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Family Farming in Angola – Towards Second-Generation Frugal Development

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ABSTRACT

Objective: The aim of the current study was two-fold: to provide an updated overview of scientific output in the field of second-generation frugal development, with a particular focus on the state of African research; and to establish a Living Lab in an experimental village to test and integrate technological systems into family agricultural production.

Methods: This study tested various search strategies across multiple information sources, including Google Scholar, OpenAlex, Lens, and Web of Science. Due to inconsistencies in OpenAlex data downloads and the restrictions associated with Google Scholar's PoP (Paywall or Publisher) feature, Web of Science (WoS) was selected for the analysis.

Results: The results show a wide dispersion of research topics, with main clusters including 3D printing in agriculture, precision farming, mechanical properties, Internet of Things (IoT) and Big Data, food sector, and environment. African research in these areas is largely in its infancy, except for South Africa and Nigeria.

Conclusion: African research in second-generation frugal development and related technologies is still in its early stages, with notable progress only in South Africa and Nigeria. The establishment of a Living Lab in an experimental village is proposed to further integrate and test technological systems in family agricultural production.

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Introduction

The development of 3D printing has rapidly expanded into nearly all areas of technology, art, and food. The literature on the subject is extensive, and many publications—particularly from countries where technological advancement is limited—explore the potential applications of 3D printing across various fields. However, in the area of mechanical applications in agriculture, only a few studies are available. In this specific context, we developed a simple yet effective concept: using patent databases to trace the historical evolution of certain agricultural technologies. This approach enables us to identify and select rustic equipment—often originating from the 19th century—that can be adapted to the current needs of family farming in Angola.

We can then incorporate modern technologies, such as 3D printing, into this equipment to create prototypes. This approach is referred to as "*second-generation frugal development*," a concept described by Dou and Sebastião (2021). These prototypes are tested in situ and improved as needed. This process also promotes the social inclusion of advanced knowledge within the domain of family farming, which is often overlooked by high-level scientists (Khalid Anser, 2021).

The current research aims to assess the extent to which the concept of implementing low-intensity technologies through modern inputs has been explored in scientific publications. In other words, whether "top-down" knowledge transfer is currently underway (Dyba, 2021), particularly in Africa.

A quick analysis of information related to 3D printing in agriculture, conducted through a simple web search and queries to various databases, highlights the emergence of this technology in the field. However, its application remains largely limited to large companies and, to some extent, medium-sized enterprises. These entities are involved in the development of seeders, sprayers, hive irrigation systems, and, in more advanced cases, small-scale agricultural equipment. Yet, the integration of low-intensity and high-intensity technologies does not appear to be a focus in current research. In most cases, we are still at the conceptual stage or moving toward highly advanced applications such as the Internet of Things (IoT), drones, and similar technologies (Prior, 2024; LNA Prototypes, 2025). While the 3D printing technology has the potential to revolutionize agricultural practices by enabling the rapid prototyping and production of customized tools and equipment tailored to specific farming needs. Its application ranges from the fabrication of spare parts and small machinery components to the development of precision agricultural devices, which can improve efficiency and reduce costs, particularly for smallholder farmers. Despite growing interest, research on 3D printing in agriculture remains limited, with most studies focusing on conceptual frameworks or advanced implementations such as sensor integration and automated systems. Expanding scientific inquiry into practical, low-cost 3D printing solutions could significantly enhance sustainable and accessible agricultural innovations worldwide.

Materials and Methods

Currently, numerous sources of information are available, ranging from patent databases to scientific databases such as Google Scholar (2025), Lens (2025), OpenAlex (2025), and the Web of Science (WoS) (2025), as well as direct search engines like Carrot2 (2025) and Lingo3G (2025). We utilized these various scientific resources with different search strategies to determine which was most appropriate for our research objectives.

We proceeded using a traditional approach (Castaño et al., 1994; Dou, 2016), by querying databases and testing various search strategies. When possible, the corpus was downloaded for offline analysis—such as with OpenAlex—or analyzed locally using VOSviewer (2025) for Lens and WoS. The analyses primarily focused on the authors, the countries involved in the research, and the authors supported keywords.

1. Study Conducted Using OpenAlex

The following search queries were conducted using OpenAlex, focusing on titles and abstracts:

“3D and printing and agriculture” yielded 400 records.

“3D printing and farming” yielded 67 records.

“Additive manufacturing and agriculture” yielded 567 records.

“Manufacturing agricultural machinery” yielded 1,356 records.

2. Study Conducted Using Google Scholar

A search for "additive manufacturing agriculture" in the full text returned approximately 291,000 records. However, when the same search was limited to titles only, it yielded just six records.

3. Study Conducted Using Lens

A search for "additive manufacturing agriculture" returned 16 records in titles and 587 records in abstracts.

4. Study Conducted Using the Web of Science (WoS)

The following search query was used:

TS = (((3D printing) OR (additive manufactur*)) AND (agriculture* OR smallholder OR farm*))

This search returned 287 records.

Results

1. Results obtained using the OpenAlex database

1.1. General Study

OpenAlex can be used to obtain a list of keywords found in these 400 records. By selecting the keyword "*agricultural machinery*," which is the focus of our research, we identified seven relevant records, distributed as follows:

- *Food Industry and Aquatic Biology* – 3 records;
- *Mechanical Engineering and Vibration Research* – 1 reference;
- *Animal Nutrition and Health* – 1 reference;
- *Surface Treatment and Coating* – 1 reference; and
- *Agriculture and Biological Studies* – 1 reference.

We note that the content of these 400 records is largely unrelated to our initial focus. Since the analysis of other keywords did not yield conclusive results, we broadened the search in an attempt to better define the concept of agriculture:

- "*3D and Printing and Farming*" resulted in 67 records. The analysis of the keywords led us to select a single relevant term: *precision agriculture*, which was associated with only one reference.
- "*Additive Manufacturing Agriculture*" returned 567 records. However, the keyword analysis does not indicate a focus on equipment manufacturing. In most cases, the content involves assessments of potential applications rather than concrete implementations.

Despite this, the latter strategy appears to be the most relevant, given the limitations of the other results.

1.2. Production of Agricultural Equipment in General

To assess the impact of research on the manufacturing of agricultural machinery—particularly in Africa—we adopted a general search strategy that excluded the field of 3D printing. The results are as follows. The search strategy "*manufacturing AND agricultural AND machinery*" applied to titles and abstracts yielded 1,356 records. This formulation appears to provide the most relevant results, which we will examine in detail. Notably, when the term "*additive*" is included in the search strategy, only 35 records are retrieved, of which only six are directly related to the topic. This finding highlights that the application of 3D printing in agriculture is still in its early stages.

We observed continuous growth in the subject between 2001 and 2024. Additionally, we note the emergence of keywords—with frequencies ranging from 229 to 2—such as: *tractor*, *spare part*, *precision agriculture*, *plough*, *combine harvester*, *sprayer*, *digging*, *fodder*, *handicraft*, *peasant, technology transfer, batch production, chopper,* and *reverse engineering*. This clearly indicates that the search strategy is relevant.

The distribution of the selected works by country shows a very low contribution from African nations, as illustrated in the following table. The main contributors are China (142), the U.S.A. (76), the Russian Federation (59), and India (48), followed by various other countries, though with a significant drop—approximately 25 publications or fewer.

Table 1. Distribution of African countries by publication frequency

Countries	Frequency of publications
Nigeria	9
Ethiopia	4
South Africa	4
Kenia	3
Ghana	2
Niger	2
Benin	1
Mali	1
Libya	1
Somalia	1
Zimbabwe	1

It should be noted that Africa is lagging behind in this field, although some countries are beginning to establish a presence. This indicates the emerging development of agricultural machinery manufacturing in Africa (Daum & Irner, 2020). Given the total number of countries on the continent (63 in total), it is clear that much remains to be done. It is also worth noting that the Global South, according to OpenAlex, accounts for 273 records.

2. Results obtained using the Google Scholar database

We used the search strategy that seemed most relevant to us. "*Additive manufacturing agriculture*" yielded approximately 291,000 records when searched across the entire database, but only six records when the search was limited to the title.

The first result, based on a search of the entire records' content, is not usable due to the overwhelming number of records. However, restricting the search to titles yields only six records, of which only one is truly relevant:

Gu, W., Styger, E., & Warner, D. H. (2020). Assessment of additive manufacturing for increasing sustainability and productivity of smallholder agriculture. *3D Printing and Additive Manufacturing*, *7*(6), 300–310.

Note that the appearance of the term "*smallholder*," which clearly situates the subject within the context of family farming. However, when this term is included in the search strategies used in the OpenAlex database, it yields no results.

3. Results obtained using the Lens database

The search strategy used was as follows. "*Additive manufacturing agriculture*" in the title yielded 16 records, and in the abstract, 587 records. Our analysis focused on the 587 records obtained from the abstract search. Although these records may not initially appear directly relevant to the topic, we present the keyword graph in the following figure. The term "*additive manufacturing*"—used in the search strategy—was excluded from the analysis to enhance the readability of the network.

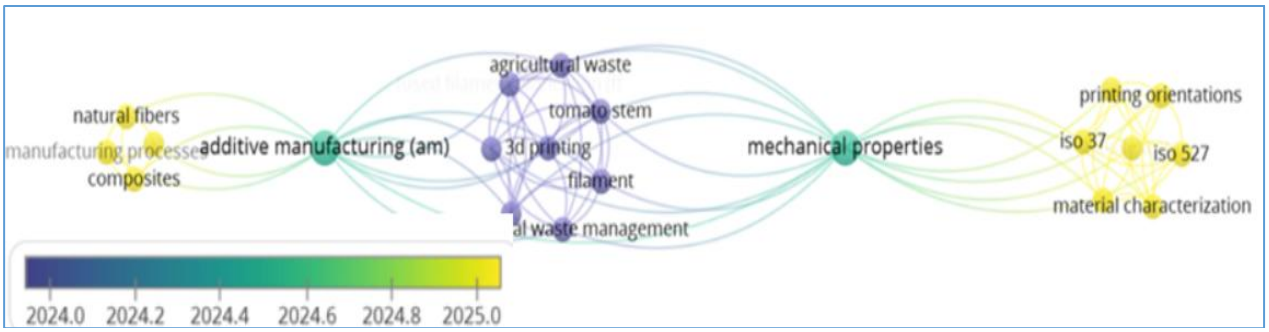

Figure 1. Keyword graph, results obtained with the Lens database

Recent topics include the emergence of standards and a shift toward natural fibers. However, almost no records focus on the creation or repair of agricultural equipment using 3D printing. This pattern holds true across all databases; the connection to agriculture is mainly through the use of waste materials to create filaments, processes related to food production, environmental sustainability, and possibly irrigation or sensor systems (precision agriculture).

4. Results obtained from the Web of Science (WoS) database

The Web of Science is an internationally recognized citation database. Although it has been criticized by some for its commercial and Anglo-Saxon orientation, it remains a valuable resource that should not be overlooked. After testing numerous search strategies, we focused on the following search query:

TS = ((additive manufacturing) OR (3D printing)) AND (agricultur* OR smallholder* OR farm*)), which yielded 297 records.

4.1. Authors

The distribution of authors reflects limited networking, indicating a very low presence of structured collaborations. This suggests that the research field is still new and that the formation of collaborative research groups remains minimal. The distribution of authors by publication frequency is shown in Table 2.

Table 2. Distribution of authors by publication frequency

No. of Authors	Frequency of Publications
5	4
4	4
3	24
2	137
1	3307
Total number of authors	3476

Since VOSviewer cannot process more than 1,000 authors, we did not create a global network. Using a publication frequency threshold of two or more results in 169 authors—analyzable by VOSviewer—but this does not produce a significant network.

4.2. Keywords

There are different types of keywords in the Web of Science: those assigned by the database (i.e., KeyWords Plus) and those provided by the authors (i.e., authors supported keywords). To stay as close as possible to the topics developed by the authors, we used the author keywords. To improve the readability of the network, the terms "*additive manufacturing*" and "*3D printing*" were removed. The keywords used to create the network have a minimum frequency of two. The network is presented in Figure 2.

It is evident that the work carried out in this field is very recent. This clearly indicates that the subject is in its early stages of development and that research is still emerging. There is also a diversity of approaches. Indeed, several clusters emerge, including *mechanical properties*, *sustainability*, *circular economy*, *soft robotics*, and *food*. Regarding agriculture, we did not exclude this theme, even though it was part of the search strategies, in order to access topics related to this field. This is illustrated in Figures 2 and 3.

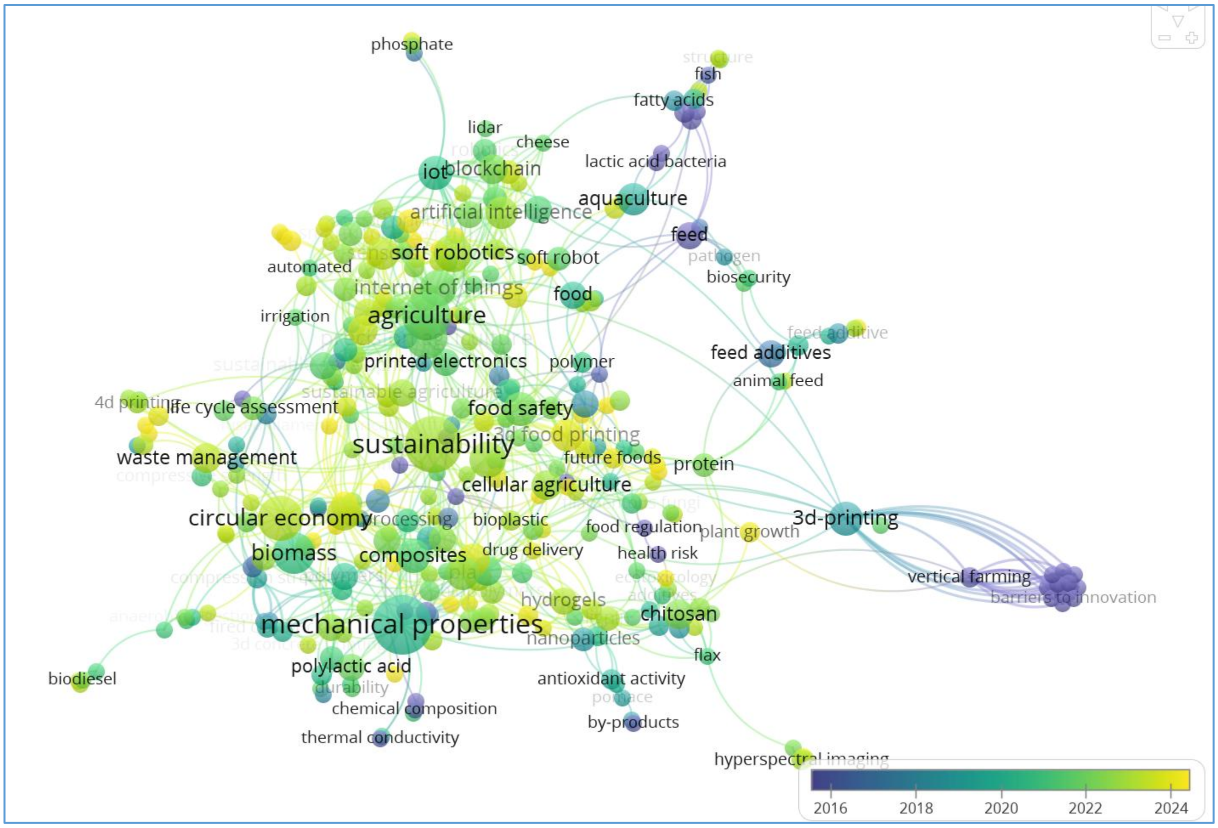

Figure 2. Network of author keywords with a frequency equal to or greater than two

Note that the term *3D printing* is used without a hyphen, whereas earlier publications prior to 2020 often included a hyphen between the two terms. In the case of agriculture, the following themes are highlighted: IoT, blockchain, and automation; sensors and printed electronics; rapid prototyping; recycling; biological aspects such as biotechnology, bioprinting, and bioplastics; medical-related topics including drug delivery; nutrition (food and feed); irrigation; additives; and wood.

If necessary, we can use the main graph to identify the links between the themes listed above and other fields. For example, the theme of *additives* is connected to *microcontrollers*, *irrigation*, *concrete*, *biomass*, and *compressive strength*. The various fields related to agriculture are presented in Figure 3.

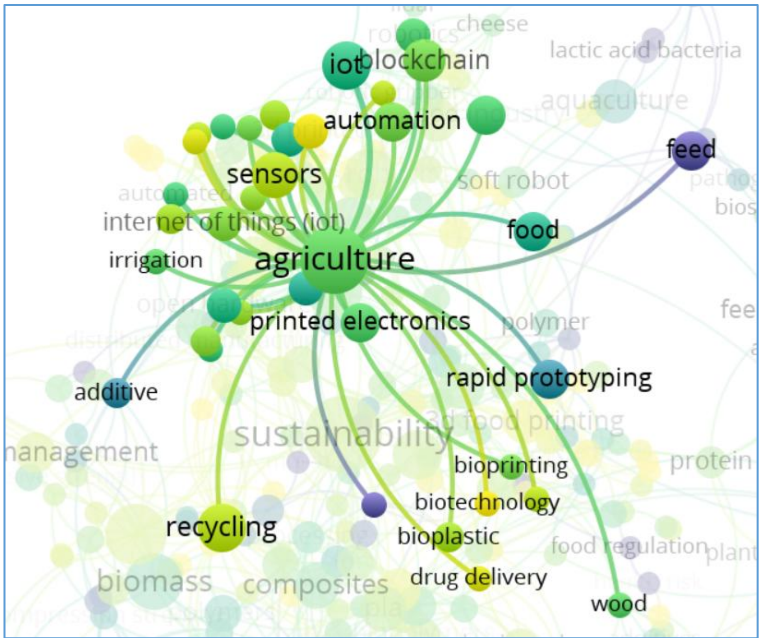

Figure 3. Topics Directly Related to Agriculture

4.3. Countries Covered by Research

The countries with the highest number of publications in this field are: the U.S.A. (154), China (93), India (83), England (51), Italy (49), Spain (38), Australia (32), France (29), Canada (29), Germany (28), South Korea (26), Japan (21), and Greece (20). The research output of African countries is presented in Table 3.

Table 3. African countries by number of publications

Countries	Frequency of Publications
Egypt	17
South Africa	11
Nigeria	4
Kenia	2
Tanzania	2
Gabon	1
Tunisia	1
Malawi	1
Uganda	1
Zambia	1
Zimbabwe	1
Ivory Coast	1
Ghana	1
Morocco	1
Sudan	1
Algeria	1
Botswana	1
Cameroon	1
Benin	1

If we consider the main African countries—excluding North Africa—we observe a growing interest in this area, with two notable exceptions: South Africa and Nigeria, which appear to be actively engaged in the field. This observation aligns with the findings from the data analyzed using OpenAlex.

5. Results obtained from web analysis

5.1. Using Carrot 2 or Lingo 3G – Querying in English

Carrot 2 and *Lingo 3G* are information clustering systems, meaning they cluster information based on similarity or affinity. We used the free version, so while the results are still meaningful, the total number of clustered data is limited.

The results obtained from scientific databases highlight that the topic is still in its infancy and that its research potential has not yet been fully explored. To complement this study, we conducted a brief analysis of data from the Internet—that is, from various websites, both commercial and potentially scientific. This provides a useful overview of the current state of the field. The results are shown in Figure 4. For this example, the search strategy used was:

additive AND *manufacturing* AND *agriculture*

However, it should be noted that the query was made in English. If the same search is conducted in another language—Portuguese, for example (the official language of Angola)—a different set of results will emerge, reflecting how Portuguese speakers (e.g., in Portugal and Brazil) perceive the topic. These results are presented in Figure 5.

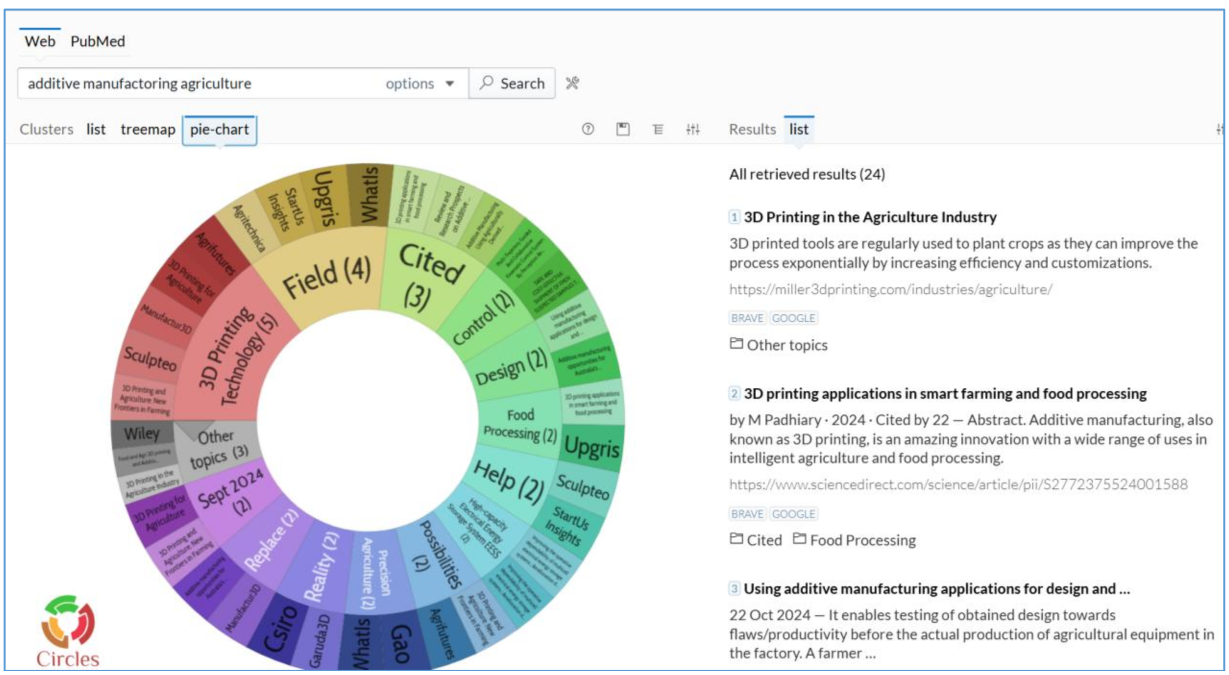

Figure 4. Using Carrot 2 – Querying in English

In addition to the data selected above, you can also access further information by clicking on various parts of the circle (clustered data), for example:

17 **Upgris** This paper presents a mini review of the applications o known as additive manufacturing, in the fields of agric and the environment protection and monitoring. The p used in 3D ... https://journal.upgris.ac.id/index.php/asset/article/view	10 **Additive Manufacturing Using Agriculturally Deriv** by AM Rahman · 2023 · Cited by 16 — Agriculturally de transformed into a diverse range of materials, including filaments, ... https://pmc.ncbi.nlm.nih.gov/articles/PMC10376353/
11 **Manufactur3D** 3D printing technology has several useful applications i industry. It allows farmers and would-be farmers to dev and equipment, replace broken parts, and test the effica The technology also ... https://manufactur3dmag.com/can-3d-printing-revolutio	5 **3D Printing and Agriculture: New Frontiers in Farm** 11 Sept 2024 — 3D printing is not yet a technology wid agricultural practices, some specialized applications ha possibilities. https://www.3dnatives.com/en/3d-printing-and-agricult

5.2. Using Carrot 2 – Querying in Portuguese

The chosen search strategy was: *agricultura manufatura additiva*. We observe that the topics related to this query differ from those obtained using English. This approach is valuable, as varying the language used for the search allows us to quickly gain an overview of perspectives from different countries.

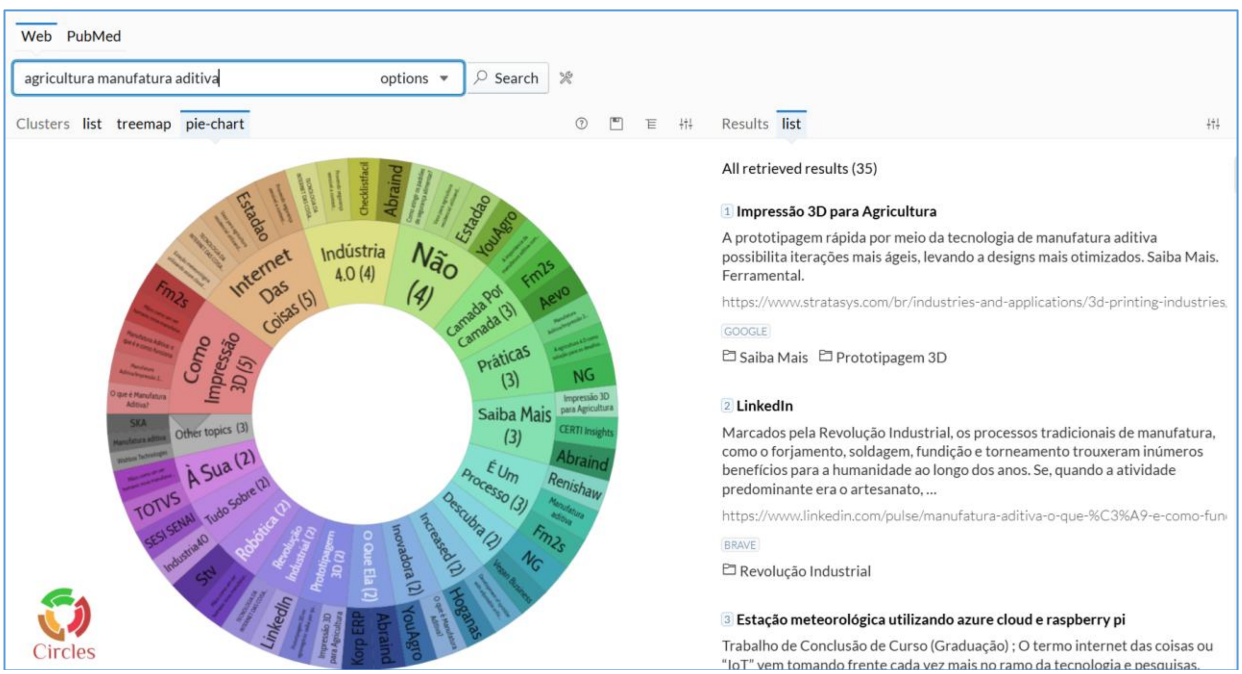

Table 5. Using Carrot 2 – Querying in Portuguese

Conclusion

The use of 3D printing in agriculture is currently in its early stages. The examples cited in the literature typically involve large companies that use 3D printing to produce spare parts. Local practices among small businesses are still emerging and limited to areas such as seeders, beehives, irrigation, etc. While ancestral practices and their improvement have been systematically studied, this research primarily focuses on technologies from the 1960s and 1970s (Jolly, 2019). These approaches are far removed from the current conditions on African family farms, where there is virtually no technological presence—particularly in areas such as mechanized seeding and irrigation.

The analyses we conducted reveal a near absence of development and research in this field across Africa, with the exception of a few isolated studies in South Africa and Nigeria. As such, the application of second-generation frugal development remains a promising opportunity. If properly implemented—and if local needs are accurately identified—it could foster the social integration of knowledge into local development efforts. The conditions observed in Angola, including the YETO Lab and the commitment of the Angolan Ministry of Science and Technology, provide a favorable context for establishing a traditional value chain linked to technology transfer (Sampson, 2024), as well as the potential creation of a Living Lab supported by an experimental village (NATAE, 2024).

Author Contributions

All authors contributed equally to the conceptualization of the article and writing of the original and subsequent drafts.

Data Availability Statement

Data available on request from the authors.

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Ethical considerations

The authors avoided data fabrication, falsification, plagiarism, and misconduct.

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Conflict of interest

The authors declare no conflict of interest.

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