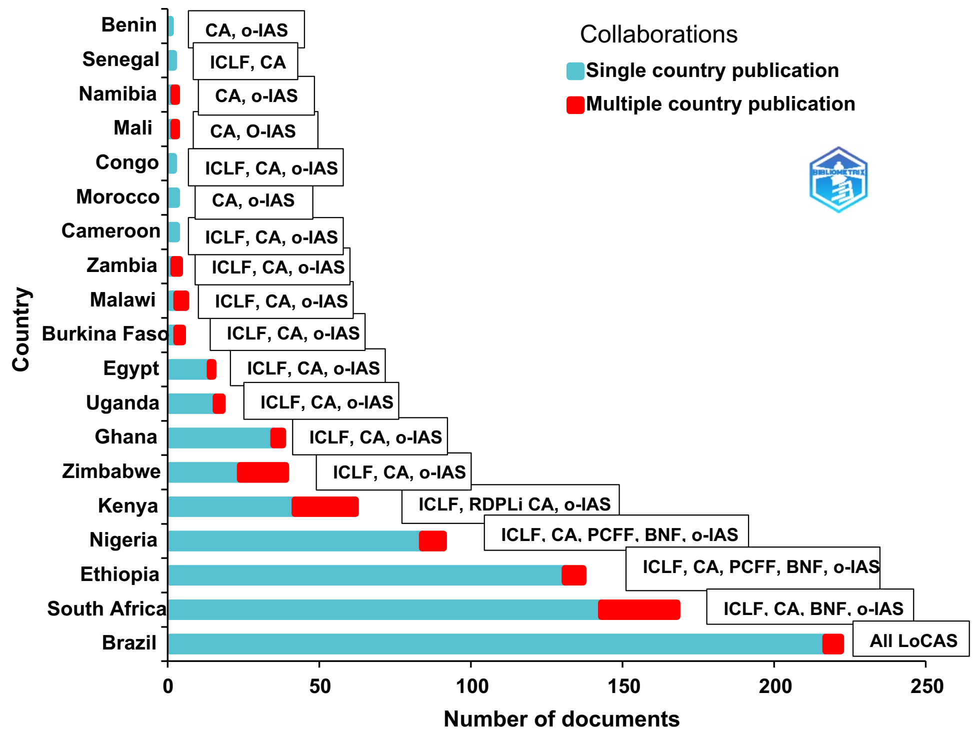


Fig. 5 Overlay network analysis of the publication chronology of the research institutions (**a**) African institutions (**b**) Brazilian institutions. Obtained from WoS database from 2015 to 2024. The rectangular shape/size shows the total number of articles, the line thickness shows the citation linkage's strength, and the color shows the clusters based on the major publication years

3.7 Research and collaborations translation into visible impacts in terms of food security

In addition to the benefits of LoCAS as discussed in the previous subsections, research development and collaborations in agriculture yielded a positive result in the study regions (See Fig. 12). Productions based on the major crops grown in the regions (such as corn, rice, and soybean) revealed a significant increase in the yields in the 10-year trend with rice yield increasing by 1.5 t/ha (Fig. 12a). In Africa, more than 90% of the main crops showed substantial

Fig. 6 Most relevant corresponding authors' collaborations. The rectangular shapes represent the LoCAS. Description of abbreviations for the different LoCAS: ICLF (integrated crop-livestock-forestry); RDPLi (restoration of degraded pastureland to promote livestock intensification); CA (conservation agriculture); PCFF (plantations of commercial forests and forestation); BNF (activities promoting biological N fixation); IAW (practices involving the treatment and recycling of industrial and animal wastes); o-IAS (other integrated agricultural systems such as IC, ICF, ILF, ICL, etc.)



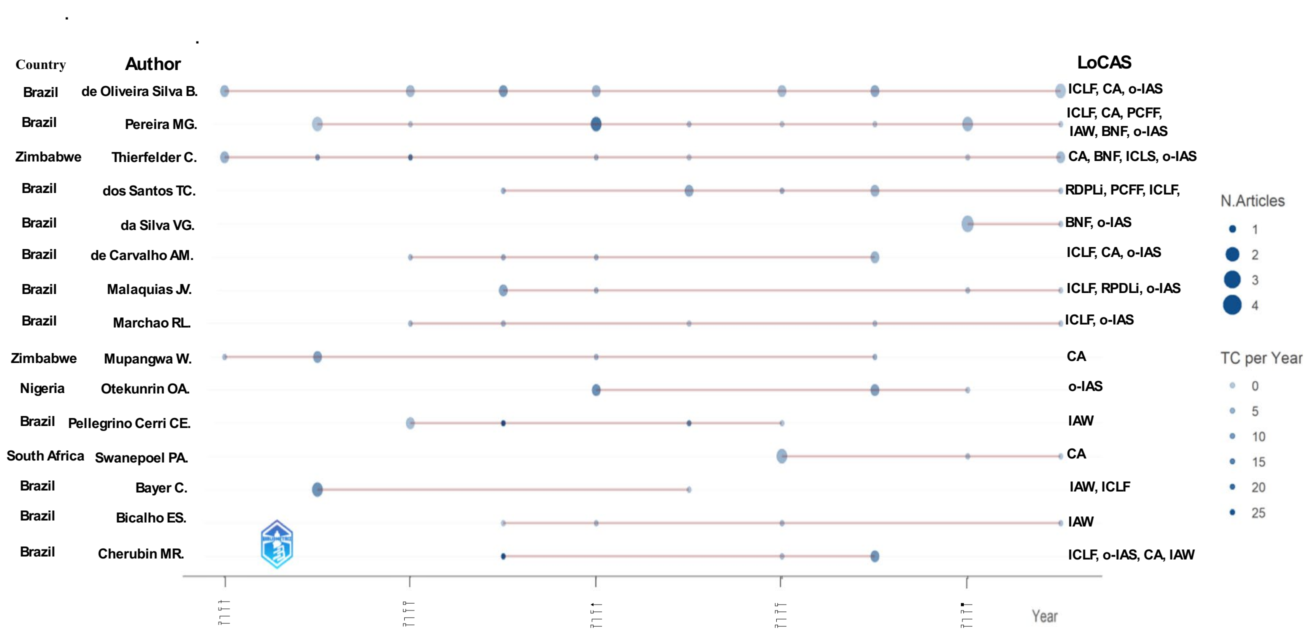


Fig. 7 Author's scientific production over time, and the most LoCAS of focus. Description of abbreviations for the different LoCAS: ICLF (integrated crop-livestock-forestry); RDPLi (restoration of degraded pastureland to promote livestock intensification); CA (conservation agriculture); PCFF (plantations of commercial forests and forestation); BNF (activities promoting biological N fixation); IAW (practices involving the treatment and recycling of industrial and animal wastes); o-IAS (other integrated agricultural systems such as IC, ICF, ILF, ICL, etc.)

increase between 2015 and 2024, and corn recorded the highest increase in production (Fig. 12b). For example, in Nigeria corn increased from 11,000 to 12,349 thousand tons from 2015 to 2024 respectively. Similarly, in South Africa, it increased from 15,886 (in 2015) to 17,000 thousand tons (in 2024).

Table 3 Top publications reflecting the various LoCAS, adopted species, study location, and conclusion

Source	LoCAS							Flora and fauna species					
with lead author	1	2	3	4	5	6	7	Crop species	Forage species	Forest species	Livestock species	Study location	Main conclusions
Abegunde et al. [18]	X	–	X	–	X	–	X	Beans, cowpea, soybean	Desho grass, guinea grass	–	Goat, sheep	South Africa	Considering food and economic compatibility, the farmers preferred mulching, organic manure, and rotational cropping
Anghinoni et al. [22]	X	–	X	–	–	–	X	Soybean, maize	Brachiaria, crotalaria	–	–	Brazil	Soil biological quality was positively affected by CA and acted as the main driver for food security
Vall et al. [10]	X	–	X	–	–	–	X	Maize, sorghum, millet, groundnut, cowpea	Guinea grass, Buffel grass, Elephant grass	*Vitellaria paradoxa, Parkia biglobosa, Faidherbia albida*	Cattle, sheep, goat	Burkina faso	Crop-livestock integration synergies and by-product recycling are major factors of agroecological transition food security among smallholder farmers
Sá et al. [1]	X	X	X	X	X	X	X	Soybeans, maize, beans, sorghum	Brachiaria	Eucalyptus	–	Brazil	The adoption of CSA practices could annually increase crop and meat production till 2050
Tadesse et al. [7]	X	–	X	X	X	–	X	Wheat, cabbage, carrot, beetroot, and garlic	Desho grass	Erythrina abyssinica, Eucalyptus obliqua, Juniperus procera	Cattle, goat, sheep	Ethiopia	Integrating CSA practices to build climate change resilience of resource-poor farmers was effective in food and environmental sustainability
Buller et al. [23]	X	X	X	–	X	X	–	Maize, beans, cowpea	Brachiaria	Eucalyptus urograndis	Cattle	Brazil	The practice of manure treatment in intensified agricultural systems can sustainably promote environmental and economic performances

Table 3 (continued)

Source	LoCAS							Flora and fauna species					
with lead author	1	2	3	4	5	6	7	Crop species	Forage species	Forest species	Livestock species	Study location	Main conclusions
Nyagumbo et al. [2]	–	–	X	–	–	–	X	Maize, pigeonpea	–	–	–	Malawi	CSA technologies could enable farmers to be more resilient, productive and adapt better to climate change shocks leading to improved food security and livelihoods
Pereira et al. [21]	X	–	X	–	–	–	X	Maize, beans	Leucaena, Buffel, Aridus grass, Urochloa	Mesquite, Sabiá, Gliricidia, Eucalyptus sp.	Cattle, sheep	Brazil	No-tillage systems with green manure and agrosilvopastoral systems support climate change mitigation, and sustainability in food security
Thierfelder et al. [5]	X	–	X	–	–	X	X	Maize, cowpeas, soybeans, groundnuts	Elephant grass	–	Cattle	Malawi, Mozambique, Zambia, Zimbabwe	Yields from CA system Increased with increase in clay and silt content
Vinholis et al. [13]	X	–	X	–	–	–	X	Maize, soybean	–	–	Cattle	Brazil	Policy makers can improve institutions to promote a favorable environment for sustainable agriculture
Oyawole et al. [12]	X	–	X	–	–	–	X	Cereals (Maize, millet, etc.)	–	–	–	Nigeria	When compared to conventional farming systems, carbon farming which involves organic amendments and agroforestry improved food security
Schettini et al. [24]	X	X	–	X	–	–	X	–	–	Eucalyptus sp.	Cattle	Brazil	Silvopastoral systems can neutralize GHG emissions in milk production

Table 3 (continued)

Source with lead author	LoCAS 1	2	3	4	5	6	7	Flora and fauna species: Crop species	Forage species	Forest species	Livestock species	Study location	Main conclusions
Radeny et al. [9]	X	X	X	–	–	–	X	Bean, pigeon pea, cowpea, maize and sorghum	Guinea grass, Buffel grass,	–	Red Maasai sheep, Galla goats	Kenya	Adoption of improved and resilient livestock breeds, and stress-resistant crops improved household dietary diversity
Lenz et al. [8]	X	X	–	X	–	–	X	Maize, soybean	*Brachiaria*	eucalyptus	Birds, cattle	Brazil	Conversion of the pasture areas into CSA would help to meet current food demand
Olajire et al. [6]	–	–	X	–	–	–	X	Maize, rice, cassava	–	–	–	Nigeria	Integrated approach to indigenous climate change adaptation strategies, as required in CSA, could ameliorate negative effects of future climate change on food security
Cavalieri-Polizeli et al. [17]	X	X	X	X	–	–	X	Maize, black oats	*Megathyrsus maximus*	Eucalyptus benthamii	Cattle	Brazil	pesticide-free farming systems, under conservative practices, were very promising in soil health
Ramborun et al. [15]	X	–	X	–	–	–	–	Maize	–	–	–	Mauritius	The combination of tillage-mulch-fertilizer resulted to a high yielding
Cerri et al. [14]	X	X	X	X	–	–	X	Sugarcane, maize, cotton, coffee, wheat, organge	*Urochloa* spp., *Brachiaria* spp.	–	Goats, sheep, dairy herds and poultry	Brazil	CSA mitigates and adapts to climate change by offsetting anthropogenic emissions through C sequestration in soils and biota

Table 3 (continued)

Source	LoCAS							Flora and fauna species					
with lead author	1	2	3	4	5	6	7	Crop species	Forage species	Forest species	Livestock species	Study location	Main conclusions
Idrissou et al.[16]	X	–	X	–	–	–	X	Maize, sorghum, millet, soybean, groundnut	Guinea grass *(Panicum maximum)*	–	Cattle	Benin	Annual C sequestration in integrated crop-livestock with cereal-legume and forage crops was significantly higher than sole cropping

Description of numbers and abbreviations for the different LoCAS: 1 = ICLF (integrated crop-livestock-forestry); 2 = RDPLi (restoration of degraded pastureland to promote livestock intensification); 3 = CA (conservation agriculture); 4 = PCFF (plantations of commercial forests and forestation); 5 = BFN (activities promoting biological N fixation); 6 = IAW (practices involving the treatment and recycling of industrial and animal wastes); 7 = o-IAS (other integrated agricultural systems)

Table 4 Most impactful journals on the research topic, and the publication trend over time

Journal	h Index	g Index	m Index	TC	NP	PY start	IF	Publication trend LoCAS	Publication trend F(in)Sec
Sci Tot Environ	17	29	1.7	899	31	2015	8.2	↑	↑
Agric Ecosyst Environ	13	16	1.444	641	16	2016	6.0	↑	↑
Agric Syst	12	17	1.2	427	17	2015	6.1	↑	↑
Land Use Policy	10	13	1.25	286	13	2017	6.0	→	↑
Soil Till Res	10	13	1.111	347	13	2016	6.1	↑	↑
Geoderma	9	12	1.5	283	12	2019	7.4	↑	↑
Agric-Basel	8	11	1.6	142	23	2020	3.3	→	↑
Front Sustain Food Syst	8	12	1.6	203	37	2020	3.7	→	↑
Environ Monitor Assess	7	10	0.778	111	19	2016	2.9	↑	↑
Geoderma Reg	7	12	0.875	152	12	2017	3.1	↑	→
J Agric Food Res	7	13	1.75	185	18	2021	4.8	↑	↑
Land	7	16	0.778	286	20	2016	3.2	↓	→

TC represents total number of citations; **NP** represents number of published papers; **PY** means publication year; IF represents the journal's impact factor. Source: analyzed by authors using Bibliometrix in Rstudio. Publication trends on low-carbon agricultural systems (**LoCAS**), and food (in)security (**F(in)sec**) between 2005 and 2024 based on each journal as extracted from WoS using our search criteria and terms. Increase in trend (arrow pointing up), decrease in trend (arrow pointing down), and constant/insignificant change in trend (arrow pointing horizontally to right direction)

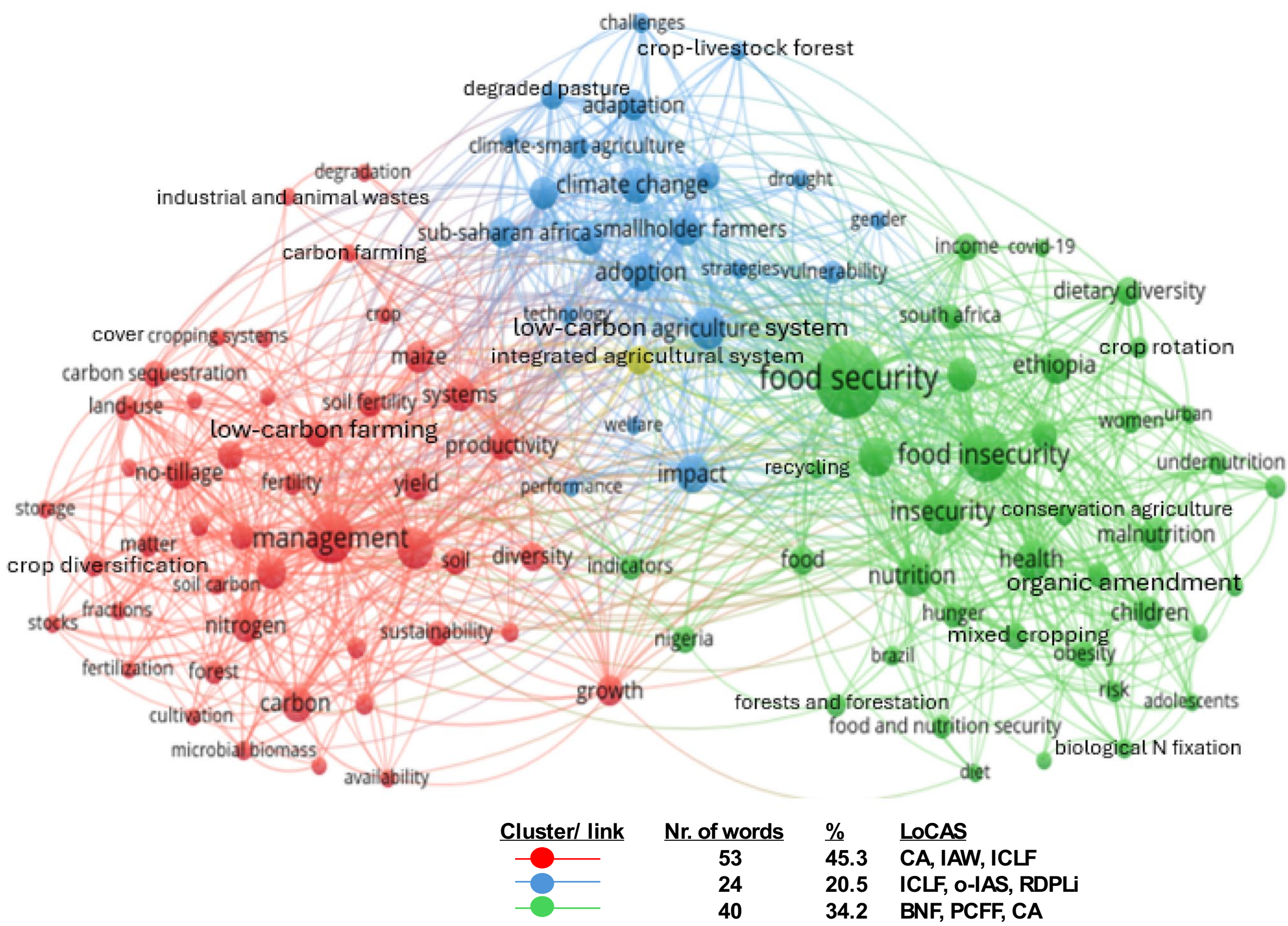


Fig. 8 Keywords network visualization analysis. The threshold value of 5 was applied for keywords in our dataset. The ball or bubble size shows the words frequencies, the line shows the keywords linkages in use, and the color shows the cluster. Analysis was performed using VOSviewer

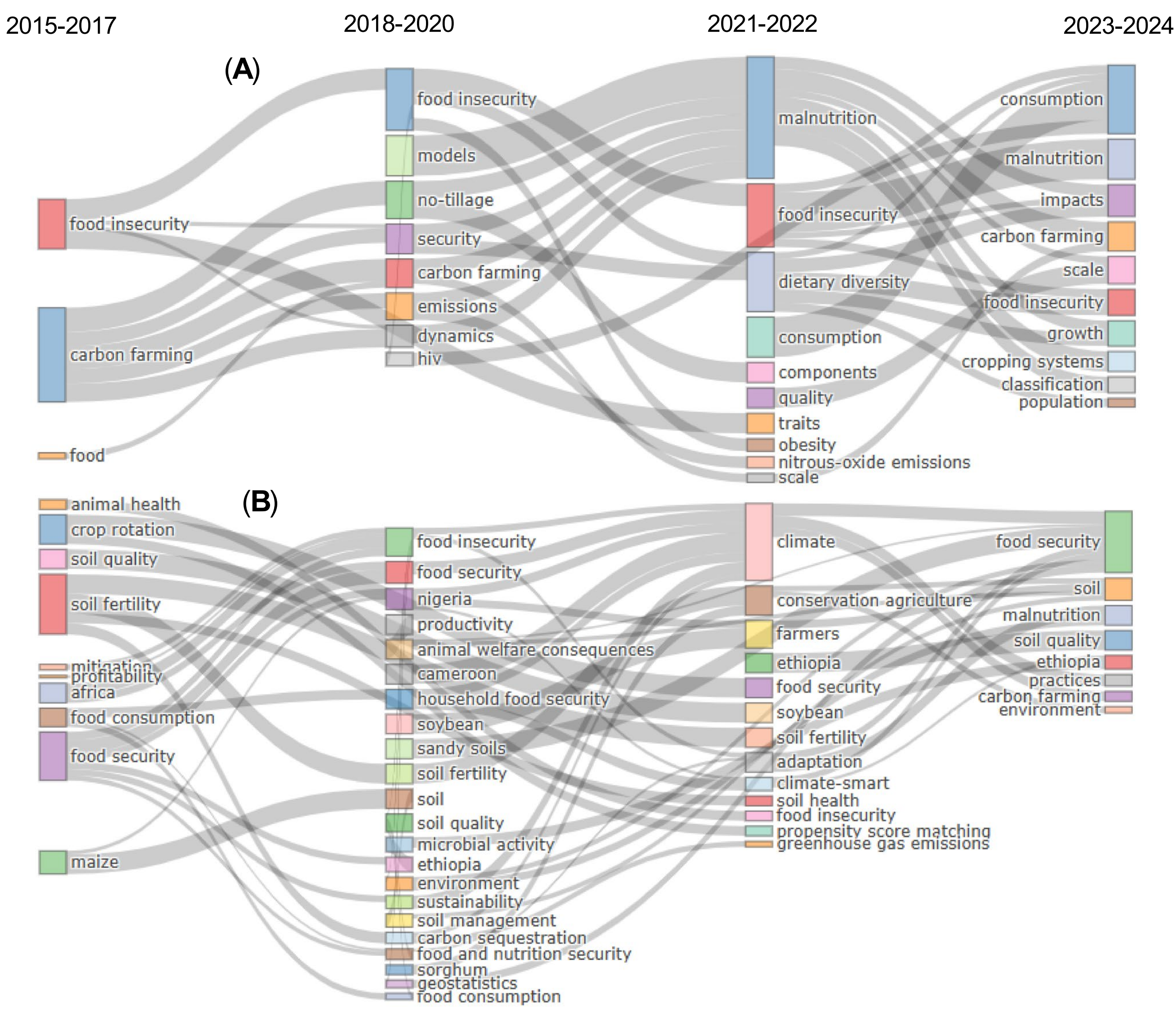


Fig. 9 Thematic evolution of (**a**) keywords plus, (**b**) authors' keywords on the research topic between 2005 and June 2024. Source: analyzed by authors using Bibliometrix in Rstudio

3.8 Challenges associated with LoCAS adoption in Brazil and Africa

In as much as LoCAS has enormous benefits, it is also befallen with some challenges that hinder its full adoption in the regions. Though, like the benefits, the challenges tend to vary between the regions due to economic, environmental, political, and socio-cultural differences, yet the challenge associated with lack of finance, funds and support for Research, Development and Innovation (RD&I) had very significant impact in both Brazil and Africa (Table 6). In Africa, another challenge that showed a very significant impact on LoCAS adoption was the high rate of crimes and insecurity. Unlike in Brazil, Africa is threatened with the problems relating to herdsmen-farmers conflicts, illegal-armed militants, Boko-Haram insurgency, kidnapping of farmers for monetary ransoms, rapping of the female farmers, and communities land disputes, which have formed bottlenecks to LoCAS. Unstable political landscape and unfavorable policies were also ranked high as primary challenges to LoCAS in both Brazil and Africa. High rates of poverty

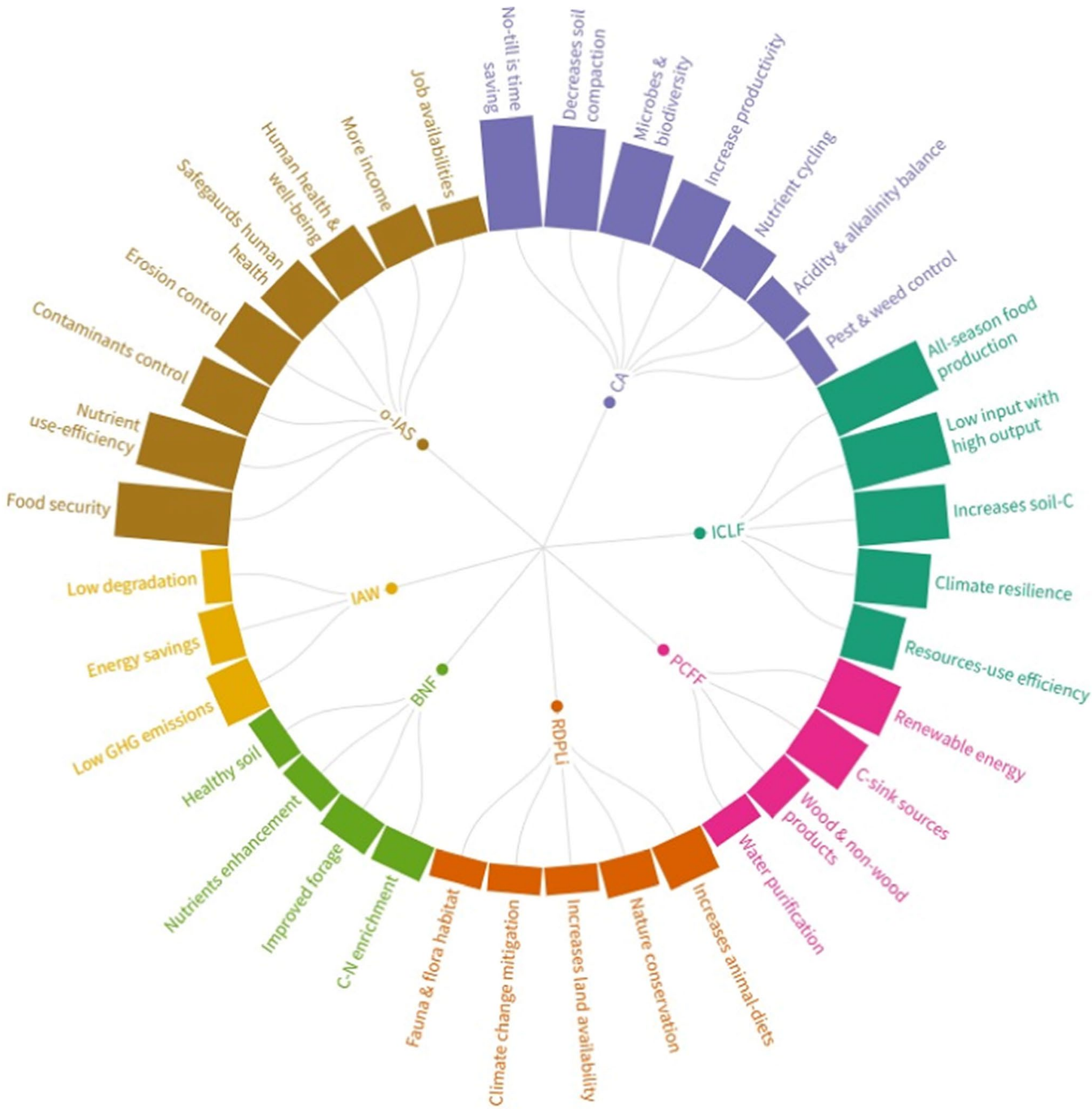


Fig. 10 Benefits of LoCAS based on the study dataset. Source: analyzed by authors using Flourish studio software. The LoCAS are integrated crop-livestock-forestry (ICLF), Restoring Degraded Pastureland and Livestock intensification (RDPLi), Conservation agriculture (CA), Plantations of Commercial Forests and Forestation (PCFF), activities promoting biological N fixation (BNF), practices involving the treatment and recycling of industrial and animal wastes (IAW), and other IAS (o-IAS) such as integrated cropping system (IC), integrated crop-livestock (ICL), agroforestry, and improved fallow

and poor infrastructural development (e.g., transport, communication networks, energy & water insecurity) were highly ranked challenges to LoCAS. Though Brazil has problems of poverty among its citizens, but African countries have more impoverished citizens with poorer economic status. These problems have significant adverse impacts on

Table 5 Benefits of LoCAS adoptions based on region (Brazil and Africa)

LoCAS	Benefits	Brazil		Africa	
		Mean	SD	Mean	SD
ICLF	All-season food production	3.54	0.79	2.73	0.64
ICLF	Low input with high output	3.08	0.84	2.95	0.69
ICLF	Increase in soil-C	4.17	1.00	4.02	0.97
ICLF	Climate resilience	4.31	0.89	4.23	1.00
ICLF	Resources-use efficiency	2.89	0.66	3.06	0.83
RDPLi	Increases animal-diets	2.75	0.64	2.54	0.65
RDPLi	Nature conservation	2.96	0.61	2.61	0.7
RDPLi	Increase in land availability	3.01	0.77	2.83	0.61
RDPLi	Climate change mitigation	4.15	1.00	2.74	0.66
RDPLi	Fauna & flora habitat	2.63	0.63	2.59	0.71
CA	No-till time saving	3.77	0.8	3.42	0.84
CA	Decreases soil compaction	3.51	0.79	3.07	0.80
CA	Microbes & biodiversity enrichment	3.26	0.85	3.88	0.91
CA	Increase productivity	4.09	0.93	4.16	0.96
CA	Nutrient cycling	4.14	1.00	4.05	0.90
CA	Acidity & alkalinity balance	2.62	0.70	2.70	0.68
CA	Pest & weed control	3.13	0.75	2.56	0.6
PCFF	Water purification	3.02	0.81	2.93	0.71
PCFF	C-sink sources	4.25	0.98	4.19	1.00
PCFF	Renewable energy	3.18	0.72	3.26	0.88
PCFF	Wood & non-wood products	3.11	0.74	4.03	0.97
BFN	C-N enrichment	4.09	0.86	3.98	0.82
BFN	Improved forage	3.46	0.78	3.75	0.75
BFN	Nutrients enhancement	3.25	0.8	3.16	0.71
BFN	Healthy soil	4.01	1.00	3.87	0.80
IAW	Energy savings	2.74	0.71	2.91	0.64
IAW	Low GHG emissions	2.99	0.68	3.07	0.72
IAW	Low degradation	2.83	0.65	3.21	0.79
o-IAS	Safeguards human health	2.61	0.69	2.53	0.67
o-IAS	Nutrient use-efficiency	3.5	0.83	3.67	0.81
o-IAS	Erosion control	3.16	0.79	4.19	0.99
o-IAS	Contaminants control	3.08	0.84	3.01	0.86
o-IAS	Human health & well-being	2.96	0.69	2.66	0.69
o-IAS	Job availabilities	2.87	0.61	3.09	0.72
o-IAS	More income	3.05	0.73	4.22	1.00
o-IAS	Food security	4.28	1.00	4.05	0.97

LoCAS implementations. Therefore, social and economic factors were prioritized as the highest-ranking categorized challenges to LoCAS (Table 7).

4 Implications of the study

The work contributed to narrow the knowledge gap on Brazil-African research trajectory on LoCAS and food security. It also revealed the principal countries, authors, institutions, and publishing journals involved in research development on the topic. Information from the study might increase the awareness among the agricultural stakeholders in Africa and Brazil, thus promoting more partnerships, fundings and training in agricultural development and publications between the regions. The results also revealed the key benefits and challenges of LoCAS adoptions in the regions, and these are vital information that will support in the strengthening and improving LoCAS. Findings from the work could contribute

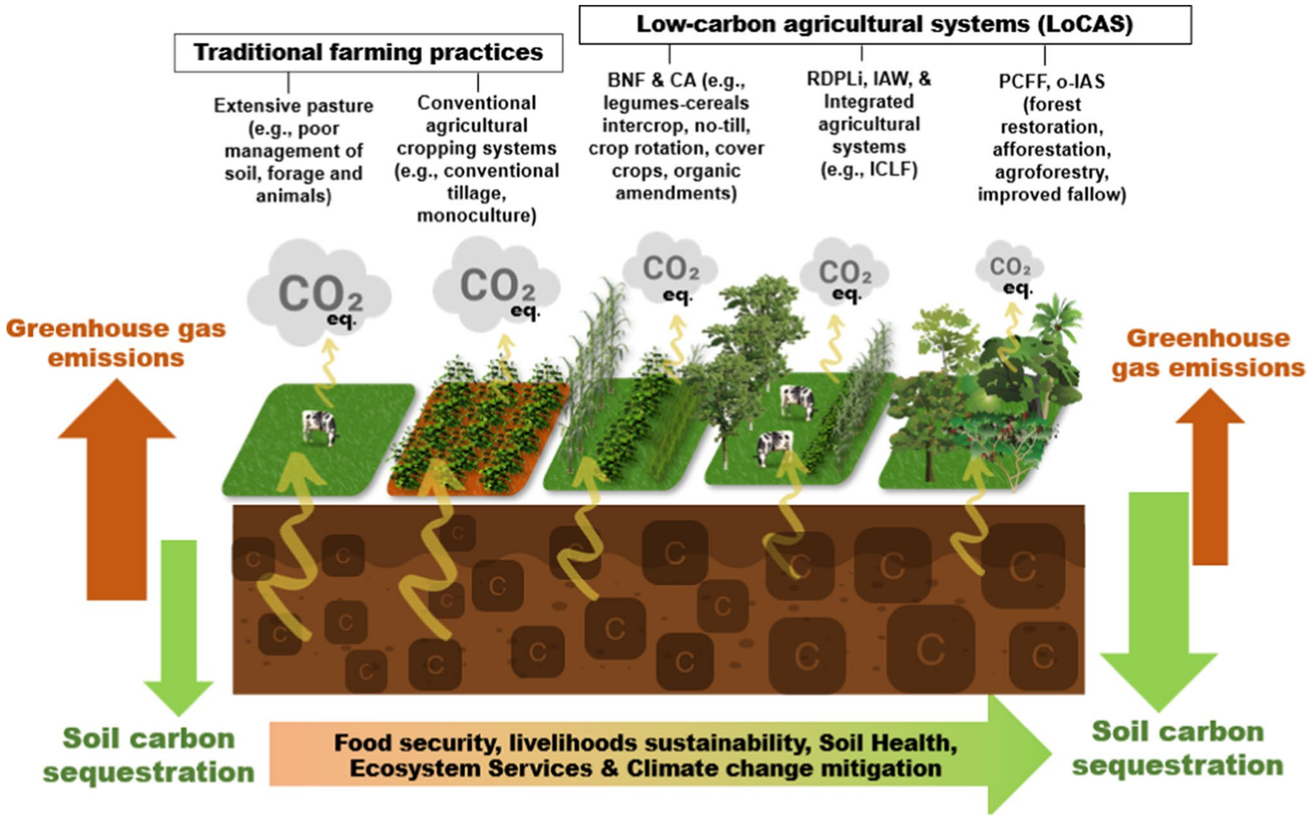


Fig. 11 Conceptual framework and comparative illustration of the practices and profitability of LoCAS over the traditional/conventional agricultural systems in Brazil and Africa. The LoCAS are integrated crop-livestock-forestry (ICLF), Restoring Degraded Pastureland and Livestock intensification (RDPLi), Conservation agriculture (CA), Plantations of Commercial Forests and Forestation (PCFF), activities promoting biological N fixation (BNF), practices involving the treatment and recycling of industrial and animal wastes (IAW), and other IAS (o-IAS) such as integrated cropping system (IC), integrated crop-livestock (ICL), agroforestry, and improved fallow

to the promotion of future agricultural policies that focused on LoCAS to enhance food security, and climate change resilience especially in Africa where there have been low research and publications on the topic. For example, most papers and authors with the highest number of LoCAS are from Brazil, and only few African countries (e.g., Nigeria, Ethiopia, and South Africa) made some notable scientific impacts. In addition to the adoption of the integrated crop-livestock-forestry, African farmers will become more informed about other LoCAS such as practices involving the treatment and recycling of industrial and animal wastes. This is because much industrial and agricultural wastes are being generated without proper management and recycling of them for soil richness and environmental sustainability.

5 Limitations of the study

This study might not be able to report or include all available papers on the research landscape on low-carbon agricultural systems and food (in)security in Brazil and Africa because of constraints imposed by the search. For example, documents published in other databases and source types, such as Scopus and the grey papers were not included in this study. In as much as we believe that WoS core collection is a very robust research database, and has justified the objective of this work, future research should focus on developing a more robust search and analysis tool and combining multiple databases (e.g., Scopus, google scholars) for a comprehensive review on the progress of research in the field. Further, because of language barrier, the search was limited to only English language, and this limitation might have had influence on the result because there might be good articles on the topic in Portuguese or other languages. In future, a collaboration with Portuguese language translator will be made possible as to include other relevant papers on the topic. In as much as we are not ignorant of these limitations, we are optimistic that the work largely has achieved its objectives.

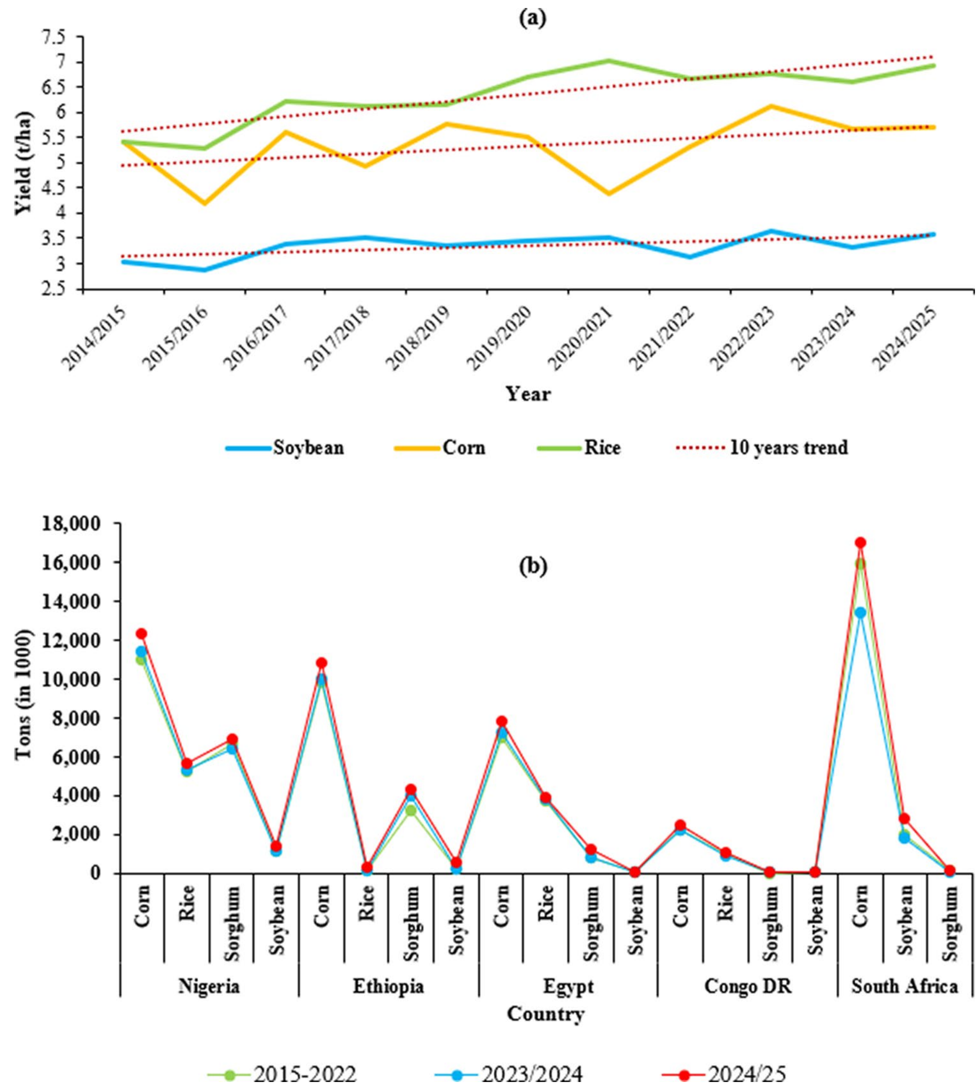


Fig. 12 Major crops production reports during the study period. (**a**) Brazil (**b**) Top African countries. Source: Authors' analysis from dataset and International Production Assessment Division (IPAD) (2025). https://ipad.fas.usda.gov/

6 Conclusion and recommendation

Corresponding authors' collaborations were more than 80% single country publication (SCP) than multiple country publication (MCP). This could be attributed to the major research funding being regional or locally based. Meanwhile, the Brazilian Agricultural Research Corporation (EMBRAPA), and the São Paulo Research Foundation (FAPESP) have contributed to creating opportunities for LoCAS research collaboration for researchers in Brazil. It will be ideal for them to leverage their existing efforts to encourage and support researchers for more international collaborations, especially with developing countries in Africa. For instance, partnerships in agricultural production systems knowledge-transfer from Brazil and other developed countries to Africa will help in enhancing the goals of LoCAS. These partnerships could be through scholarship grants to students and scholars in Africa to acquire advanced skills and modern farming innovations from Brazil and other developed nations. Establishing sustainable agricultural projects and funding research institutions by the Brazilian government, United nations organizations (e.g., FAO), and developed countries might also support in the adoption of LoCAS in Africa. In addition, stakeholders support in the promotion of very tolerant and high yielding crop and animal species could also help the African farmers to cope sustainably with the exacerbating environmental stress in the region.

Seven different LoCAS were identified in the dataset and the number of LoCAS increased with corresponding authors countries' research relevance. Corresponding authors from Brazil covered all the seven LoCAS (e.g., ICLF, RDPLi, CA, PCFF, BNF, IAW, and o-IAS), while in Africa especially authors from Benin, Senegal, Namibia, and Mali

Table 6 Challenges to LoCAS including their categories, responses, ranking and other statistics for Brazil and Africa

Cat	Challenges	Ranking_Africa (N = 20)				Ranking_ABrazil (N = 10)			
		Africa	Responses	Mean	SD	Brazil	Responses	Mean	SD
E	Lack of finance, funds & support for Research, Dev & Innovation (RD&I)	1	20	4.52	0.87	1	10	4.47	0.91
Ev	Geographical settings (e.g., climate, soil, relief, etc.)	6	17	3.61	0.95	2	9	4.22	0.83
S	Political landscape and policies	3	19	4.28	0.76	3	9	4.05	0.87
T	Poor technical know-how/expertise	7	17	3.54	0.92	6	7		0.94
E	High cost/inadequate technologies & tools	5	18	3.77	0.81	5	8	3.53	0.77
S	High rate of crimes & insecurity(e.g., herdsmen-farmers conflicts)	2	19	4.39	0.98	10	1	1.17	0.61
SE	Poor infrastructural development (e.g., transport, communication networks, energy & water insecurity, etc.)	4	18	4.15	0.99	4	8	3.98	0.95
S	Land tenure systems (ownership) crises	8	16	3.31	0.74	7	6	3.45	0.88
S	Socio-cultural beliefs & traditions	9	15	3.24	0.69	8	6	3.31	0.75
S	High illiteracy rate among farmers and households	10	14	3.19	0.85	9	5	3.26	0.79

Cat Categories which includes, *E* Economic, *Ev* Environment, *S* Social, *T* Technical, and *SE* Socio-economic, while *N* Total number of invited respondents, *SD* Standard deviation

Table 7 Ranking categorized challenges to LoCAS adoption in Brazil and Africa

Categorized challenges	Mean	SD	CV	Rank
Social (S)	39.56	5.23	0.147	1
Economic (E)	22.74	4.06	0.169	2
Environment (Ev)	19.62	3.88	0.171	3
Socio-economic (SE)	13.08	2.49	0.178	4
Technical (T)	9.91	1.95	0.203	5

covered only one or two LoCAS. This limited the achievement of the benefits of LoCAS in the region. Besides seeking and beckoning for supports from other countries and international organizations, the governments of African countries should during yearly budgets allocate substantial amount of money to the agricultural RD&I sector of their economy. Overdependency on imported foreign food items by most African countries needs to be totally abated or reduced as to encourage local farmers through friendly patronage. By doing this more innovations will erode into the African farming systems for the consolidation of LoCAS.

The hybrid bibliometric approach provided a clear roadmap in understanding the Brazil-African research trajectory on LoCAS and food security, as well as the roles of countries, authors, institutions, publishing journals. This knowledge could support in championing future debates on LoCAS for effective discussion and policies to enhance food security, and climate change resilience especially in Africa where there have been low research and publications on the topic.

Globally, Africa ranks top among regions in dare need of food for its rapidly growing population. Therefore, LoCAS and its associated practices are critically necessary to promote soil health, ameliorate the effects of environmental stress (e.g., climate change), and increase food production. As the population expands, the available landscape for agriculture becomes reduced, thus the adoption of LoCAS will significantly provide sustainable solutions to food insecurity in the region. Agricultural research development and publications are vital to achieving improvement in the agri-food chain. As seen from the result, the prevailing little collaborations between Brazil and Africa in agricultural research yielded some benefits because the major crops showed some levels on increase between 2015 and 2024. Therefore, it is recommended that African countries implement policies to promote research and publications, and international collaborations with Brazil and other developed countries which are famous in food production and publications in this sector. This will enhance the transfer of knowledge on scientific innovations, and sustainable farming systems (such as LoCAS) to ameliorate the impacts of poor soil and climate change in favor of food security.

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Declarations

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