VOL IV

Estudos em Ciências Agrárias e Ambientais

Eduardo Spers
(Organizador)

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APRESENTAÇÃO

É com grande satisfação que apresentamos o volume IV da coletânea **Estudos em Ciências Agrárias e Ambientais**, resultado do esforço colaborativo de pesquisadores de diferentes regiões e instituições, que compartilham aqui reflexões, dados e contribuições relevantes para o avanço do conhecimento técnico-científico em suas áreas de atuação.

Este volume reúne 13 trabalhos organizados em cinco eixos temáticos que refletem a diversidade e complexidade do campo agrário e ambiental contemporâneo: Sistemas de Produção Aquático e Animal; Sustentabilidade Ambiental e Conservação de Recursos Naturais; Sistemas de Produção Vegetal e Agricultura de Precisão e Educação e Inovação no Meio Agrário.

Os temas abordados vão desde o manejo sustentável de recursos naturais, passando por inovações tecnológicas na agricultura e aquicultura, até discussões sobre formação profissional e segurança sanitária nas cadeias produtivas. Essa pluralidade é o reflexo da crescente interdisciplinaridade que caracteriza os estudos agrários e ambientais hoje – exigindo diálogos entre a ciência, a tecnologia, a educação, a economia e a sociedade.

Além da qualidade dos estudos apresentados, destacamos o compromisso dos autores com a pesquisa aplicada, a sustentabilidade e a busca por soluções adaptadas às realidades locais, muitas vezes desafiadoras. A presença de autores da América Latina e Europa também fortalece o caráter internacional da obra, fomentando o intercâmbio de experiências e metodologias.

Agradecemos a todos os autores pela confiança em compartilhar seus trabalhos conosco. Que esta publicação possa inspirar novas pesquisas, colaborações e, acima de tudo, práticas que contribuam com a construção de sistemas agrários e ambientais mais resilientes, justos e inovadores.

Desejamos a todos uma excelente leitura!

Eduardo Eugênio Spers

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SECOND GENERATION FRUGAL INNOVATION - TOWARDS APPROPRIATE FRUGAL AGRICULTURAL INNOVATION FOR FAMILY FARMS IN ANGOLA

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ABSTRACT: Second-generation frugal development is based on the fact that locally, on family farms, crops remain based on ancestral protocols far removed from all current technological aspects. Based on this observation, it is possible, through a retrospective search for old technologies, to select those that would be adaptable to the local context, then to improve them using more modern technologies. Behind the expression "more modern technologies", lie, as discussed in the rest of this article, 3D polymer or metal printing, but also, in fact, all the basic elements of enterprise 4.0 and in particular the possibilities of computer-aided design, simulation and optimization. Possibilities necessary for production by 3D printing and allowing an upstream study of structured production around digital technology. This is what we call "second-generation frugal development". The use of 3D printing in Angola has been developed over the past 10 years at Agostinho Neto University in collaboration with France, which led to the creation of the experimental laboratory Yeto Lab. Based on this experience and because the use of 3D printing is beginning to develop in agriculture, we will implement "second-generation frugal development" using products developed locally at the university. The objective is to create a Living Lab in an experimental village to test and integrate technological systems into family agricultural production. The work presented here aims to take stock of scientific productions in this field and mainly on the state of African work. To this end, various search equations were tested on the Web of Science (WoS). It took several attempts to arrive at a

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search equation representative of the subject. The results highlight a wide dispersion of topics, with the following overall clusters: 3D-related aspects - agriculture and precision farming - mechanical properties - IoT Internet Big Data - food sector - environment. However, African research remains embryonic except for South Africa and Nigeria.
KEYWORDS: family farming; 3D printing; additive manufacturing; agriculture; frugal development; Angola; enterprise 4.0; Africa; competitive intelligence.

1. INTRODUCTION

Access to suitable agricultural tools is a crucial issue for the development of family farming in Angola. In a context where imported equipment is often expensive, unsuitable for local conditions, or difficult to maintain, it is becoming strategic to explore more frugal, inclusive, and locally anchored avenues of technological innovation. This contribution proposes an original methodology consisting of revisiting old technical patents [Dou & Sebastião, 2021], which have fallen into the public domain, to reinterpret them using the design and production tools of the Industry 4.0 era.

The objective is twofold: first, to identify robust and proven technical solutions that could meet the needs of small producers; second, to promote their adoption through modern design and production methods and tools that enable local adaptation, low-cost manufacturing, and active user participation. A pilot project is currently underway to redesign a seed drill for the needs of Angolan family farms. It is expected to be followed by other projects, such as a solar dryer. It aims to illustrate a circular, open, and territorialized engineering approach.

2. CONTEXT

Angola, like many sub-Saharan African countries, relies primarily on family farming for its food supply. [Corazza et al. 2016] In Angola, it represents almost 80% of national production [de Oliveira Pinto et al. 2023]. However, this agriculture remains largely under-equipped and poorly mechanized, which severely limits its productivity and resilience to climate change. Commercially available agricultural machinery, often designed for large-scale intensive farms, is difficult to adapt to local realities: it requires unavailable engine power, requires specific technical skills, or relies on imported spare parts that are too often unavailable for too long, if ever.

Too often, technological approaches to agriculture ignore the material, social, and cultural realities of their main stakeholder: the farmer [Fernand & Zié 2024]. Solutions that appear simple and technically sound fail to be deployed locally due to their inadequacy in real-life living and working environments. This is not due to a lack of skills or knowledge on the part of producers, but rather to a failure to adapt the proposed technologies to their uses, constraints, and perceptions.

This observation leads to a broader question: how, historically, has innovation – understood as the progressive improvement of practices and tools – spread in agricultural environments? What forms of local ingenuity, trial and error, have enabled the emergence of appropriate solutions? We hypothesize here that old patents, often forgotten, constitute tangible traces of this pragmatic innovation process [Davies 2009]. Reexamining them in the light of contemporary tools could pave the way for a new, more deeply rooted technological dynamic to serve Angolan family farming. In this context, the rereading of old patents offers an underexploited potential [Dou 19a, 19b]. These technical documents contain solutions that are sometimes simple, robust and designed for contexts where resources were also limited. The idea is therefore to extract from these technological archives relevant material to feed frugal innovation processes, at the crossroads of participatory engineering and digital manufacturing.

3. MATERIALS AND METHODS

3.1. PATENTS: A LIVING TECHNOLOGICAL ENCYCLOPEDIA

Patents, which represent all technological achievements developed over the years, are rarely or not at all used in research [DOU 2015]. Indeed, a quick analysis of the bibliographies of most scientific works highlights the absence of patent citations. This is due, among other things, to a lack of collaboration between universities and industry, which is particularly true in developing countries but also in advanced countries. Patents, which are considered here simply in terms of their technological content, precisely describe the protected objects, uses, and equipment, both textually and often descriptively with drawings. There are many patent databases, among the most used are the "patent worldwide" database of the EPO (European Patent Office) [EPO 2025a 2025b], the Patent Scope database of the WIPO (World International Patent Organization) [WIP 2025] or the European patent database [EUP 2025]. Other national patent databases are also available. These databases can be consulted free of charge via the Internet, but to perform an automatic analysis, subscription systems such as Patent Pulse [MAT 2021] which will be used in this presentation facilitate the work.

A patent thus provides access to the technological content it protects. Note that patents over twenty years old are in the public domain, as are patents (lapsed) whose holders no longer pay annuities. The patent databases will be searched (here we consider the worldwide database) in English, using words or expressions contained in the titles or titles and abstracts. This database contains approximately 130 million documents. This search can be completed by using the International Patent Classification |EPOb 2021}, which divides all technologies into a set of 8-digit codes, ranging from a general aspect to increasingly specific areas. For example:

A = human necessities

A01 = agriculture; forestry; animal husbandry; hunting; trapping; fishing

A01B = soil working in agriculture or forestry; parts, details, or accessories of agricultural machines or implements, in general

A01B3= other machines for working soil

A01B35/26 = other machines for working soil; rigid tools

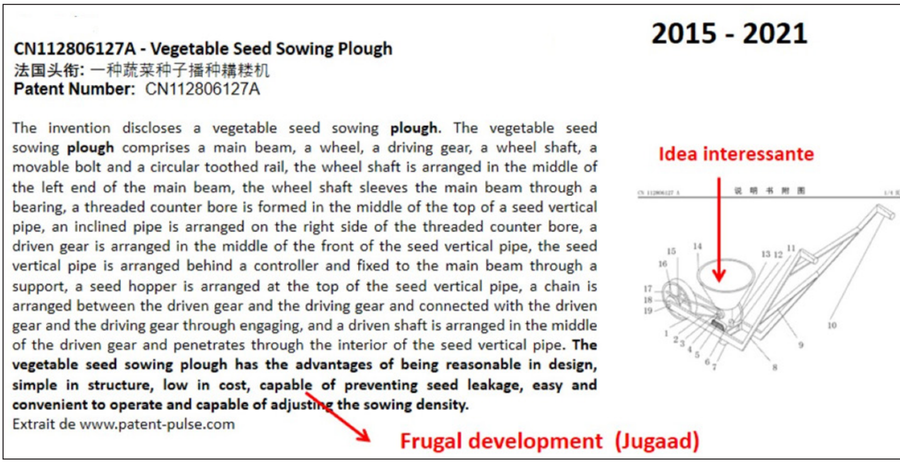
The reader will find a complete description of the IPC on the EPO website [EPOb 2021].

3.2. THE TECHNOLOGICAL WINDOW OF OPPORTUNITY

What do we observe when analyzing the contents of the EPO's worldwide patent database? We see that the number of patents is growing, and that around 2019, the number of Chinese patents and utility models became predominant in global production [GUR 2020, DOU 2012]. It should also be noted that in many cases, 20 to 30% of this Chinese production involves universities as applicants, highlighting the technological commitment of the Chinese higher education system. We also note that technological complexity increases over the years; in more recent years, the protected technologies, equipment, and applications are increasingly sophisticated, and the technologies are increasingly complex, generally speaking, with rare exceptions.

However, among recent patents, we can cite Chinese patents that address the subject with frugal improvements or that present particularly simple and transposable ideas. As an example, we selected the following Chinese patent shown in Figure 1 (window of opportunity 2015-2021).

Figure 1 – Recent Chinese patent presenting a simple and interesting idea.



2015 - 2021

CN112806127A - Vegetable Seed Sowing Plough
法国头衔: 一种蔬菜种子播种耩楼机
Patent Number: CN112806127A

The invention discloses a vegetable seed sowing **plough**. The vegetable seed sowing **plough** comprises a main beam, a wheel, a driving gear, a wheel shaft, a movable bolt and a circular toothed rail, the wheel shaft is arranged in the middle of the left end of the main beam, the wheel shaft sleeves the main beam through a bearing, a threaded counter bore is formed in the middle of the top of a seed vertical pipe, an inclined pipe is arranged on the right side of the threaded counter bore, a driven gear is arranged in the middle of the front of the seed vertical pipe, the seed vertical pipe is arranged behind a controller and fixed to the main beam through a support, a seed hopper is arranged at the top of the seed vertical pipe, a chain is arranged between the driven gear and the driving gear and connected with the driven gear and the driving gear through engaging, and a driven shaft is arranged in the middle of the driven gear and penetrates through the interior of the seed vertical pipe. **The vegetable seed sowing plough has the advantages of being reasonable in design, simple in structure, low in cost, capable of preventing seed leakage, easy and convenient to operate and capable of adjusting the sowing density.**
Extrait de www.patent-pulse.com

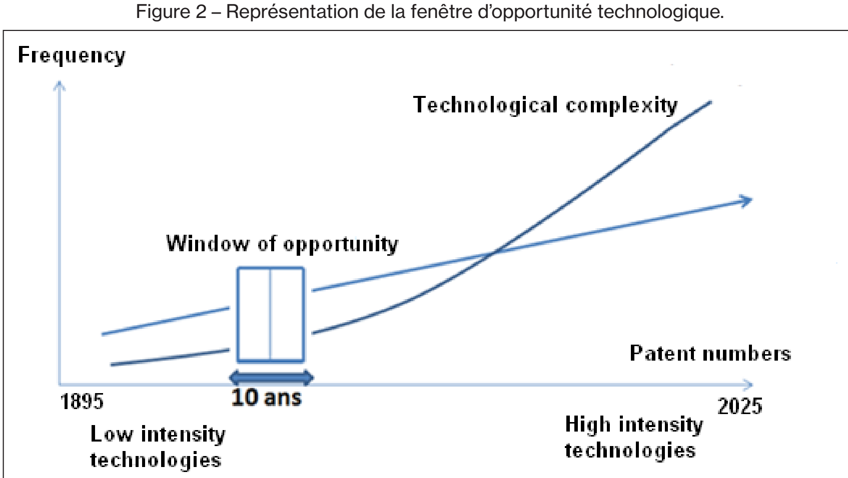
Idea interessante

Frugal development (Jugaad)

Since this patent is recent, it will be necessary to wait at least two years to know if it has been extended to African countries. If not, the idea and its implementation could be legally copied.

The technological window of opportunity will work as follows: by taking a date range, for example, 10 years, and using the same query, but varying the date range, we will move through the years, highlighting more or less advanced technologies. Thus, the window of opportunity can be represented as shown in Figure 2. By conducting multiple queries limited to intervals of 10 years or other years (10 is the time range chosen for this example), we can thus observe technological developments for a given object or piece of equipment and thus choose, based on local possibilities, the most appropriate technology to achieve the set objective: developing endogenous production.

Figure 2 – Représentation de la fenêtre d'opportunité technologique.



4. EXAMPLE – AUTOMATED SEEDER

4.1. SECOND-GENERATION FRUGAL TECHNOLOGIES

A pioneer in the use of frugality, Navi Radjou [RAD 12] states in his founding principles:

To seek opportunity in adversity requires a new look and charisma.

To do more with less is often the way to respond to consumers' needs, those who want to meet a particular need without constantly offering "improvements" intended by the manufacturer and not necessarily desired by the consumer.

Achieve lower costs through clever use of existing technologies. Doing more with less is often the solution to meet the needs of consumers, who wish to satisfy a specific need without constantly proposing "improvements" planned by the manufacturer and not necessarily desired by the consumer. Reducing costs through the intelligent use of existing technologies.

Today, while these principles remain in force, spectacular developments have been made in general technological applications that can be applied to a wide range of activities. Thus, the production of simple tools or systems found in retrospective research, if they fall directly within the frugal principle, will benefit from much more advanced technologies than those used at the time. This is what we call "second-generation frugal technologies." In fact, the final product will be the same or may possibly be improved, but the technological advances used to create it will not be apparent. Thus, the initial simplification sought and the ease of use will remain the same.

To clarify, we can give an example. In hot countries, greenhouses are often used to grow, for example, market garden plants. Their role is the opposite of what we are developing in Western countries. Indeed, in Africa, the undergrowth cultivation that protected plants from the effects of the sun and heat has disappeared due to deforestation (to obtain charcoal). We must therefore examine the problem of greenhouses not to produce heat, but to prevent its accumulation! Different solutions are possible, including pagodas with successive ventilated roofs that will create a beneficial air current as well as shade. This solution has existed for several millennia, but the modern implementation of such systems will benefit from all the progress made in fluid mechanics, measurements obtained with thermal cameras, etc. This will ultimately lead to a greenhouse that, for an uninformed person or for the end user, will seem very simple or even trivial, without realizing the modern technological contributions used to establish its final structure. We then have a solution that appears simple, even simplistic, but which underlyingly comes from a second generation and the "invisible" integration of advanced technological contributions.

It is within this framework that the experiments carried out in Angola in the field of agriculture are situated. These experiments are partly the work of the Yeto Lab developed within the framework of the Angola-France cooperation at the Agostinho Neto University in Luanda. An analysis of the value of the family farming sector (generally 2-hectare farms) made it possible to determine the products (services will be addressed in a second step) that it needs most. This list, with the necessary priorities established, leads to a search, firstly, for frugal solutions and, secondly, for the realization of these solutions by including in an "invisible" way the decisive contribution of new processes with high added value. This refers to 3D printing, for example, but also, in fact, all the basic elements of the 4.0 company and in particular the possibilities of computer-aided design, simulation and optimization.

4.2. TRACKING A TECHNOLOGY OF AUTOMATED SEEDERS OVER TIME

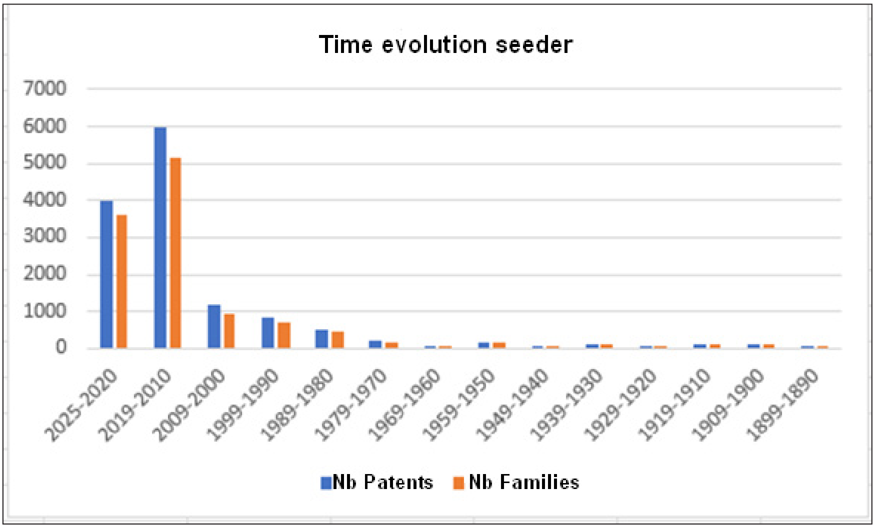
For this tracking, we conducted queries of the global patent database over ten-year periods. This allows us to see the flow of patents produced, on the one hand, and to analyze this flow based on the filing countries and the protected technologies, on the other. The use of patent databases and their statistical analysis has been described by Dou et al. [DOU 19a, DOU 19b]. The data obtained are as follows:

Table 1 – Temporal Evolution of automated seeders.

Interval	Number of patents	Number of families[4]
2025,2020	3987	3619
2019,2010	5964	5173
2009,2000	1178	932
1999 ,1990	864	686
1989,1980	509	432
1979,1970	194	167
1969,1960	78	73
1959,1950	153	147
1949,1940	50	49
1939,1930	98	97
1929,1920	88	88
1919,1910	121	121
1909,1900	130	130
1899,1890	33	33

[4] A patent can be extended in different countries. Therefore, the same invention can lead to different patents. This set is called a patent family.

Figure 3 – Seeder: Change in the number of patents over time.



A transition period should be noted: 1979-1980, which could be explained by the beginning of a change in agricultural practices, as farms became increasingly large, hence the need to better control seed distribution, both to save time and to increase its regularity.

Analysis of the countries registering patents will complement this argument. (See below.)

4.3. ANALYSIS OF DEPOSITING COUNTRIES

Table 2 – Countries submitting applications for seed drills.

Interval																													
2025, 2020	CN3564	US56	EP51	CA36	BR34	KR33	WO31	AU24	RU18	JP15	ZA15	TW13	AR10	PL10	UA10	DE8	ES8	FR8	PH8	HU6	MY4	RS3	CH2	EA2	IT2	MX2	SA2	AT1	CR1
2019, 2010	CN4904	US165	EP129	KR106	CA65	AU73	DE64	RU63	FR51	WO50	JP49	PL42	BR34	EA24	ES19	UA15	PH10	HU7	IT7	AT6	AR5	SE5	TW5	MD4	ZA4	CL3	GB3	HR3	PE3
2009, 2000	CN584	KR105	DE77	EP60	JP45	US40	CA36	FR35	AU27	UA25	PL20	WO18	BR15	ES15	RU13	AT11	TW9	AR6	DK4	EA3	FI3	HU3	SE3	RO2	CO1	CZ1	GB1	MD1	OA1

1999, 1990	CN 286	JP 136	KR 131	EP 42	FR 41	AU 38	ES 26	US 21	DE 23	CA 20	SU 19	RU 15	PL 11	BR 9	IT 8	AT 6	HU 6	UA 4	WO 4	GB 3	AR 2	DK 2	YU 2	BG 1	MA 1	PH 1	SI 1	TN 1	TW 1
1989, 1980	JP 195	SU 67	ES 36	AU 31	EP 25	CN 23	US 21	KR 19	CA 13	FR 13	DE 10	PL 10	BR 8	GB 8	DD 4	AT 3	CS 3	SE 3	ZA 3	IT 2	NZ 2	PH 2	RO 2	BE 1	DK 1	GT 1	HU 1	IE 1	MA 1
1979, 1970	SU 58	JP 42	ES 34	US 12	FR 11	AU 9	BR 5	CA 4	PH 3	DE 2	IT 2	PT 2	BE 1	BG 1	CH 1	GB 1	GT 1	IN 1	CA 1	PL 1	RO 1	YU 1							
1969, 1960	SU 22	FR 19	ES 14	US 9	CA 6	BE 3	CH 2	FI 2	AU 1																				
1959, 1950	US 42	ES 18	FR 13	CA 8	CH 4	GB 3	FI 1																						
1949, 1940	SU 23	US 14	FR 6	CA 4	CH 2	ES 1																							
1939, 1930	SU 58	US 19	ES 9	CA 6	FR 5	FI 1																							
1929, 1920	US 30	CA 24	FR 23	SU 7	ES 3	FI 1																							
1919, 1900	US 83	CA 35	FR 7	ES 5																									
1899, 1890	CA 19	US 8	CH 2	ES 2	GB 2																								

Table continued. As much data as possible has been included in the table for better comparison.

1989,1980 YU=1 PT=1 MA=1 1999,1990 ZA=1 YU=1 TW=1 **2009,2000** PE=1 PH=1 YU=1 ZA=1 **2019,2010** CO=2 DK=2 MA=2 PT=2 TR=2 AP=1 CR=1 DO=1 EC=1 GE=1 HK=1 IL=1 JO=1 LU=1 MX=1 NL=1 RO=1 SG=1 **2020,2015** DK=1 FI=1 GB=1 HR=1 LU=1 NL=1 NZ=1 PT=1 RO=1 TR=1

The meaning of the country codes used in the table can be found at the following internet address: https://register.epo.org/help?lng=fr&topic=countrycodes

We can see from the table above that initially, in the earliest years, it was countries that had developed agriculture over large areas or had a strong agricultural culture that were concerned with seed drill issues, since they were an essential step towards achieving the best possible yield.

Thus, Canada, the United States, Russia, France, and Spain were leaders in the field. This continued until the 1970s. The decade from 1970 to 1980 appears to be a transitional period that heralded a change in agricultural practices, moving towards a massive expansion of cultivated land. The following period saw the direct introduction of this change in practice. This led to both national technological developments and a market for seed systems, with the emergence of patents from countries that did not necessarily have an agricultural tradition. The case of China is classic, as it only extends its patents very little, but it constitutes, due to the number of Chinese patents filed, a protection against any extension or filing of patents from other countries. This is often referred to as the “patent great wall” [DOU 12]. It should also be noted in the case of China that a very large number of “patents” are in fact utility certificates, the examination of which is often carried out on the form, the substance being examined in the event of a dispute. [DOU 13]. In recent periods, we note a fairly low number of real innovations, the patents often being focused on improvements.

It should be noted that countries with a strong agricultural tradition, particularly in the areas of cereals and market gardening, remain prominent throughout all periods considered.

It should also be noted that the potential effects of the two wars of 1914-1918 and 1939-1945 do not disrupt the patent filing graph shown in Figure 1.

5. FRUGAL DEVELOPMENT SYSTEMS

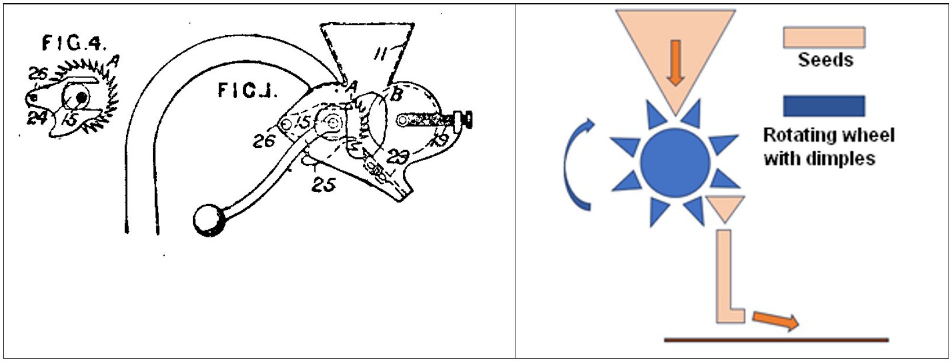
The term frugal is used here to mean the search for low-intensity technologies that can be easily adapted to countries whose technological and economic development does not allow for a rapid and significant qualitative leap in the practices concerned by this development [BOR 21] [IQB 21] [KIS 22]. We will therefore seek simple ideas, which in our case will be derived from patents that have “fallen” into the public domain (more than twenty years old) or have been abandoned. The method used as exeplained above, is to vary a 10-year window of opportunity and analyze, within these time intervals, the ideas, concepts, and techniques that could be integrated into frugal development. In this case, the applications are intended for very localized family farming, i.e., smallholdings. This is often found in various African countries where the lack of material resources does not allow for a direct technological leap. We will give two examples that can easily be integrated into the development of low-tech products, which does not mean that we are returning to the materials used in those earlier years.

Example 1

Great Britain Patent GB189711721A date 1898

This patent does not directly concern a seed drill, since it concerns the extraction of grape seeds by means of toothed wheels. But, what is important is that it generates the idea that one could make a simple seed drill, where from a reservoir of seeds, these could enter by gravity between the teeth of a toothed wheel animated by a circular movement resulting from the path of the seed drill on the ground. The seeds are then distributed according to the interval present between two teeth of the wheel and also by the speed of rotation of the latter. Such a system could be made via 3D printing [SCH 23].

Figure 4 – On the left, diagrams from the British patent. On the right, a seeder based on the previous idea.



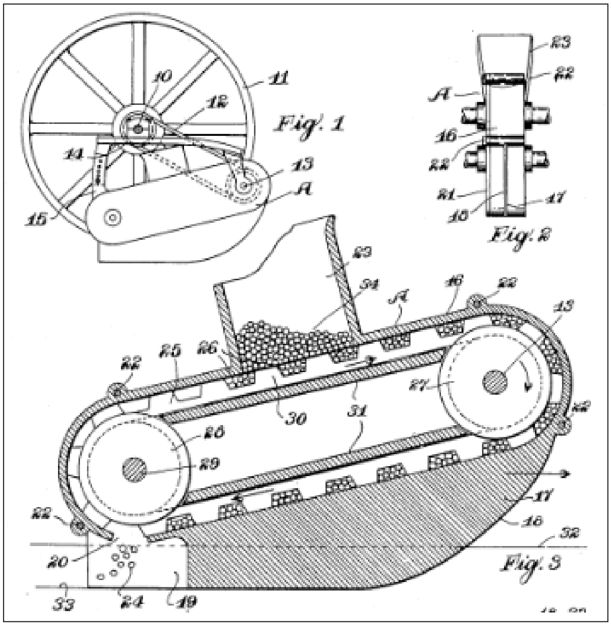
The seed spacing can be adjusted using different wheels with different diameters. The cells on the wheel are designed according to the size of the seeds to be placed. The circular movement of the wheel is achieved via the wheels supporting the system, which can be manipulated manually or attached to an animal or a mechanical system. The system designed based on data from the British patent is currently undergoing a utility model certificate with the Patent Office of the Republic of Angola [OFF 25].

Example 2

United States Patent US2141044 date 1935

The main feature of this system is the distribution of seeds from a belt with cells allowing the capture of seeds from the reservoir containing them. Then a rotary movement linked to the motion of the system drives the belt and therefore the deposit of seeds on the ground. The speed of motion as well as the interval between the cells allow the seed deposits to be spaced appropriately. It should be noted that 3D printing is often used for the production of transmission belts [PAM 25].

Figure 5 – Seed distribution by belt system.



6. PROGRESS OF THE FIELD IN AFRICA

For the remainder of the study, it is important to have a clear view of the progress of studies in this field in Africa. This is both to understand their level and to potentially establish collaborations based on the progress of certain projects. To do this, we used the World of Science (WoS) database using a search equation that includes the use of 3D technology, since we want to introduce it into the implementation of basic ideas that could lead to products integrated into the development of family farming.

6.1. RESULTS OBTAINED FROM THE WEB OF SCIENCE (WOS) DATABASE

The Web of Science is an internationally recognized database. Although criticized by some for its commercial and Anglo-Saxon orientation, it nevertheless constitutes a working basis that should not be overlooked. To this end, and after testing numerous search equations, we focused on the following research:

TS = ((additive manufacturing) OR (3D printing)) AND (agricultur* or smallholder* or farm*)) or 297 references

Authors

The distribution of authors reflects low networking, meaning the very low presence of structured networks. This indicates that the field of research is new, and that the formation of collaborative research groups is particularly low. The distribution of authors by publication frequency is shown in the following table.

Table 3- Distribution of authors by publication frequency.

Frequency of publications	**Number of authors**
5	4
4	4
3	24
2	137
1	3307
Total number of authors	3476

Because VoSviewer [WOS 2025] (free software to draw networks between authors, keywords,..) cannot process more than 1,000 authors, we did not create a network. Indeed, with a publication frequency greater than or equal to 2, which results in 169 authors, and therefore analysable by VoSviewer, we do not obtain a significant network.

6.2. KEYWORDS

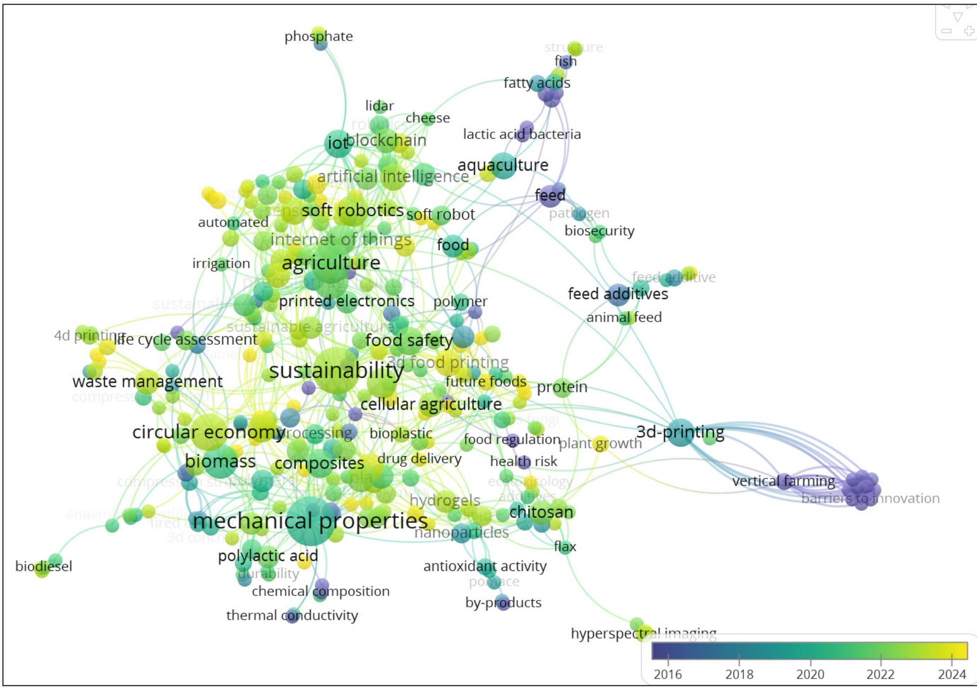
There are different types of keywords in the WoS: those of the WoS and those of the authors. To stay as close as possible to the topics developed by the authors, we used the author keywords. To make the network more readable, the two terms "additive manufacturing" and "3D printing" were removed. The frequency of the keywords used to create the network is 2. The network is presented in figure 6.

It can be seen that the work carried out in this field is very recent. This clearly shows that the subject is in its early stages of development and that we are at the emerging stage of research. There is also a diversity of approaches.

Indeed, various clusters emerge: mechanical properties – sustainability – circular economy – soft robotics – food.

For agriculture, we did not exclude this theme, although it was part of the research equation, but this enable to access topics related to this field. This is presented in figure 7.

Figure 6 - Network of author keywords with a frequency equal to or greater than 2.

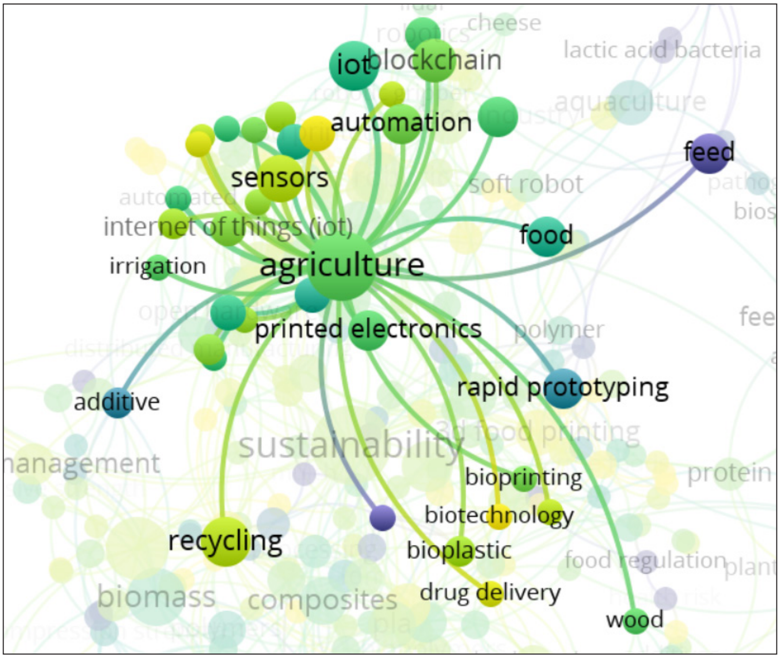


Note that the term 3D printing is used because of the hyphen separating the two terms, which was written in years prior to 2020.

In the case of agriculture, the following themes are highlighted: IoT, blockchain, and automation – sensors and printed electronics – rapid prototyping – recycling – biological aspects of biotechnology, bioprinting, bioplastics – aspects related to medicine, drug delivery – aspects related to nutrition (food feed), irrigation – additives – wood

If necessary, we can then use the main graph to determine the links between the themes listed above and other fields. For example, the field of additive is linked to microcontrollers – irrigation – concrete – biomass – compression strength.

Figure 7 - Topics Directly Related to Agriculture.



6.3. COUNTRIES COVERED BY RESEARCH

The main countries covered by the research in terms of the number of publications are the USA (154) – People's Republic of China (93) – India (83) – England (51) – Italy (49) – Spain (38) – Australia (32) – France (29) – Canada (29) – Germany (28) – South Korea (26) – Japan (21) – Greece (20)

The production of African countries is presented in Table 4.

Table 4 - 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 see a beginning of interest, with two exceptions: South Africa and Nigeria.

7. CONCLUSION

The use of retrospective research in the field of intellectual property allows the highlighting of old technologies, relatively crude, but adaptable to the context of the development of family farming in Africa. The development of equipment from these technologies can currently benefit from the contributions of new technologies such as, for example, 3D printing. In this field, and in agriculture, this technology is in full development mainly at the level of large companies in terms of spare parts and electronic inventory management. As far as Africa is concerned, very few publications concern the subject, but nevertheless we note that certain countries: South Africa, Nigeria and Egypt (although this country does not directly enter the geographical area that concerns us) are beginning to acquire significant experience. Given the ease of implementation of 3D printing technology, its use in the design of small mechanical equipment will only continue to grow. Its use in agricultural equipment is therefore an orientation to be developed, which will allow a more inclusive approach to research.

8. REMERCIEMENTS

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