A SYSTEMATIC REVIEW OF THE CONCEPT OF VITALITY IN AGRICULTURE

ABSTRACT

Vitality is a complex and multifaceted phenomenon with a pluralistic nature and philosophical implications. It has been scarcely addressed in agriculture, sometimes through metaphysical explanations but also by a series of correlated terms that express vitality through biological and sociological manifestations. The objective of this research was to identify definitions and comprehend how vitality was assessed in agricultural research from scientific papers from 2002 to 2022. In addition, to examine the identified concepts to select parameters to be used in the controlled trials as well as to source information to be contrasted further with the data from the survey and interviews chapters, aiming to get a better comprehension of the phenomenon of vitality. To do so, a systematic review was carried bout using the systematic review protocol PRISMA. Overall, around 21 scientific terms addressing vitality in agriculture were identified. Out of 2153 papers yielded, 74 papers met the robustness criteria to be analyzed in this review. Around of 39% were ranked as "A" (all robustness criteria met), 54% were classified as "B" (one of the robustness criteria was missed) and 7% were ranked as "C" (more than one of the robustness criteria was missed). Brazil, China, Canada, France and Germany, were the countries who had the biggest percentage of papers ranked as "A". From the higher ranked (A) studies, the terms plant vitality (19%), ecosystem vitality (14%), seed vitality (9%) and crop vitality (7%) composed the biggest number of papers within that category. There was a significative increment of 79.72% in the number of publications using the term vitality in agriculture since 2017. From this number, China (17%), India (7%), France (7%), Germany (6%), Poland (6%) and Brazil (6%) were the countries who had more publications in the period.

Key words: Vitality; Agriculture; Publications; Vitality indicators; Systematic review

INTRODUCTION

Vitality emphasizes manifestations towards health, harmony, and the capacity to be alive (NORMANDIN et al 2015). In addition, vitality from its philosophical definition is interconnected to resilience, growth, development, functionality, and life stimulation in a harmonious way (NORMANDIN and WOLFE., 2013).

From the homeopathic philosophy, vitality is the vital force defined as an autocratic, dynamic, immaterial action-principle that governs physical life, that integrates the entirety of the organisms and governs all physiological phenomena being distinct from the body and the spirit (HAHNEMANN, 1842). The imbalance in this vital force could potentially generates inharmonious manifestations facilitating the appearance of pests and diseases (BETTI et al., 2009).

Outside the philosophical discussion, assessing vitality is perhaps one of the biggest challenges of addressing the term in scientific investigations, mainly on natural sciences, and this issue has fomented debate between the west and east therapeutic traditions over the methods used to do so (GULMEN, 2004; TEIXIERA, 2021). Similarly, in agriculture, the ways to assess the health and vitality of the agroecosystem are debated between industrial and agroecological farming approaches (DÖRING et al., 2012).

In this sense, more information on the topic of health and vitality of the agroecosystem is needed to keep an up-to-date dialogue between research and agricultural practices towards sustainability and its benefits for the society (DÖRING et al., 2012).

METHODOLOGY

Systematic review: a method to find and cluster information

A systematic review refers to the research method of finding and bringing together the available information about an effect or subject. By combining results from several studies, it is possible to assess an overall outcome (DAVIS et al., 2014). In addition, this analysis helps to clarify how a field of research stands, determine if an effect is constant across studies, and identify what further research is required (HARDEN and THOMAS, 2005).

A good systematic review should have a focused question, clear inclusion and exclusion criteria for the papers, and a transparent search strategy. It should identify papers which fit under the review criteria, assess the quality of the studies, synthetize the

study's results and address the review limitations (HIGGINs and GREEN, 2011). Davies et al (2014) suggests the overall structure of the systematic review should follow:
A formulated focused question, comprehensive search and inclusion of studies, quality assessment of studies and data extraction, synthesis of study results and interpretation of the results and reported writing.

There are different strategies to communicate the results of a systematic review, however, Koricheva et al. 2013 explain that one of the most used ways to report the data from a systematic review is by using a traditional narrative review. Such an approach focuses on describing and contrasting results found in the systematic review, in order to understand the causal processes behind the phenomenon under study (SLAVIN, 1987; KIRICHEVA et al.,2012). In this way, a systematic review is an adequate method to locate, evaluate and synthesize evidence.

This systematic review selected papers from 2002 to 2022 and included exclusively peer reviewed papers, both empirical trials as well as literature reviews. The search was conducted in English and focused on papers available on the academic research platform Scopus®.

The systematic flow of this review used the PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses principles (MOHER *et al.* 2009). The PRISMA has been commonly used to carry out systematic review in agricultural research (DOEHRING and SUNDRUM, 2016; MATHIE and CLAUSEN, 2015). According to Liberati and colleagues (2009), the PRISMA framework ensures a transparent and complete reporting of systematic reviews and meta-analyses.

Figure 7 illustrates the PRISMA process flow of this research, and the explanation for step-by-step methodology is given next.

Identification

A search was conducted using the database Scopus®. Only journal articles were included. The searches were carried out based on the combination of word *Vitality* plus another key word – Agriculture, Farming or Food. The search collected papers that contained at least two of the words on their title, keywords or abstract.

Screening

The records were initially screened to include only peer-reviewed empirical trials and literature reviews published in academic journals papers from 2002 to 2022, aiming to represent an up-to-date literature. Books, abstracts and summarised reporting for conferences were also excluded. In addition, any paper that was not directly linked to agriculture was excluded.

Eligibility

After the screening, a two-stage sorting process was carried out to determine each paper's eligibility.

Sort 1: Articles retrieved were assessed via a thorough scan, analysing publication title, key words and abstract to determine relevance to the research questions.

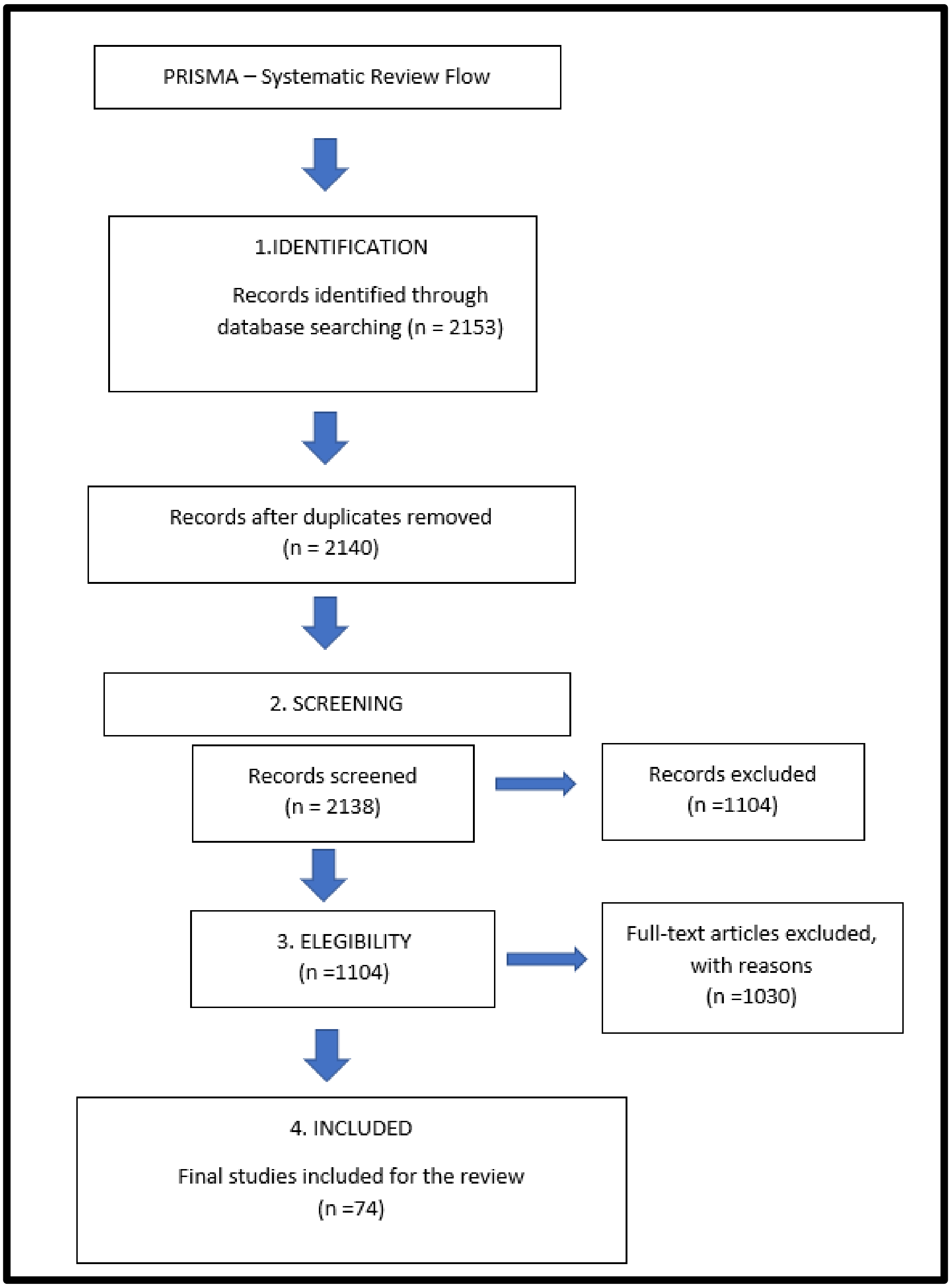
Sort 2: All articles were categorised into 2 types:

1) Empirical research
2) Literature review

These two categories, empirical trials and literature reviews, were further reviewed in more detail for robustness. The robustness criteria were based on those used on systematic reviews in agriculture by Fayet at al (2022), Cidón et al (2021), El Chami et al (2020) and Petticrew (2001) and considered as robustness criteria:

- For empirical research: a) peer reviewed and clearly described methodology; b) minimum of 2 replications per trial; c) statistical analysis at p=0.05 or less.
- For literature review: a) peer reviewed and detailed methodology; b) clear justification and problematization; c) clear study results, outcomes, and limitations.

Figure 1 - PRISMA Systematic Review Flow



Source: developed by the author (2022).

Any complete paper that met all criteria for its type were classified as ranking 'A', whereas papers that missed one criterion were classified as ranking 'B", and finally if two criteria were missed, it was classified as 'C". If none of the criteria were met, the paper was excluded. Only publications where the full text was available in English were considered.

Included

The publications included for the qualitative analyses were categorised under each category (empirical study or review). The data collected identified scientific terms used to address vitality; the country where the research was done, year of publication; research outcomes (positive or nil/inconclusive or negative).

Parameters for Analysis

Scientific term used to assess vitality

Robustness criteria (A, B, C)

Geographical location

Publication Date

Result (‘Positive’ or ‘Nil/Inconclusive’ or negative).

RESULTS AND DISCUSSION

In total, the systematic review yielded 2153 publications that went through a sorting and exclusion process. After a thoroughly analyses following the PRISMA process, 74 papers were selected for the final analyses.

Identification of terms addressing vitality

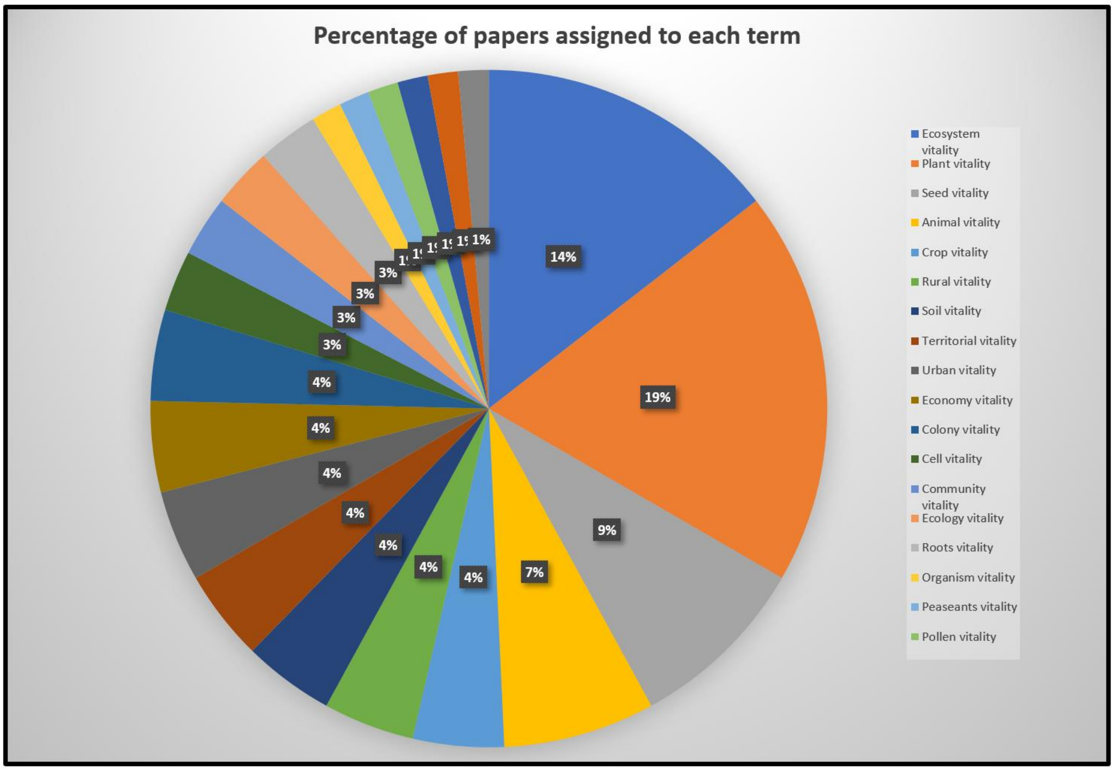
Overall, the systematic review identified 21 scientific terms used in empirical and literature reviews addressing vitality in agriculture (table 3). The terms plant vitality (19%), ecosystem vitality (14%), seed vitality (9%) and crop vitality (7%) composed the biggest number of papers (figure 8) addressing vitality in agriculture.

Table 1 – Scientific terms identified in the systematic research

Used Term	Number of studies	Empirical	Review
Animal vitality	5	4	1
Cell vitality	2	1	1
Colony vitality	3	3	0
Community vitality	2	2	0
Crop vitality	3	3	1
Ecology vitality	2	1	1
Economy vitality	3	3	0
Ecosystem vitality	10	5	5
Organism vitality	1	1	0
Peasants' vitality	1	0	1
Plant vitality	18	13	5
Pollen vitality	1	1	0
Rhizome vitality	1	1	0
Roots vitality	2	2	0
Rural vitality	3	0	3
Seed vitality	6	5	1
Seedling vitality	1	1	0
Soil vitality	3	3	0
Territorial vitality	3	3	0
Urban vitality	3	3	0
Vegetation vitality	1	1	0
Total (21)	**74**	**56**	**19**

Source: developed by the author (2022).

Figure 2 - Parameters assessing vitality in agriculture



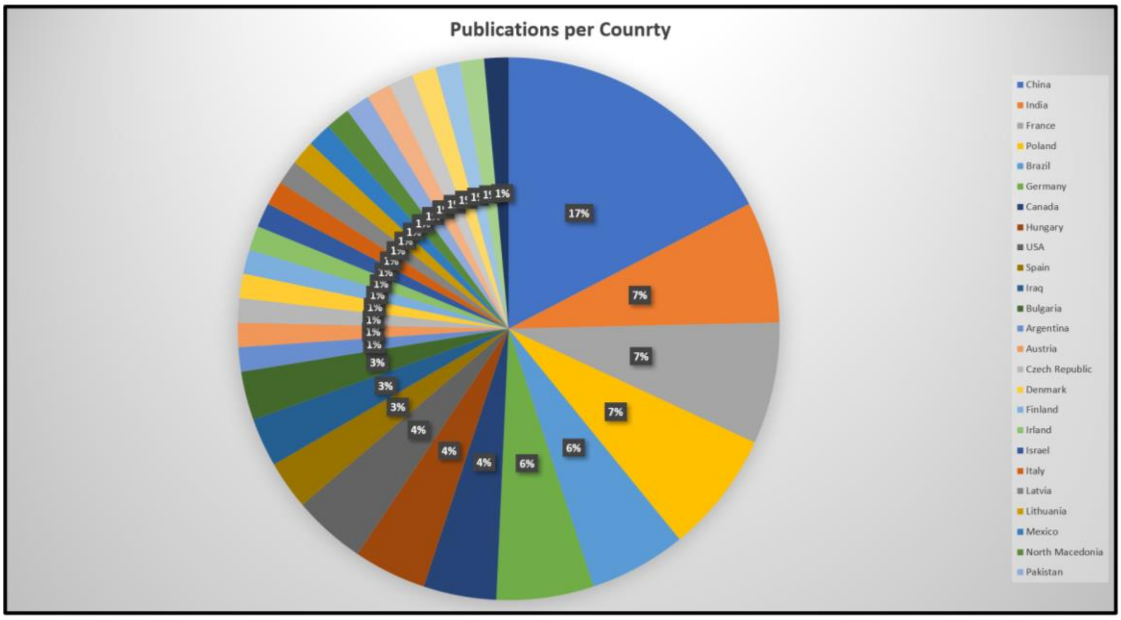
Source: developed by the author (2022).

Origins of the publications: which countries are researching vitality?

Overall, the publications came from 31 different countries (figure 9 and 10). It's possible to highlight that China (17%), India (7%), France (7%), Germany (6%), Poland (6%), Brazil (6%) were the countries that had more publications. If we group the data by regions, Europe makes around of 58% of the publications, Asia accounts for 25% (Russia included here), Middle East (5%), South America (7%), North America (5%). There were no papers from Africa or Oceania.

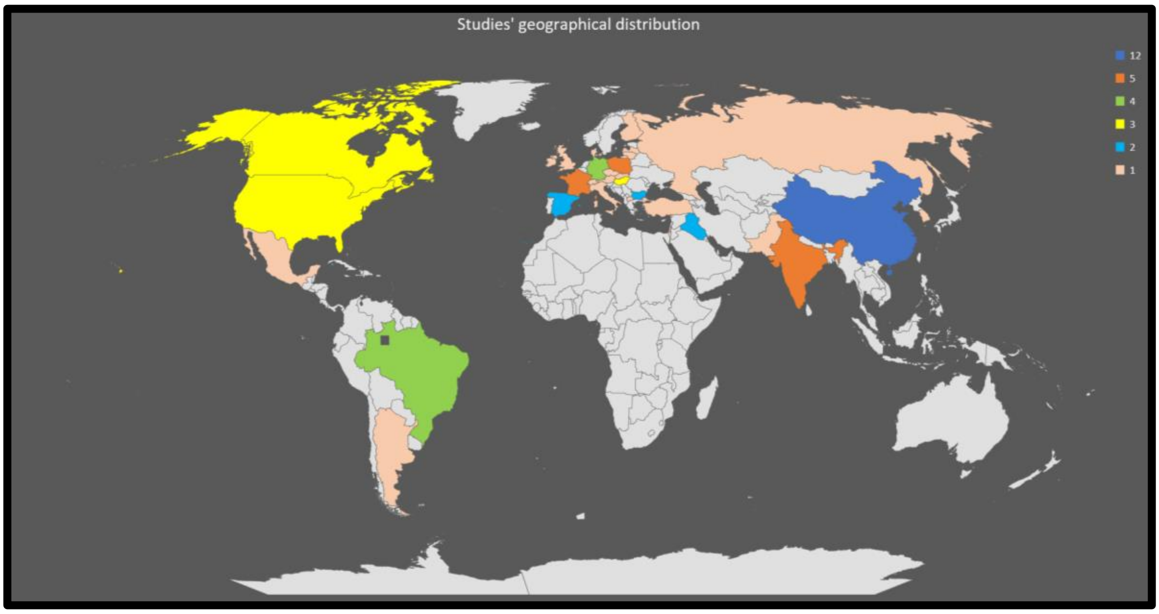
It is interesting to notice how China and India, both countries with big cultural-philosophical vitalist influences (GLUMEN, 2009) are two of the countries with more publications on vitality in agriculture. It is also noticeable that France, Germany, Poland and Brazil identified here also as main publishers on vitality in agriculture, are listed on the top 15 countries which have experienced increment on their areas of biodynamic farming - a farming method heavily influenced by vitalist and anthroposophical philosophies - in the last five years (PAULL and HENNING, 2020).

Figure 3 - Percentage of publications per country



Source: developed by the author (2022).

Figure 4 - Number of publications per country



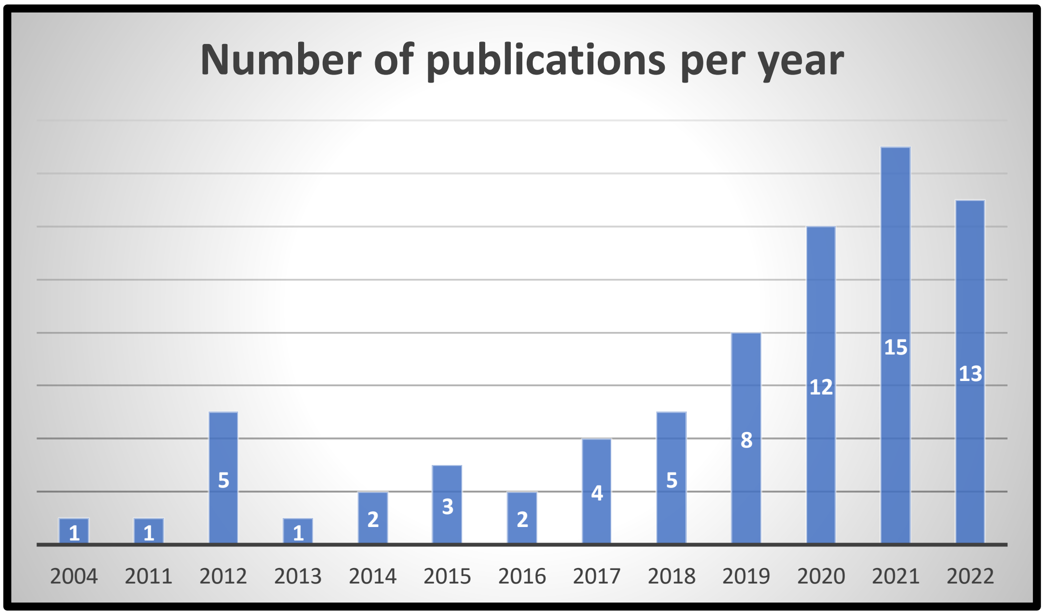
Source: developed by the author (2022).

Number of publications per year.

There has been a significant increase in the number of publications addressing vitality in agriculture, particularly from 2017 onwards (figure 11). The first publication identified in the period analysed (2002 to 2022) was from 2004 and, from that period until 2016 the number of publications were less than five per year. However, from 2017 a significative growth of 79.72% in the number of publications was experienced in the period, reaching a peak of 15 publications addressing vitality in agriculture.

The growth in the number of publications on vitality in agriculture could be related to a general growth on the number of research done on agroecological farming across the globe (PRETTY et al., 2018; TITTONELL et al., 2020). This growth in publications on agroecology is stimulated by an ever-growing interest on agroecological farming and organic food consumption due to the benefits that this farming method and food can offer to people (LIMA et al.,2020).

Figure 5 - Publications addressing vitality in agriculture from 2002 to 2022.



Source: developed by the author (2022).

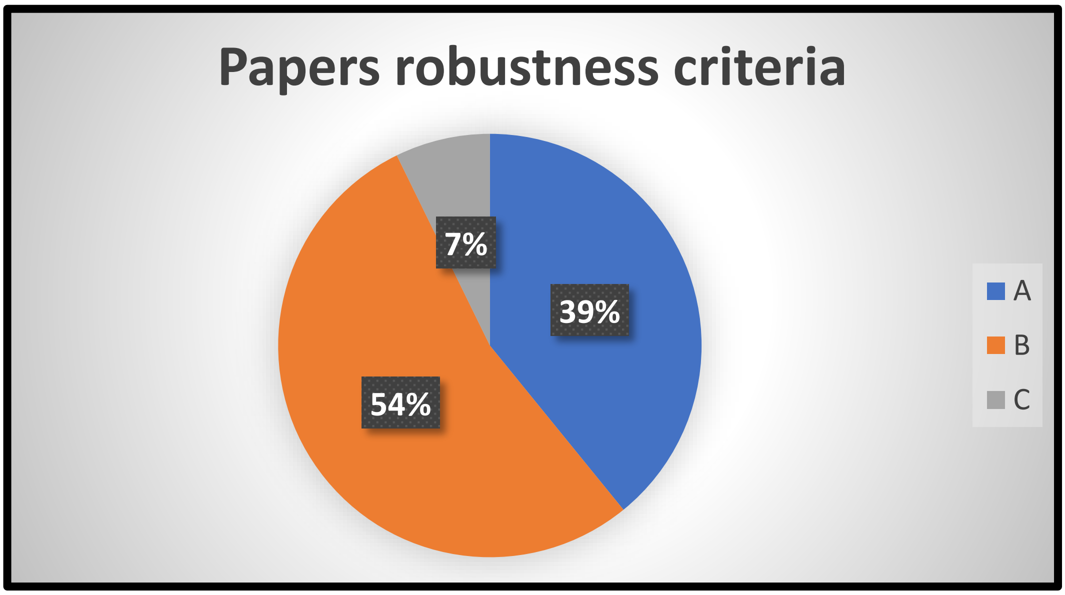
Papers' robustness

After analysing the papers for their robustness (figure 12), it was possible to assess that 54% of the papers were classified as "B", meaning that most of the robustness criteria were achieved. The main reason for this classification was that most of the empirical studies had only one repetition of their trials. As seen in the table 3, most of the papers yielded for this review were empirical studies, therefore explaining the bigger number of "B" studies.

On the other hand, over 39% of the papers were classified as "A" meaning that all the robustness criteria were achieved. Most of this percentage is made of papers addressing plant vitality and crop vitality and is complemented by robust literature reviews on ecosystem vitality.

Only 7% of the papers were classified as "C" meaning that more than one the robustness criteria were not successfully addressed. In this case, the literature review papers were the main causes for this classification. The reason for that is because even though the there was a clear problematization described, the results and outcomes presented slightly diverged from the initial problematization, thus making the papers' conclusions and outcomes vague.

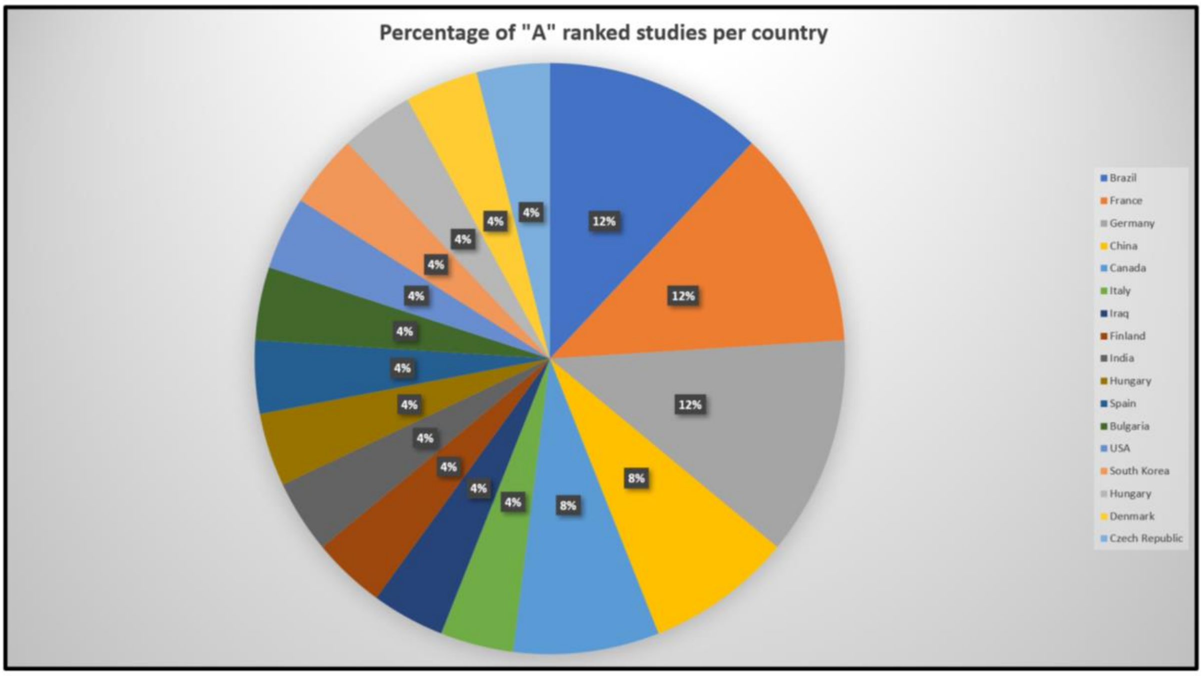
Figure 6 - Percentage of studies according to robustness criteria



Source: developed by the author (2022).

The figure 13 illustrates the cross correlation between the geographical spread with the robustness. The biggest percentage of the papers ranked as "A" comes from Brazil, France and Germany, followed by Canada and China.

Figure 7 - Countries with “A” ranked publications in vitality in agriculture



Source: develped by the author (2022).

Examining terms and selecting parameters

As part of the narrative method to explore systematic review results (KORICHEVA et al. 2013), I examined data from the papers selected for the final analyses, looking into the terms and definitions. In this way I could better comprehend how the phenomenon of vitality in agriculture and put it into context to contrast this information with further data collected from the other methods.

Vitality in agriculture: a plurality of definitions for a multifaceted phenomenon

It was intriguing to find out how vitality has been addressed and measured in agriculture, albeit not to a great extent based on the number of papers reviewed. The discussions on vitality orbit around biological and social effects. In general, the results elucidated different sets of characteristics, that each express an optimum state of existence or manifestation, no matter whether for a biological system (seed, plant, animal or ecosystem) or a community. This optimum/harmonious positive feature could only be comprehended if described in terms of vitality, due to the meaning that the term implies. Here I'll discuss the data going from micro to macro definitions of vitality.

Cell vitality

Huang et al (2022), use the term cell vitality to describe the capacity of cells to multiply and perform their metabolic functions appropriately. The authors use metagenomics, metatranscriptomics and gene sequencings, to understand bacterial metabolic activity, and when referencing the optimal development and activity of the bacteria studied (*A. pasteurianus, L. acetotolerans, L. helveticus, Ac. Jinshanensis),* they did so use the concept of cell vitality.

In contrast, Teixeira et al (2020), argue that cell vitality means the capacity of the cell to perform its physiological functions which is a property maintained by the vitality or vital force of the cell. This was the only paper that used a metaphysical background to relate the biological cell functions. The authors suggest that the vital force is intrinsically linked to the genome structure and manifestation:

> "*The vital force and the genome are the fundamental substrates for the emergence and maintenance of life, vitality of living beings; the vital principle is responsible for maintaining the balance of the body's sensations and functions, just as the genome stores the biochemical information which will produce the proteins responsible for maintaining vital processes and developing organisms; diseases generally occur due to dystonia of the vital principle, as well as genomic changes which promote disease; the vital force and the genome are both affected by the influences of the same external and internal etiopathogenic factors, among others…the vitality here is expressed in the telomeres and telomerase process*" (TEIXEIRA et al, 2020, p 4).

In this case, vitality is addressed as a force that manifest itself through the physiological cell function and the activity of the telomerase enzymes may be used as a biomarker of the organic vital force state due to functional physiological. The authors base their argument is on the findings of research by Blackburn et al (2009) who received a Nobel Prize for finding that telomeres and the telomerase enzyme are responsible for the chromosomic and genetic information integrity.

Finally, the authors explain their analogies:

> "*We highlight that the vital force and chromosomes are the substrates for maintaining the phenomenon of life, and the integrity of the organic vital force and the chromosomal endings (telomeres) are responsible for cellular vitality, longevity and*

maintenance, whilst cellular senescence, biological aging and the disease process result from vital imbalance and alteration in telomeres (TEIXEIRA et al., 2020, p 8).

In this hypothetical context, the telomeres would reveal the organic vital force state.

Organism vitality

Polcyn et al (2019), used arbuscular mycorrhiza to help maize plants to overcome drought impacts. For the authors, the organism vitality will be reflected in the organism's resilience in the face of stress and also by the bonding relationships created by the crop with its surroundings and in this particular case, establishing symbiotic connections. The authors relate organism vitality to chlorophyll content, nutritional concentration of leaves, photosynthetic and transpiration capacity, and crop senescence.

The authors conclude that ecological dynamics such as symbiotic associations are fundamental for plants to make better use of nutrients and water. It's possible to relate the organism vitality to other reviewed terms such as plant vitality, ecosystem vitality, seed vitality and others. Organism vitality is interconnected here to resilience, growth and development.

Seed vitality

Several authors used the term seed vitality. In common, all these authors used the term to describe the seed germination time, seedling growth, morphogenetic features (development of shape and structures), stress resistance and its capacity to become a full established seedling. As highlighted by the authors, this latter phase is critical because the seed is vulnerable to environment stress. Other than that, according to all the authors, seed vitality expresses the life potential of that seed to become a mature productive plant. All studies use cereals (maize, sorghum wheat, barley or oats) in their studies.

The approach to measure seed vitality varies though. Shihab and colleagues (2020) studied the influence of gibberellic and salicylic acids in seed vitality. These authors use a seed vitality index (composed of germination rate and speed, seedling root and first leaf length, shape and development of seedling). They verify a positive influence on germination and seedling development through seed treated with gibberellic and salicylic acids. Similarly, Bláha et al (2013) use a seed vitality index to study cereals (wheat, barley and oats) from organic and conventional origins. They couldn't verify differences in the seed vitality index between the two origins. According to them, the use of a seed vitality index is considered common practice in agriculture, but often the results are reported in terms of vigour rather than vitality.

A different approach is taken by Pang et al (2020) who use hyperspectral image techniques to estimate maize seed vitality: the image technique was efficient to predict germination rates in a short time (3 hours when compared to traditional seed germination tests of 72hrs to one week), but the system was not able to assess seed resilience against stress and others. However, the costs of the software and use of deep learning programmes were higher when compared to germination chambers commonly used to perform those estimations. Al-Dawoodi and colleagues (2022) study the effects of storage time (1,3,5 years) on sorghum seed vitality and used nanoparticles of iron (0, 100, 200 and 300 mg $^{L-1}$) to stimulate seed germination. Their results demonstrate that seeds stored for one year and treated with nano-iron at 300 mg L-1 had higher germination rates, radicle length, plumule length and fresh and dry weight of seedling.

A slightly different route is taken by Ciacka et al (2020), who review the influence of aging on seed vitality, adapting the free radical theory of aging (documented for animals) to seeds. The authors explain that reactive nitrogen species (RNS) participates in metabolic process such as protein modification (posttranslational protein modifications) and modulation of reactive oxygen species metabolism, which are involved in physiological processes in plants, including seed formation, maturation, dormancy, and germination. Here, the authors argue that assessing seed vitality by means of RNS would be interesting, particularly on seedbanks and warehouses because the method allows a close correlation with seed lifespan (typical length of time that a seed survives) and longevity (length of time that seeds can remain viable) and that the use of nitric oxide (NO) could be used as a means to mitigate the negative aging effects over seed lifespan and longevity. Despite the potential, the authors make clear that their proposal should be investigated further.

Rhizome vitality

This term was cited by one paper Zsiláne-André et al (2019) study the influence of effects of six pre-storage rhizome treatments on *Canna × generalis.* The authors select bud numbers, disease incidence of rhizome, number of sprouted plants, leaf numbers and plant height as rhizome parameters. Similarities can be observed with the studies addressing plant vitality.

Seedling vitality

Nasim et al (2019), used the term to describe survival rate of grape seedlings. The authors used molecular information to evaluate viability and survival rate of dormant seedlings before transplanting. Their focus is to correlate the expression of housekeeping genes (HKGs) which are typically constitutive genes, known as plant, live related genes, required for the maintenance of cellular functions, expressed in all cells of an organism for cellular survival (cell wall structure and primary metabolism). The results reveal that HKGs expression indicates *vitality and survival of plants, and* a lower expression is associated with lower vitality and survival rate. They also concluded that the DNA and RNA quality can superficially determine seedling qualities.

When contrasting this data with the that on cell vitality, it’s possible to discern the theoretical correlation between gene expression and vitality. The authors even state that the genes are known as ‘plant life related genes’ – genes associated with life force. However, the authors prefer to discuss the cell’s natural expression.

Pollen vitality

Radice and colleagues (2018) studied flower development and pollen vitality in *Moringa oleifera* cultivated in a temperate climate. The authors looked at flower morphology and anatomy (number of flowers and flower structures), as well as microsporogenesis and viability of pollen grains, using fluorescent and light microscopy to collect data. They observed that cold temperatures influenced the number of flowers produced as well as their structure. Pollen vitality was associated by these authors with the maintenance of fertilization levels, or in other words, the capacity to become fruit.

Root vitality

Two papers used the term root vitality. Zhu et al (2018) developed a study with soy, and Cseresnyès et al (2018) with maize. Both papers referred to root vitality as comprising root morphologic characteristics (growth, root length, surface) and root system colonization by microorganisms, however Cseresnyès et al (2018) simultaneously measured leaf chlorophyl content and stomatal activity. Both authors argue that root morphology and physiological activity directly influence the absorption area and capacity of the root for water and nutrient absorption. This set of characteristics are seen as indicators of root vitality.

Moreover, both studies verified that the presence and abundance of microorganisms are essential for plants to overcome environmental stress, absorb water and nutrients at a more efficient rate.

Plant vitality

The studies using the concept of plant vitality were the most numerously identified in the systematic having the 75% of the papers were classified as robust ("A"). Overall, the studies recognized an association linking plant vitality to plant growth, canopy development, ecological structures and crop health.

Gräf et al (2022) studied the use of greywater (domestic water without urine and faeces) in comparison to municipal tap water to irrigate sycamore (*Acer pseudoplatanus*) and small leaf lime (*Tilia cordata*). The authors assessed plant vitality, measuring plant growth, including leaf area, number of leaves, average leaf area and annual growth. Also, the chlorophyll content was determined using both *SPAD* measurement and image analysis aiming to identify necrotic leaf parts. The results revealed that grey water had a negative effect on the plant's growth boosting leaf necrosis. İşçi et al (2019) also evaluated the effect of water (hot water treatment) on dormant cuttings of *Vitis vinifera* rootstocks. They observed that hot water significantly helped to break the dormancy of the cuttings faster than normal temperature water. For them, plant vitality was expressed as the quality of root development and health of these cuttings.

He and his collaborators (2022) studied the potential of mapping crop areas using fractional green canopy cover (FGCC) assessment of management practices designed to promote crop productivity whilst maintaining environmental sustainability. The mapping method (FGCC) measured the canopy development, light interception, and evapotranspiration of corn fields. The authors argue that FGCC was able to measure the influence of the management used during that season. Here, plant vitality is associated with plant development and the plant-soil relationship.

Malk and colleagues (2021) reviewed biostimulant uses in agriculture. The authors explored how biostimulants, for example plant-based, fulvic and humic acids and others, stimulate a series of metabolic and biological responses in plants rather than specifically focusing on solving one issue such as disease or abiotic stress. According to the authors, biostimulants are essential tools to catapult agriculture towards sustainability, reducing the use of chemical fertilizers and pesticides and ultimately, promoting crop resilient plants and better use and assimilation of nutrients.

A similar approach was used by Kocira and colleagues (2018) who evaluated the effect of plant extracts (40 different plants) on germination capacity and surface contamination of spring barley. They found that plant extracts (particularly *Marrubium vulgare*) enhanced germination and diminished the seedlings' contamination by harmful microorganisms. They conclude that the plant vitality (vitality and healthiness) of grains were enhanced.

Ogar et al (2015) studied the extent to which the inoculation of microorganisms (arbuscular mycorrhizal fungi and N fixing bacteria) could help plants (they used *H. pilosella* L. and *M. sativa* L as plant models) to overcome environmental stress conditions (soil contaminated with Pb and Zn). They described plant vitality as the capacity of plants to overcome such environment stresses and still have the capacity to develop. The authors used a plant performance index to express plant vitality. Such an index was composed of leaf chlorophyl content, biomass (root and aerial part dry mass) and root colonization by the inoculated microorganisms. They concluded that microorganism inoculation (bioremediation) can help plants to overcome soil contamination.

Boroviona et al (2012) included the pathosystem dynamic (incidence x severity) into their interpretation of plant vitality, and for these authors, plant vitality was expressed as the resistance and susceptibility of the apple trees n being attacked by apple tree complex disease. Rawat et al (2014) associated plant vitality with the plant's composition and the potential benefits they can bring to human health.

Further, Cekstere and colleagues (2021) considered the relationship between yield and fruit quality in tomatoes as a representation of plant vitality.

Sugár et all (2019), also used the term plant vitality for measuring flag leaf chlorophyll content and vegetation index (leaf area) to estimate spelt wheat production. In the same way, Lindener et all (2017) used mapping and vegetation index (percentage of soil covered by plants, plants mosaic diversity and chlorophyll content) to express plant vitality.

Two reviews analyzed the issues of industrial agriculture and argued that this approach is responsible for diminishing plant vitality, meaning plant resilience, production, adaptability and its ecosystem role. Ashkenazi et al (2020) reviewed how the vitality of Bedouin orchards was promoted in arid areas. They describe how these people used complex management strategies of the land to mitigate climatic changes and promote environmental stability, while promoting the plant's vitality, pointing out the capacity of their fruit trees to thrive in arid areas.

Likewise, Gerber and Hiernaux (2022) criticize what they claim to be the current view of plants as machines, and how this conception has led mainstream agriculture to lose its connection to nature itself. The authors' claim that this conception based on rhetoric centred on breeding, biotechnology, and production separates man from his/her innermost and subjective connection to the land and how this understanding has legal and ethical consequences. Ultimately, the authors propose that new models of agriculture are needed, particularly ones that create different sets of values and relationship between, plant, man, and the environment they share. They argue that promoting plant vitality is to promote humankind vitality.

Crop vitality

The term crop vitality appeared in three papers. Synonymous with plant vitality, crop vitality for all the authors meant crop growth and development, canopy development, vegetation composition, crop diversity, and crop resilience in face of environmental stress. Liebisch et all (2014), attributed crop vitality to leaf chlorophyll, carotenoid, anthocyanin, and water content, leaf greenness, biomass, and leaf area index. In addition, the authors propose the use of the Airborne Prism Experiment (APEX) imaging spectrometer to measure the growth and vitality status. According to them, this tool could help to enhance resource efficiency in agriculture.

Del Mar Algucil and collaborators (2012) linked crop vitality to resilience and adaptation as the authors presented data of a 43-year study which looked in the influence of treated urban wastewater on the arbuscular mycorrhizal fungi, diversity of soil microbial activities and production of an orange orchard. The authors found that no negative effects were observed on crop vitality and productivity and that the ecosystem resilience influenced the selection of microorganism species present in the orchard.

Similarly, Taqdees and colleagues (2022) linked crop vitality to crop resilience. These authors investigated the potential use of biochar enriched with nanoparticles of Zn to solve soil salinity stress. The enriched biochar helped the seedlings of radish to overcome this stress. The authors associated their results with support for natural crop vitality which they measured by means of plant fresh weight, germination and concentration of biochemical parameters.

Soil vitality

Three papers used the term soil vitality. These authors (Gagnarli et al, 2021; Wang et al, 2022; Song et al, 2022) indicated soil vitality as being associated with soil quality and functionality, biological diversity indicators (plant and microorganisms), management strategies (soil cover, mulching, cover crops), physical structure and nutritional soil profile. Moreover, the authors point to this set of characteristics as being key factors in reducing soil – physical, biological, and functional- degradation. They suggest that soil vitality could be achieved by agricultural practices as well as use of bioremediation (using plant and other amendments).

Soil vitality is also considered to be a key concept when taking actions around climate change. The authors argued that land management focusing on soil quality and functionality are essential for C sequestration, water maintenance and production of high-quality food and enhancement of biodiversity. They criticize the simplification of the agroecosystem as being the strongest driving force causing soil degradation.

Gagnarli et al (2021) used an index called LUC (land use change) to assess soil vitality in vineyards. The authors were able to monitor soil biodiversity (for 2 years) which enabled the detection of biodiversity hot spots, as well as areas susceptible to changes, helping to accomplish successful ecosystem management. Whereas, Wang and colleagues (2022), studied soil phytoremediation (white clover cover and mulching) and its effect over microbiology diversity and functionality in apple orchards. These authors used metagenomic analyses and biological techniques to measure microbiology activity. After 14 years, they concluded that cover crop and mulching enhanced the soil biological diversity and functionality, having as a consequence stable soil, more resilient and productive apple trees.

Very similar was the work of Song et al (2022), who looked on how exogenous substances such as river sediment, lake sediments, straw, algae, submerged plants, and livestock manure influenced soil properties. These authors analyzed changes of soil water soluble organic carbon (WSOC) and soil dissolved organic matter (SDOM) in the process using the above listed amendments. They observed that river sediment and straw, algae, livestock manure can change the content of SDOM and WSOC in the soil, positively influence soil vitality, improving the structure, composition, and quality of the soil.

Animal vitality

Five studies used the term animal vitality, comprised research with piglets, hens, calves, lambs and marine hydroids (*Hydractinia echinate)*. Regardless the kind of animal studied, animal vitality was taken to mean survival rates, or number of animals that survived or completed their development to the next stage of the production chain. All the studies used a survival/vitality index (that resembles the one used for seed vitality) adapted to each animal category.

Tschink at al., (2021), studied the population dynamics of *Hydractinia echinate*, a marine organism, aiming to understand possible impacts of warming climate and the rising seawater temperatures on marine ecosystems. The authors counted the *Hydractinia echinate* colonies via morphometric analyses (number of organisms and shape of colonies) as indicators for individual growth performance. The authors demonstrated that ocean warming may have major impacts on biodiversity and ecosystem function, explaining:

> "*We currently lack a mechanistic framework for integrating the effects of multiple interacting physiological functions on the vitality and growth performance of marine invertebrates" (2021,p 12)*

Condon et al (2021) investigated genetic and non-genetic factors associated with health and vitality on calves. The authors collected data of health (number of suspected calves having Scur (incompletely developed horn) and pneumonia, where 0 = no occurrence, 1 = one occurrence, or 2 = more than one occurrence) and the birth rate (which was scored on a scale where 1= very small and 5= very large). There was no discussion regarding implications of such vitality parameters, but on the other hand, in this study, vitality was correlated to the capacity of the calves for not having a disease and also for the size they were born. At the end, the authors verified a positive correlation between size and the incidence of disease – bigger calves (vigorous) were less likely to succumb to Scur or pneumonia.

Comparably, De Sousa et al., (2022), analyzed the birth rate in lambs' survival but this time, in the postpartum period (up to 72 hours), while Schild and colleagues (2020) evaluated neonatal piglets' mortality (up to 72 hours) in outdoor organic production. Both studies used similar birth indices that considered how long the animals lived until they overreached a critical period but also, qualitatively described the animal. Finally, Grezilov et al (2015) studied the effect of herbal mixture supplemented to chickens (form hatching to 52 weeks of age). The authors here correlated animal vitality to growth performance, egg production and overall health conditions. The authors confirmed benefits of herbal blends in the treated fowls, improving egg productivity, vitality and health.

The studies that used the term animal vitality basically made a connection between survival rates and animal growth. Production was the focus of interpretation for those data sets, with exception with the study of the marine ecosystem dynamic. Vitality and health are considered as different but interconnected terms.

Colony vitality

Four papers used the term colony vitality as main core of their studies and, all of them were related to honeybee colonies. In common the papers explained in detail what vitality meant for the authors: life stimulation, biodiversity, ecosystem balance, production, interconnection man-nature.

Wintermantel and colleagues (2019) assessed how organic farming improved the vitality of honeybees' colonies, even in periods when the landscape has less abundance of flowers. Based on a study of six years, the authors provide data showing how industrial agriculture is directly linked to the reduction of pollinator diversity, hence decreasing the life of the agroecosystem itself. On the other hand, organic farming increased honeybee colony performance, colony survival and vitality, enhancing life manifestation. Wegener et al (2016) confirmed this negative effect of pesticides on the colony vitality, identifying the most dangerous pesticides to beehives. Judova et all (2016) assessed the impacts of electromagnetic emissions, the reduction of flowering period due to expansion of monocultures and confirmed negative effects on the dynamic of the honeybee hive.

Ecosystem vitality

This term was one of the most used and definitions varied amongst the authors. Sheldon (2020) used the term to make a series of connections between ontologies, respect for the environment and how these ontologies influence the conceptions of human and environmental health. This author argues that ecosystem vitality comes from the traditional indigenous views, in which a vital force underpins all physical manifestations of health and harmony both for the land and for humans. He makes his case using as an example the traditional native knowledge from India which linked vitality with prana, the Sanskrit word for ‘life force”.

He later explains how ecological vitality is a concept that advocates for environmentalism awareness, bonding people, food, and their environment. At the same time, this perspective allows phenomenological critiques of the Cartesian model of embodiment. The author makes the case that what he calls naturalistic philosophy that allows for an applied integration of biology, ecology, and cosmology. The consequence of such ideas allows processes that enhance the ecosystem's natural way of healing itself, potentially bringing about moral change in the population.

By linking vital force with naturalistic concepts of human health to its food and environment, Sheldon (2020) claims that searching for vitality solidifies the vision of the human-nature context and, that such a view can influence political decisions. He again gives the example of the Indian government which has been supporting holistic and complementary forms of treatments for humans rather than an exclusively western approach to health, and that this attitude held a liberating potential to oppose colonial rule and concomitant forms of western-mind intervention in agriculture.

The work of Oksanen and Kontunen-Soppela (2021) argues that vitality of the ecosystem is expressed with the overall potential of plants to develop and produce food. They highlight that those plants use different strategies to overcome environmental stress, such as air pollution which can influence the vitality of the ecosystem. The authors described how air pollution (full of heavy metals and other substances) causes oxidative stress in plants, impacting growth, photosynthesis, crop production, nutritional value, compromising the ecosystem functionality posing a threat to food production. In this sense the authors suggest that, to maintain ecosystem functionality or vitality, a diversity of plants species should be planted in urban spaces. Such variety would offer a rich source for air pollutant mitigation through their canopies in areas suffering from mixtures of air pollutants. Ecosystem vitality therefore is linked to biodiversity and ecosystem services.

Liu et al (2020) undertook an empirical field test evaluating ecosystem services of a rice-fish co-culture system as an alternative for the monoculture of rice paddy. They did so using an ecosystem service (ES) index based on the Millennium Ecosystem Assessment and Ecosystem Functions. For these authors, ecosystem vitality was expressed via a series of components: regulation of physical, chemical, and biological conditions; protection from farmland erosion; air purification; improvement of environment; development of tourism; physical and intellectual benefits and spiritual, symbolic, other interactions. All of these items are part of the ES index used. Liu et al (2020) argue that ES valuation is a useful technique that can foment interdisciplinary and holistic environmental decision-making by linking policy decisions to human benefits. It is suggested that each component of the ecosystem is interrelated and influenced by the other components – expressing an overall vitality.

A slightly different approach is taken by Caka (2020) when using ecosystem vitality. To this author, ecosystem vitality could be seen as synonyms to sustainable development goals in agriculture. The author expands his perspective:

> "*Sustainable food and agriculture have great potential in addressing hunger, poverty and sustainability issues through the provision of affordable and nutritious food, strengthening of livelihoods, promotion of inclusive growth, revitalization of rural and urban landscapes, and improvement of environmental performance structuring an ecosystem vitality" (2020, p 26)*

The authors concludes that a *holistic and systemic approach* towards strengthening the urban, peri-urban and rural is needed by integrating ecosystems preserving and restoring the natural capital and promoting ecosystem vitality.

Peng et al (2017) uses ecosystem vitality as an equivalent of ecosystem health. To express vitality or health, the authors used quantitative ecosystem indicators to support their equivalence. The authors explore data from the use of normalized difference vegetation index (NDVI), landscape metrics, and ecosystem elasticity coefficient based on different land use types as quantitative indicators and later complementing these indicators with the coefficient of spatial neighbouring effect which characterizes the adjacency effect on ecosystem services that ultimately generates the index of integrated ecosystem health and vitality.

According to the authors: Promoting health means the integration of natural, social aspects involved in the land use. For the plants the vigour, metabolism or primary productivity are good parameters. Therefore, an integrated healthy ecosystem should focus on the ecosystem homeostasis, stimulating biodiversity.

If on the one hand, the authors offer a series of well explained ecological indicators to characterize their conception of health, on the other hand vitality is not described, but rather quoted as the overall umbrella term to connect all the nuances explored, including health.

Robert and colleagues (2012) argue that ecosystem vitality means agrobiodiversity and the conservation of the cultural and biological process, that agrobiodiversity practices are inseparable from the production and transmission of values and knowledge associated with cultivated plants. This interesting research developed by Brazil and France in the Amazon region, explores the agricultural method of the Mebêngôkre-Kayapó (traditional indigenous and non-indigenous people), using research methods combining anthropology, geography, agronomy and ethnobotany. Agrobiodiversity is analysed observing the organization through space and time, focusing in the number of the species and varieties cultivated.

Their results demonstrated that a vast number of plants (more than 400) continues to be cultivated despite the external influences promoted by big companies working in the region, confirming the vitality of the indigenous knowledge associated to agrobiodiversity enhancing the agricultural heritage. The authors highlight that this knowledge plays a significant role in forest conservation. A quote from one of the Mebêngôkre-Kayapó states:

> *"The diversity of cultivated plants means more beauty; it means the life force".*
> *(2012,p 20)*

In this paper the results show that the construction of agrobiodiversity is linked with extensive social networks; and that the vitality of the agroecosystems is the beauty of the plots as manifested by the diversity of plants that it shelters because it reflects exchanges of knowledge, food, and objects.

Similarly, the impact of diversified agroecosystems is investigated by Doanah et all (2020). The authors examined the impact of the Association of Southeast Asian

Nations (ASEAN) on ecosystem vitality (EV), from 2007 to 2016 in Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam.

The authors found a positive correlation between the quality of ecosystem vitality and the volume of agricultural exports. They claim that such positive association is found when applying the Ecosystem Vitality index. They explained ecosystem vitality as complex multi-faceted universe that reflects ecosystem health and each country's natural resource management. The EV is measured via six elements: I) water resources; indicate the proportion of wastewater treated in each country; II) agriculture; indicates the excessive nitrogen fertilizer use. III) forests; considers habitat preservation, climate change mitigation. IV) fisheries; reflects the sustainability of fishing activities. V) biodiversity and habitat; assesses the preservation of essential elements of biodiversity whilst maintaining associated ecosystem services. VI) climate change, and energy; reflect the ability of countries to reduce the number of carbon emissions per unit GDP and kWh electricity generation.

The main contribution of this paper is its attempt to embrace the complexity of factors that might reflect ecosystem vitality. Because of the diversified nature of ecosystem vitality (EV), environmental impacts on agricultural production and exports go beyond CO2 emissions to include biodiversity and habitats, irrigation and water sources, fertilizer discharges, and marine biological environments.

Here, vitality is associated with complexity and holistic analyses in the sense of multidisciplinary approaches to understand it.

Ecosystem vitality was also used in two studies related to water management. De Jonge et all (2019) reviewed the concepts of the marine environment in relation to subsets of food webs to assess the functionality of the marine ecosystem. Whereas Sonwane and colleagues (2020) focused on automatization of water systems and quality to rice irrigation systems. However, neither of the studies explores the concepts of ecosystem vitality, instead using the term to describe the overall welfare condition of the studied system.

Roy and colleagues (2020) also investigate the correlation of water and the ecosystem. However, these authors review the influence of ecosystem services and diversified livelihoods and how human activity has been compromising this relationship, particularly in wetlands areas in India, where the negative impacts of the current agriculture model are seen. Different from the other water related studies, this one explains the authors' view on ecosystem vitality, referring to it in terms of *synergetic agroecosystem practices* that ultimately lead to homeostasis.

Again, it's possible to grasp an understanding of vitality as a force or condition related to harmony and equilibrium.

Finally, Mehla and Kumari (2012) explore the benefits of organic agriculture for health and sustainability. Throughout this review the authors present a series of data sets on how organic farming has helped in the livelihood of farmers. The benefits were perceived in their income, in the restoration of their soil fertility, the return of pollinators and the reduction of disease amongst the farmers.

Here it is possible to observe that the authors make a slight differentiation between health and vitality, the former being a consequence of the latter.

Rural vitality

Carvalho and colleagues (2012) used the term rural vitality to address the human composition of the system - the quality of life of rural workers of the sugar cane crop. The authors conducted a field study with 340 workers for three crop seasons, evaluating the health index. This index is composed of functional capacity (FC), physical aspects (PA), pain (P), general health (GSH), vitality (VIT – liveness), Social Aspects (SA), emotional aspects, (EA) and mental health (MH).

They found that most of the time the health index was reduced, meaning "a reduction in the health index, diminishing workers vitality". Here the authors clearly mean that the quality of life of those rural workers was compromised.

Vidickiene and Gedminaite-Raudone (2019), used a similar approach. In this case the authors links rural vitality to quality of life. The authors explore the potentialities of the 'servitization initiative' that means to "rent a piece of garden in rural areas". This strategy focuses on engaging new rural people to old rural people in order to create new business models as well as promoting awareness of the importance of the agricultural sector in transition from a product-driven business model to service-driven business model. This platform-based networking would also be used as a way to tackle the problem of ageing society and the decreased numbers of rural populations.

Community vitality

Two papers approached vitality and extrapolated its definition towards community – community vitality. The authors used surveys and interviews to understand the impacts of agriculture and how it was perceived by their study communities. Goldberger (2011) focused on organic farmers and how they perceive their operations contributing to sustainable agriculture goals. According to the author, farmers said that their main contributions were related to environment, civil engagement (including community service, political activism, volunteering, and group membership) and economic benefits.

Robitaille et al (2022) studied the impacts of local food production on the wellbeing of communities. They were able to identify all the components involved on local food production and commercialization are determinants to enhance the ability of health eating whilst promoting access to healthier food with better prices, encouraging economic development by stimulating corporativism, thus promoting community health and vitality.

Peasants' vitality

One paper extended the meaning of vitality towards peasants. Junya et al (2021) traces historical connections, elucidating transformations on the agricultural world and how the autonomy of the peasants influences its vitality, where Vitality is taken to mean autonomy. The authors explains that during the historical transformation that society faced, changing from agrarian to industrial, some sociological studies painted peasants as vulnerable, in the face of big business entities. What the authors demonstrate with demographic and socioeconomic data is that the peasants, mainly small family-farmers, are:

"*Fragile but unbreakable; weak but never slackening (Junya et al., 2021,p 13)*"

Economy vitality

Three papers linked vitality to an economic facet (Zhang et al., 2022; Russiana et al 2017; Wòjcik 2020). In common, all of them focus on the sustainable development agricultural economy. They have focused on combining social and economic benefits as the way to reframe public policies, rural credit, and subsidies.

Strategies to develop shorter food supply chains that focus on the circular economy are suggested to enhance farmers' livelihoods.

Although important suggestions were made for sustainable economics, none of the papers approach vitality directly, but it was interesting to notice how the authors used the term to express the aliveness that new economic models can achieve.

Urban vitality

This term exemplifies how the term vitality express aliveness or a process towards life. The authors define urban vitality as elements of the built environment that generate urban spaces that attract the presence of people, street buoyancy and the combination of diverse activities. Gómez-Varo et al (2021) vitality and its relationship with food retailers and food services (one of the most essential everyday activities). Using spatial analyses, the authors verified that food dynamics (through food stores, restaurants, bars, community gardens, takeaway services) play a significant role in integrating citizens as well as promoting consciousness regarding social aspects associated wellness.

Finally, Demling (2018) proposes urban vitality as the capacity of city buildings to be active spots for food production (living walls), climate change (green roofs) and recreational spaces (communal gardens) as urban citizens create a closer connection with the land, mainly in times of virtual reality.

This term complements community vitality, even though using different methods to do so. But, in common, both terms encompass the integration of the human and its close interconnection with its local environment exploring how the quality of life could be improved. In this case, urban vitality relates to food, human interaction and how this makes the urban spaces alive.

Territorial vitality

Two papers used the term territorial vitality, both of them from France and focusing on sustainable livestock systems (Bedou et al 2017; Gourdine et al, 2021). Clustering their information, territorial vitality is associated with environmental conservation, development of sustainable food systems, valorization of cultural and territorial services, and strengthening of relationships between farmers and society. Also, items such as gastronomy heritage and cultural landscapes are key components of territorial vitality which ultimately contribute to create social bonds in the territories.

Different methods were used to comprehend this complex dynamic. Bedou and colleagues (2017) studied how cultural and territorial services influence agroecological transition in livestock. The authors interviewed key stakeholders and their questions were framed using Social Environmental Economic Goods and Services (SEEGS) indicators to analyze territorial vitality. For the authors, territorial vitality could be expressed via provisioning of services referring to food products, environmental services such as biodiversity maintenance, climate regulation, and water purification, cultural services such as recreational, esthetic, and heritage benefits and, rural community vitality and employment. Gourdine et al (2021) clustered indicators that would represent territorial vitality in provisioning services, ecological and socio-cultural aspects.

To conclude, territorial vitality is directly associated with the development of cultural services that could serve as prospects for the agroecological transition.

limitations of this systematic review

It's important to mention some limitations of this research. Firstly, I only looked for papers in English and in limited publication time frame (2002 – 2022). If in the one hand the time frame used yielded up-to-date literature, on the other hand older valuable papers could be left behind. The same applies for the language. It's true that most of the international papers are currently published in English, however many authors from non-English speaking countries certainly would have elaborated contributions in their own languages.

I also used only the search platform Scopus® for collecting the papers. I decided to so in order to minimize duplicated papers and to make the research agile. It's possible that different papers could be available using different searching platforms.

CONCLUSION

The objective of this systematic review was to identify and explore how vitality has been assessed in agricultural research. The systematic review reveled that vitality has been addressed in agriculture, sometimes through by metaphysical explanation but in most cases by a series of correlated terms that expressed vitality through biological and sociological manifestations.

Overall, around 21 scientific terms addressed vitality in agriculture were identified. Out of 2153 papers, 74 papers met the robustness criteria to be analyzed in this review. Around of 39% were ranked as “A” (all robustness criteria met), 54% were classified as “B” (one of the robustness criteria was missed) and 7% were ranked as “C” (more than one of the robustness criteria was missed). Brazil, France, Germany, China and Canada were the countries who had the biggest percentage of papers ranked as “A”. From the higher ranked (A) studies, the terms plant vitality (19%), ecosystem vitality (14%), seed vitality (9%) and crop vitality (7%) composed the biggest number of papers within that category.

There was a significative increment of 79.72% in the number of publications using the term vitality in agriculture since 2017. From this number, China (17%), India (7%), France (7%), Germany (6%), Poland (6%) and Brazil (6%) were the countries who had more publications.

After thoroughly analysis, parameters addressing vitality in agriculture were selected to be compared in the controlled trials: crop production, plant growth and development, dynamic of crop pest and diseases; fruit quality. These indicators were selected from “A” ranked studies exclusively. Individually, each of these indicators cover one aspect of vitality in agriculture. Together, they express the multifaceted aspects of vitality in agricultural experimentation, and ultimately can help to support the claim of homeopathic preparations (HDD) promoting crop vitality. Finally, the nuances concerning vitality manifestation will be combined with ones obtained from the other methods used in this study in the final analysis.

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