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Review

Sustainable Agriculture Through Agricultural Waste Management: A Comprehensive Review of Composting's Impact on Soil Health in Moroccan Agricultural Ecosystems

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Abstract: Agricultural activities generate substantial quantities of waste, which are often relegated to landfills or incineration. However, these residues can be effectively valorized through composting, which transforms them into valuable organic fertilizers (OF). Composting agricultural waste (AW) mitigates environmental impacts and offers significant benefits in enhancing soil fertility and productivity. This practice is particularly beneficial in regions with low soil fertility and degraded land, where compost can improve soil health and productivity. This review provides a comprehensive analysis of the literature on the valorization of AW through composting, focusing on its environmental, agricultural, and economic impacts on soil health, especially in Morocco's agricultural ecosystems. It synthesizes findings from studies published over the past two decades to offer critical insights and recommendations for optimizing composting practices. By systematically evaluating, this review highlights composting as a pivotal strategy for enhancing soil health, reducing environmental impact, and promoting sustainable AW management. Future research is essential to explore opportunities for optimizing the composting process, including content enhancement and processing duration. In summary, the composting process can be seen as an effective and sustainable solution that fits within the principles of circular economy (CE) and that requires careful evaluation and ongoing monitoring.

Keywords: agricultural residue; organic waste; soil fertility; soil health; waste management; circular economy; composting

1. Introduction

Global population growth, economic expansion, and increased food consumption have resulted in the generation of substantial quantities of organic waste (OW). The observed increase is due to the intensification of agricultural and livestock production systems, leading to a substantial rise in waste generation [1]. This surge necessitates the implementation of appropriate waste management (WM) practices to mitigate environmental risks, including releasing odorous gases, degrading soil health, and water resource pollution [2]. Previously, natural systems were believed to efficiently absorb and decompose waste from population centers, industries, and agriculture [3]. However, it is now clear that this assumption is incorrect, making proper waste treatment a necessity.

In 2017, global municipal solid waste generation reached around 2 billion tons, with OW accounting for around 30–50% of this total volume. Within this percentage, green waste (GW) accounts for around 11% of the total volume with an average per capita generation of 47 kg yearly, with a wide range between 1 and 336 kg per capita [4]. Projections indicate that the global population will reach 9.7 billion by 2050 and 10.4 billion by the mid-2080s, significantly amplifying the pressure on agricultural systems [5]. This increased pressure is expected to amplify the generation of AW, even as the availability of cultivable lands continues to decrease due to many factors such as soil fertility degradation and urbanization expansion [6].

Agriculture is among the largest producers of OW in Morocco due to the nature and quantity of residues generated [7,8]. Morocco's agricultural sector plays a crucial role in the country's economy, contributing around 15% of the national gross domestic product and serving as an important source of income for nearly 40.5% of the population [9]. This sector also dominates the landscape, accounting for over 80% of the total crop production areas [10]. Consequently, inappropriate disposal of the residues of these activities can adversely affect the environment and the population's health.

Effective management of agricultural soil is achievable through the adoption of sustainable practices, particularly by selecting appropriate methods such as the use of OF and the strategic handling of crop residues [11]. Unlike chemical fertilizers, OF offers a multifaceted approach to enhancing soil health by providing complex molecules and essential nutrients that benefit both plants and soil microorganisms [12,13].

The interaction between increasing population demands, declining arable lands, and rising waste generation highlights the pressing need for innovative and sustainable strategies in both WM and agricultural practices to ensure food security and environmental sustainability [14]. This urgency is further amplified by the pressing need to preserve soil health, particularly as it is a non-renewable resource threatened by the intensifying impact of climate change, which is pronounced in arid and semi-arid regions such as Morocco [15].

As an innovative approach, the CE significantly contributes to minimizing waste and reducing pressure on fragile ecosystems [16]. By promoting sustainable product design and optimizing production processes, the CE helps extend the useful life of materials and products at the end of their life cycle. Given the growing need for this approach, WM through composting is proving to be a key method in helping all the components of the environment from deterioration and restoring a new balance [17–19]. Composting offers multiple advantages for agricultural practices by not only reducing pathogen levels but also enhancing crop productivity and preserving soil health [13]. The synergistic benefits of composting lie in its ability to convert OW into a valuable resource, thereby mitigating the environmental impacts associated with waste disposal and contributing to enriching soil conditions [14].

Compost exhibits distinct characteristics that are largely influenced by its nutrient content, which is determined by the raw materials used for its production [20]. When compost is rich in nitrogen, it plays the role of an effective fertilizer to enhance soil fertility, while compost with low nutrient contents functions as a soil conditioner to improve overall soil health [2]. However, the performance of compost can vary depending on factors such as climate and soil type. For instance, elevated soil temperatures and moisture levels can influence key chemical processes, including ammonium volatilization and phosphorus sorption [21]. Consequently, the application rate of compost should be calibrated according to the specific characteristics of the soil to maximize its benefits and ensure effective soil management [22].

The research objectives are to (1) emphasize the importance of understanding composting processes, assessing compost quality, and recognizing the benefits of compost as a soil improver and OF in Morocco, and (2) highlight how compost can enhance soil fertility, structure, nutrient availability, and promote sustainable agricultural practices. This research aims to increase farmer awareness to optimize compost use and support sustainability in Moroccan agriculture.

2. Materials and Methods

Data Collection

The assessment of the evolution of the composting process is a complex procedure, requiring meticulous control of various key parameters to ensure the production of high-quality end products with an effective effect on soil and plants. To obtain an overview understanding of the composting process and its impact on agricultural soils, a collection of relevant publications was carried out using inclusion and exclusion criteria. The keywords selected as inclusion criteria included 'waste management', 'composting process', 'organic waste', 'agriculture waste', 'soil fertility', 'soil health', 'composting trends', 'carbon sequestration', 'stabilization', and 'maturation'. Particular emphasis was placed on articles indexed by reputable databases—Web of Science and Scopus. An exhaustive bibliographic search was carried out, covering studies written in English and whose full text was available online, published between 2004 and 2024, using renowned electronic databases such as Google Scholar, World Cat, Science Direct, Scopus, Web of Science, Springer, and Researchgate.

The search approach comprised two main phases. In the first phase, articles were screened for relevance to the study objective, followed by a selection based on keywords. The selected database was organized using an Excel sheet, thus eliminating duplicates.

3. Results and Discussion

3.1. Analysis of Bibliometric Data

The initial results of the search yielded a total of 120 articles from 26 different countries, including Morocco, Spain, Italy, the United States, Canada, Chile, Egypt, Turkey, Finland, Japan, Mexico, India, and China (Figure 1).

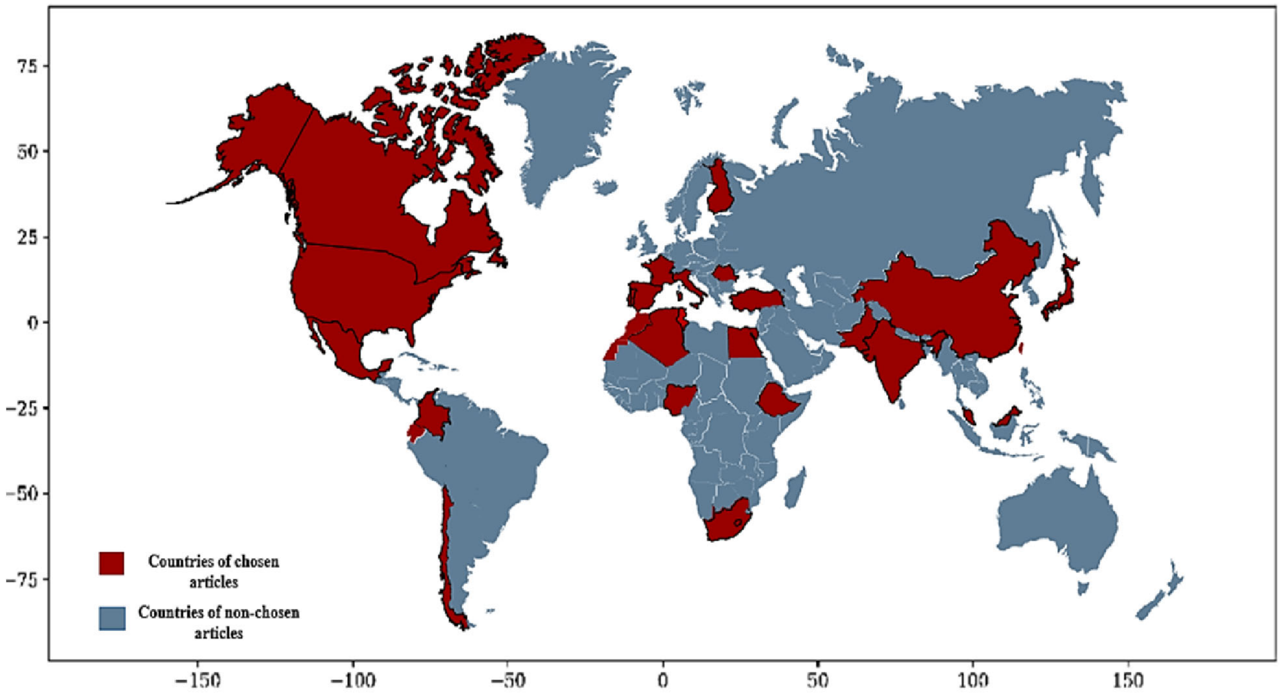

Figure 1. Spatial distribution of chosen publication on the topic of composting across the world.

The studies that aligned with the scope of the review were identified and listed in Table S1 of the Supplementary Material. This table includes information such as the year of publication, main idea, recommendations, countries, and references for each study.

The VOSviewer software version 1.6.20, developed by Leiden University in the Netherlands, was used to map and visualize the database. Using this software, the data collected were processed and bibliographic analysis techniques were used to construct visual maps.

Figure 2 shows a network visualization map representing the 35 most important keywords for this study.

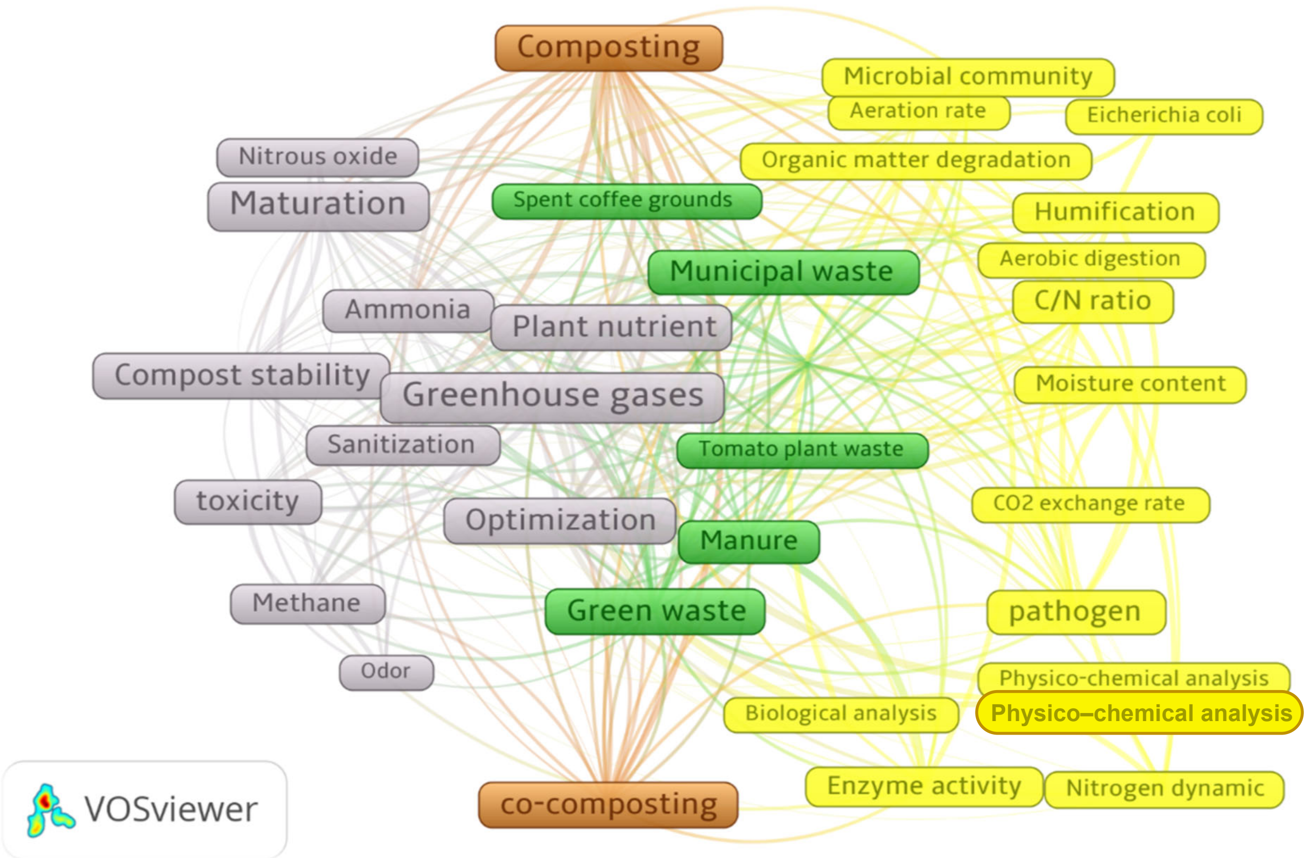

Figure 2. Visual network representation of keywords derived from VOSviewer analysis.

The size of each element on the map is determined by its weight, corresponding to its frequency and importance. Elements with higher weights are presented more prominently, while the color of a component indicates the group to which it belongs. Connecting lines between elements represent strong associations and interdependencies. By visualizing these connections and the importance of each element, we gain insights into the multifaceted nature of the composting process. This interconnected complexity underscores composting's reliance on multiple elements, illustrating the indicated dynamics contributing to its effectiveness and challenges.

In addition to the insightful keyword analysis, Figure 3 showcases a density visualization map that further emphasizes the significance of specific elements. Each point on the map is color-coded, denoting the density of elements at that specific location, ranging from shades of blue and green to hues of red and yellow. Points closer to the red and yellow spectrum indicate higher weights and a greater number of neighboring elements, while points closer to green and blue signify fewer elements in the vicinity. This visualization significantly underscores the importance of key aspects related to the composting process, composting objectives, monitoring parameters, and composting advantages, elucidating them as hot topics of discussion within the scope of this study.

To gain insights into the temporal dimension of research in composting management, Figure 4 presents a visually informative representation of the results, complemented by a color bar indicating the year of publication.

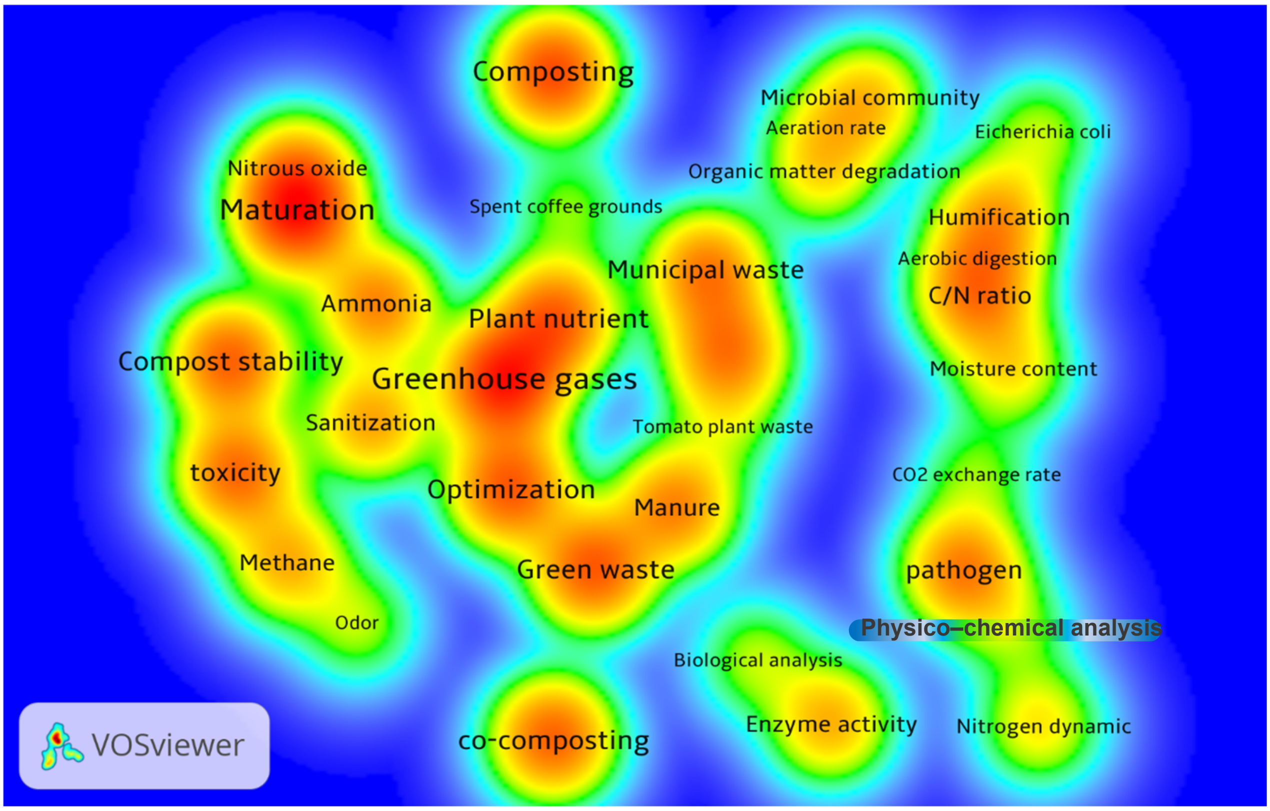

Figure 3. Density visualization map illustrating the distribution of keywords generated by VOSviewer.

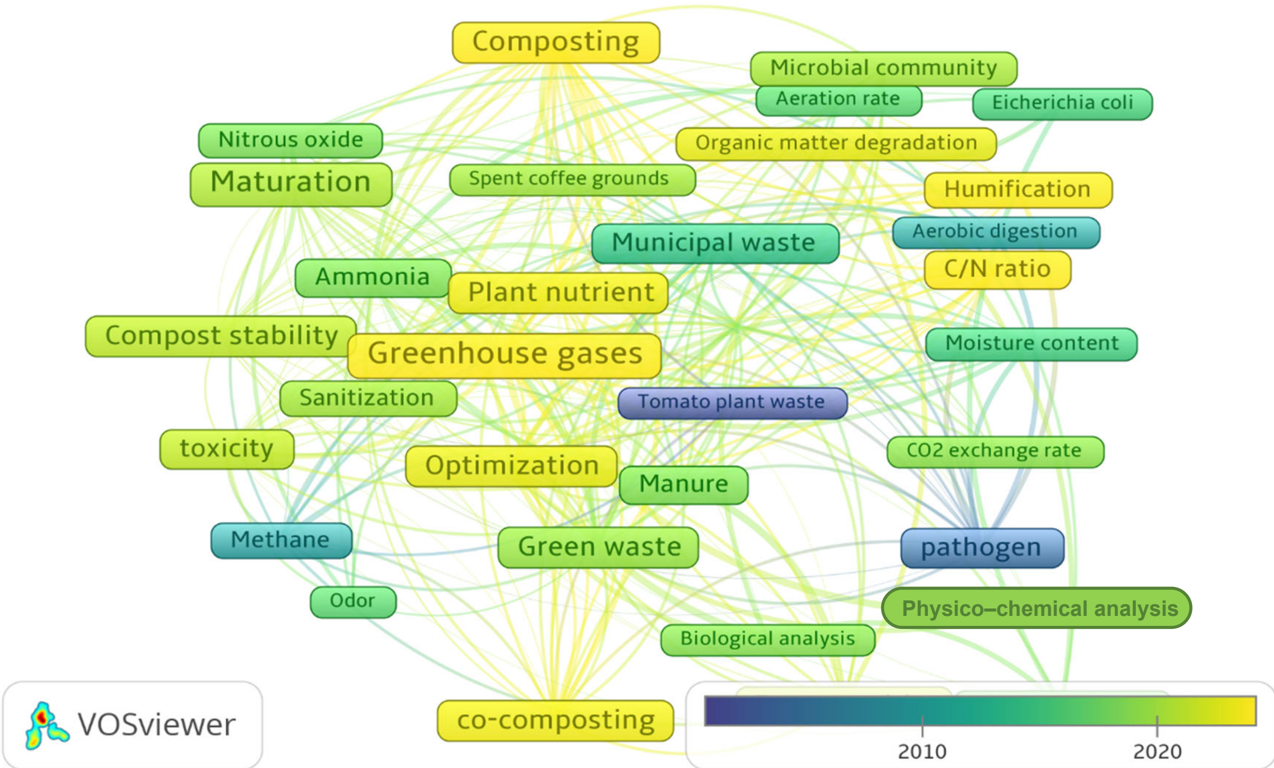

Figure 4. Visualization of temporal analysis of keyword patterns in VOSviewer.

The visual analysis of the data reveals that the majority of the identified keywords reflect the contemporary relevance and currency of research in this dynamic field. The data's visual analysis reflects the growing interest in composting as a sustainable practice, with research intensifying not only the optimization of composting processes but also comprehensively understanding its diverse benefits on environmental ecosystems. By employing these robust research methods and leveraging effective visualizations, a comprehensive understanding of the prevalent keywords, clusters, and emerging trends in composting management research has been attained. This trend showcases a shift towards recognizing composting's potential in advancing environmental sustainability, particularly through improved WM strategies and soil health enhancements.

Key findings from the bibliometric analysis indicate a steady increase in publications over recent decades, with notable contributions from countries such as China and India. Keyword co-occurrence mapping revealed emerging themes, including carbon sequestration facilitated by enzymatic functions, adding biochar to optimize composting parameters, and using inoculants and microbial mixtures to accelerate organic matter (OM) decomposition. Additional strategies identified include incorporating bulking agents, odor control mechanisms, and methods to reduce greenhouse gas (GHG) emissions, contributing to climate change mitigation.

Current trends focus on innovative strategies to enhance and optimize composting processes while mitigating climate change impacts, such as extracting specific nutrients and integrating renewable energy sources like solar power into composting systems. The interconnectedness of these topics underscores a comprehensive approach to improving composting technologies. However, despite this global progress, significant gaps persist in addressing the economic and socio–environmental dimensions of composting, particularly in semi-arid regions such as Morocco and other North African countries.

Through the use of these methodologies, an overview understanding of the research landscape and fundamental concepts related to composting technologies has been achieved.

3.2. Organic Waste

The OW refers to a specific subset of biodegradable waste that encompasses a range of materials from different sources such as agriculture and livestock [23]. The transformation process of these residues releases nutrients and contributes to the formation of humus-rich compost, which can be used as a soil amendment in agricultural and horticultural activities [24]. GW is a predominant type of OW that encompasses a variety of plant residues. They are distinguished by their relatively high lignocellulose content, comprising cellulose, hemicellulose, and lignin, which account for around 27% to 57% of dry matter [25]. The characteristics of GWs can vary according to factors such as season, climate, location, and maintenance and frequency strategies [4]. GWs decompose slowly in nature [26] and have a low density, ranging from 200 to 400 kg/m^3, which leads to higher collection and transportation costs [27]. Importantly, GWs contain low levels of heavy metals (HMs), making them suitable for safe recycling [28]. The green part of GW is more nutritious, containing three times more nutrients compared to the brown part [4]. In contrast, the brown part is around 90% lignocellulose with a higher lignin content, which hinders biodegradation and slows down the breakdown of hemicellulose and cellulose [29]. Recent studies have also highlighted the role of GW compost as an excellent source of humic substances [30].

Manure is another important component of OW. This material is a valuable resource, rich in OM, essential nutrients, and diverse microorganisms [31]. One of the main characteristics of manure is its high OM content, which contributes to the overall nutrient density of the material [32]. In addition, manure is known to be rich in nutrients such as nitrogen, phosphorus, and potassium, which are essential for plant growth and development [7,20].

3.3. Organic Waste Management

3.3.1. Composting Process

Proper management of OW is crucial to minimizing their environmental impacts and exploiting their resource recovery potentials [33]. Composting is a form of OW management that has gained acceptance over the years [9]. It is a widely used technology for the treatment of agricultural residues, offering numerous benefits in terms of waste reduction and soil improvement [34]. It is an exothermic, aerobic, and spontaneous process that involves the transformation of OW into relatively stable substances, resulting in a final product of reduced volume, weight, and toxicity, and also contributing to the destruction of weed seeds and pathogenic organisms [31,35].

The composting process is similar to the natural processes of mineralization and humification, mimicking the decomposition of organic residues in cultivated soils [7,36–38]. It is influenced by several factors such as temperature, moisture content, C/N ratio, aeration, pH value, EC levels, turning frequency, nutrient content, and the physical structure of the compost raw material [39]. In agriculture, composting, as a good OF, reduces the use of chemical inputs and offers the possibility of recycling OW. This practice supports sustainable agriculture systems as part of an integrated approach to sustainability [40,41].

The process can be divided into different phases based on temperature evolution. Each phase is characterized by specific populations of bacteria and fungi that thrive in particular temperature ranges [13]. According to Ref. [7], the composting process consists of two main phases. The first is the decomposition phase, which involves the degradation of both simple and complex OM, while the second is the humification phase, characterized by the reorganization of OM into stable molecules called humus. Contrary to the findings of [42,43], the composting process has four distinct phases, each with its specific characteristics [44]. The first phase is the mesophilic phase, in which an active and thriving community of mesophilic organisms plays a crucial role [45]. This phase is characterized by their activity, which leads to a rapid rise in temperature mainly due to the presence of easily biodegradable OM [7]. The second is the thermophilic phase, with exponential proliferation of fungi and actinobacteria [46]. These microorganisms play an essential role in the degradation of complex organic compounds present in compost, including cellulose, lignin, hemicellulose, and proteins [43]. After around 5 to 10 days of composting, thermophilic fungi begin to thrive, further enhancing the decomposition process [24]. Simultaneously, the pH of compost heaps increases due to the microbial degradation of proteins and the subsequent release of ammonia (NH_3) [7]. The third is the cooling phase of composting, during which mesophilic microorganisms continue their essential role in breaking down the remaining quantities of cellulose and hemicellulose [43]. As the composting process progresses towards its final phase, characterized by a drop in temperature, there is a noticeable change in the dominant group of microorganisms [24]. The final phase is the maturation phase, which can last from a few weeks to several months, depending on several factors [47]. This phase is characterized by the emergence of micro and macro fauna, indicating a flourishing ecosystem within the compost [48]. This phase is further distinguished by minimal heat release and weight loss, signifying stabilization of the composting process [49]. In addition, secondary polymerization and condensation reactions take place during maturation, leading to the formation of humus containing highly resilient humic acids [50].

3.3.2. Compost Conception Methods

Various composting methods are employed to efficiently decompose OM into nutrient-rich compost, each tailored to specific operational needs and environmental conditions [1].

Windrow composting, widely adopted due to its simplicity, is an open-air composting system that relies heavily on mechanical aeration, typically using compost turning [51]. This method involves piling solid materials in elongated parallel rows, called windrows, which are turned periodically to optimize oxygen availability, porosity, moisture content, and temperature distribution within the compost pile [52]. This method proves particularly advantageous especially when processing a large volume of OW; however, it requires a large surface area and a longer curing time compared with other composting methods [52]. Despite these requirements, it remains the most commonly adopted method among Moroccan farmers [8].

Static aerated piles (SAP) use an innovative air distribution system, with perforated tubes located at the base of the compost heap [53]. This system revolutionizes the composting process by eliminating the need to move materials for aeration, thus reducing the overall surface area required for composting and ensuring optimal composting conditions [43]. However, once established, challenges arise in adjusting moisture levels inside static piles, leading to the development of anaerobic conditions at their core [54]. SAP is mainly used in the composting of municipal sludge, often incorporating a bulking agent such as wood chips to improve airflow and porosity [55]. This addition plays a crucial role in increasing oxygen availability, thus facilitating the degradation of biomass into a more stable and refined compost [11].

In-vessel composting involves confining the composting process to specially designed containers or vessels [56]. In-vessel systems use solid-state bioreactors, usually in the form of cylinders, offering the ability to precisely control key parameters such as temperature, humidity, and oxygen supply [48]. However, when implementing such control measures on a large scale, practical challenges arise due to hydrodynamic constraints associated with increasing bioreactor size [43]. The effective control of operational parameters enables compost production in a relatively short timeframe, guaranteeing rapid and consistent results [2]. However, it is important to note that in-vessel composting is generally the most expensive system among the available alternatives, mainly due to the necessary infrastructure and control mechanism [41]. Therefore, enclosure composting is commonly used in small-scale laboratories and research, where these challenges can be better managed [43].

Vermicomposting, often referred to as worm composting, is specifically carried out using red worms, in particular *Eisenia foetida* and *Lumbricus rubellus*, which have proven to be highly effective in transforming decomposing OM into rich vermicompost [57]. It is a unique approach that capitalizes on the collaborative efforts of earthworms and microbial populations to effectively degrade organic residues [31]. Earthworms possess remarkable capabilities that enable them to effectively eliminate pathogens through intestinal actions, as well as the suppressive activity of intestinal fluids and the selective grazing of OM [58]. In addition, the release of coelomic fluids by earthworms contributes to the pathogen-killing process, as these fluids exhibit antibacterial properties. Unlike other composting methods, vermicomposting does not require high temperatures, as earthworms cannot survive in such conditions [59].

3.3.3. Composting Parameters

To achieve successful composting, several key parameters must be considered. In the literature, several composting parameters have been widely studied, including C/N ratio, microbial activity, germination index, cation exchange capacity, humic substance content, water-soluble carbon concentration, and dissolved OM, NH_4^+-N/NO_3^--N, WSC/TN, and WSC/organic-N ratios [8]. All these parameters maintain a complex and strong relationship with one another, underscoring the intricate dynamics that govern their interactions, as is clear in Figures 2 and 4. This complexity is critical for understanding processes where each variable can significantly influence outcomes. The C/N ratio, water-soluble carbon content, humic substance content, and CO_2-C evolution are reliable indicators of compost maturity [60]. In addition to these primary parameters, assessing the compost quality and maturity also involves monitoring parameters such as NH_4/NH_3 ratios, CO_2 evolution, pH, electrical conductivity, cation exchange capacity, water-soluble carbon, self-healing capacity, oxygen uptake rate, humic substance production, and germination index as a measure of phytotoxicity [61]. While no single parameter is universally accepted, a combination of tests is probably required to assess composting progression and biodegradation levels accurately [7]. The monitoring and analysis of key indicators, including the C/N ratio, microbial activity, and humic substance content, along with chemical and physical parameters, are essential for accurately assessing the stability and maturity of the end product [13]. These metrics ensure that the compost reaches an optimal state and meets the standards required for safe and effective agricultural uses [62].

3.4. Impact of Applying Compost on Agricultural Soil

3.4.1. Environmental Impact

Composting stands out as a powerful bioremediation technique for stabilizing contaminated soils, primarily due to its high humic substance content, which plays a crucial role in enhancing soil structural integrity and nutrient retention [35]. It also reduces erosive processes indirectly due to the large amount of OM it introduces, which is particularly important for degraded and polluted soils where OM content is typically low [34,46,63].

As noted by Ayilara et al. [1], composting is a multifaceted approach that involves the controlled decomposition of OW into a stable, nutrient-rich end product that significantly improves soil quality. This process results in compost rich in humic substances, improving nutrient retention, strengthening soil structure, and promoting the proliferation of beneficial microorganisms [15,35,64]. These attributes make composting particularly valuable for the remediation of contaminated soils, as it effectively immobilizes pollutants and reduces their bioavailability in the environment [65,66].

In a critical review by Bouhia et al. [67], the potential of composting olive mill waste was emphasized as a dual-purpose strategy to rehabilitate degraded soils and immobilize contaminants, thereby mitigating their environmental impact. The study suggests that composting is one of the most effective bioremediation solutions, especially for addressing the significant waste generated by the olive industry, particularly in Morocco and Tunisia, the leading olive producers in Africa.

While compost is recognized as a potential solution for immobilizing certain contaminants, its application requires careful consideration. Compost containing residual, non-degraded contaminants can harm environmental ecosystems [68]. To mitigate this, extracting specific nutrients from compost and applying them directly to the soil can enhance soil health while reducing the risk of groundwater contamination [59].

Mature compost products typically contain trace elements within acceptable limits. However, when applied to soils with certain levels of trace elements, there is a risk of cumulative addition, potentially exacerbating trace element levels rather than mitigating them [66,69]. Additionally, a critical concern with compost use is the potential bioaccumulation of non-degradable chemical compounds, such as persistent organic pollutants and endocrine-disrupting chemicals. While composting has demonstrated some capacity to reduce these compounds, complete eradication is often unachievable. Compost microbes may absorb these substances, but their absorption behavior remains complex and not fully predictable [1].

Beyond its role in soil remediation, composting transforms OW into valuable products, enhancing the efficient recycling of resources while reducing land occupation and the wastage of natural resources [70,71].

Composting, in addition to its critical role in recycling organic waste, has seen significant advancements with the introduction of inoculation techniques. These methods have been shown to substantially improve both the duration of the composting process and the quality of the end product [55,59,72,73], marking a key innovation in the composting industry. The study by Ozi et al. [74] underscored composting as a natural bioconversion process that converts agricultural waste into valuable OF. By optimizing the composting process through inoculation, the study demonstrated a reduction in the duration of composting, thereby accelerating the transformation of waste into useful products. Conducted in Morocco, the study highlighted that composting could significantly decrease the approximately 5 million tons of AW generated annually that would otherwise end up in landfills or be incinerated [75], thereby contributing to more sustainable WM practices in agriculture-based regions.

Recent studies highlight the potential for multi-stage processes to generate more valuable end products and increase energy recovery. One promising approach involves integrating vermicomposting, known for its efficiency in decomposing lignocellulosic compounds [58,76], as a pretreatment step before anaerobic digestion. This combination not only accelerates OM breakdown but also enhances biogas production, achieving 63–65% higher yields compared to conventional methods. Such synergistic strategies underscore the potential of combining biological processes to optimize resource recovery and improve composting efficiency [59].

During the rainy season, compost acts as a protective layer that reduces leachate infiltration, thereby mitigating potential groundwater pollution, especially in sandy soils with a high infiltration rate [8].

According to Abdelilah et al. [23], applying an OF positively influences the physicochemical parameters of soil, including improving soil structure, higher water retention capacity, and enhanced microbial activity. These enhancements contribute to long-term soil fertility and health, making the soil more resilient to erosion and degradation, and protecting the groundwater resource, which is a natural solution to resolve this problem, especially in semi-arid countries like Morocco [8].

A recent study by Zgallai et al. [77] underscores the critical role of OW compost in mitigating soil erosion and preventing the infiltration and leaching of contaminants into groundwater. The study emphasizes that the high OM content and superior water-holding capacity of compost significantly enhance soil aggregate stability. These stabilized aggregates function as a natural filter, retaining water and trapping potential pollutants, thereby preventing their leaching into groundwater [78,79]. This natural process not only fortifies soil against erosion but also acts as a barrier against the contamination of water resources, making compost an invaluable method in sustainable land management.

Composting plays a crucial role in enhancing soil and plant health by significantly reducing the presence of harmful elements such as pathogens and bacteria, including Escherichia coli, total coliforms across, and toxic elements in various organic materials [80]. This is particularly evident in the studies of Jiang and Wang [81], where they demonstrated that inoculating compost can substantially reduce the presence of Escherichia coli, harmful microorganisms that may present a risk to human health. Other studies have consistently demonstrated the efficacy of composting in reducing pathogen loads such as *Fusarium oxysporum*, *Oomycota pathogens*, and *Pythium*, thereby minimizing risks associated with plant diseases and food safety [82,83]. Furthermore, composting processes have demonstrated significant potential in the degradation and mitigation of various chemical compounds, including chlorinated and non-chlorinated hydrocarbons, solvents, petroleum products, pesticides, and even certain HM [59]. Through different mechanisms such as absorption and microbial degradation, composting can effectively reduce the environmental and health risks associated with these hazardous substances.

The composting process typically spans from several days to a few months, depending on various physiochemical and biological factors [13]. To accelerate this process and enhance microbial and enzymatic activity (e.g., laccase, lignin peroxidase, dye-decolorizing peroxidase), researchers have explored strategies to boost the degradation of OM [59]. These enhancements also contribute to reducing GHG emissions, odor generation, and the leaching of nutrients or potentially harmful elements. Over the years, studies have adopted the addition of various organic and mineral additives, including biochar, zeolite, gypsum, and lime, as well as inoculating the composting mixture with single or mixed microbial cultures [66,84,85]. These interventions directly impact key parameters of the composting process, enhancing the quality of the final product and significantly reducing the degradation time. This optimization makes the compost more efficient and suitable for agricultural applications.

Recently, Garau et al. [84] investigated the effectiveness of biochar and compost in the remediation of soils contaminated with toxic elements. The study demonstrated that applying compost significantly reduced the bioavailability of a fraction of Zinc in the soil and significantly stabilized this contaminant. Additionally, the compost application achieved a 4% reduction in the labile fraction of antimony, highlighting its potential to mitigate the mobility of these potentially toxic elements [86].

A review conducted by Ejileugha et al. [66] highlights the significant impact of the incorporation of biochar or zeolite into composting processes, as they facilitate the transformation of HM into more stable, residual forms, thereby enhancing their immobilization and reducing both their leaching and bioavailability. HM are highly bioavailable elements that pose significant challenges during traditional composting processes [87]. These metals originate from various sources and accumulate in agricultural soils, particularly through the prolonged application of raw manure in agriculture. This has contributed to the accumulation of HM in soils, posing severe risks to human and animal health [88].

Controlling the bioavailability of HM during composting requires careful regulation of physicochemical parameters and input materials. Several mechanisms can aid in immobilizing HM, including chemical precipitation, adsorption, redox reactions, the formation of stable complexes with organic ligands, surface precipitation, and the use of additives [89]. Additives, in particular, have demonstrated significant potential in reducing HM mobility and bioavailability [90]. Due to their optimal particle sizes, extensive internal surface areas, and active binding sites, physical additives such as biochar, zeolite, and clay, alongside chemical additives like superphosphate, oxalic acid, and phosphogypsum, enhance the binding capacity of compost, effectively lowering HM bioavailability by over 40% [91]. The compost's physicochemical properties also play a critical role in determining HM bioavailability. According to Chen et al. [92], the increase in pH values significantly reduces HM bioavailability, while humic substances formed during composting contribute to HM immobilization. Furthermore, longer composting durations—over 50 days—promote the formation of humic substances, further decreasing HM bioavailability [93]. The appropriate dosage of additives is critical for optimizing these effects. For instance, Li et al. [94] recommend a 2.5% addition of bentonite to reduce HM bioavailability, whereas Chen et al. [92] identify a 5% biochar application as optimal for achieving the maximum decline. Similarly, Villasenor et al. [95] propose a 10% zeolite addition for more effective reductions.

Recent research by Umair Hassan et al. [96] examined the effects of combining biochar with compost on mitigating GHG emissions and improving soil fertility in rice cultivations. Their study demonstrates the efficacy of biochar co-compost in reducing the emission of methane (CH_4) and nitrous oxide (N_2O). The synergistic application of compost and biochar not only mitigates N_2O emissions but also promotes CS. This combined approach enhances overall soil health by addressing conditions that typically contribute to high GHG emissions such as excessive moisture and nutrient imbalances.

Additionally, innovative approaches, such as the use of insects like the black soldier fly (BSF) (*Hermetia illucens*), have shown remarkable efficacy in degrading a wide range of OW and substrates [97,98]. Integrating BSF into composting processes has been documented to reduce GHG emissions by up to 47 times, highlighting its potential as an efficient strategy for WM [59].

In Morocco, Maaouane et al. [99] explored various WM strategies by evaluating their impact on energy conservation and GHG emission reduction. The study highlighted that traditional methods contribute significantly to CH_4 and CO_2 emissions, and alternative methods like advanced composting processes offer a significant reduction in GHG emissions and lead to effective energy savings by minimizing the need for energy-intensive processes.

Although, during the microbial degradation of OM and the formation of humus substances, composting generates odors and releases various gases, including NH_3, volatile organic compounds (VOCs), hydrogen sulfide (H_2S), CO_2, CH_4, and N_2O. These emissions can contribute to environmental pollution and result in thermal energy and nutrient losses [96,100]. However, studies have demonstrated that these emissions can be effectively managed throughout the composting process. For instance, H_2S and CH_4 emissions can be mitigated by preventing anaerobic conditions through improved aeration, the use of bulking agents, and increased oxygen supply [101]. Advanced technologies, such as modern bioreactors, have demonstrated remarkable efficiency in trapping toxic gases during the composting process. By capturing gases like NH_3, these systems not only mitigate environmental emissions but also enable the recycling of NH_3 within the composting mixture [102]. This recycling process enhances the nitrogen cycle, leading to an increase in nitrate content in the final compost, thereby improving its quality as a soil amendment. VOCs and CO_2 can be managed by covering compost piles with absorptive membranes [103], while NH_3 emissions can be controlled using buffering agents within the compost mixture [104]. Additionally, optimizing initial physicochemical parameters, particularly the C/N ratio, has been proven to reduce emissions of CO_2, CH_4 and N_2O [59,96].

Recent research highlights the importance of regulating enzymatic activity to further control GHG emissions and odor production [59]. By carefully managing these parameters and optimizing the composting process, the negative impacts on soil, air, and water can be minimized.

3.4.2. Agricultural Impact

In agriculture, compost functions as a slow-release OF that gradually supplies essential nutrients to plants while significantly enhancing the soil's OM content over time [53]. This is crucial for improving nutrient retention, maintaining soil structure, and enhancing the physicochemical characteristics of the soil (Figure 5).

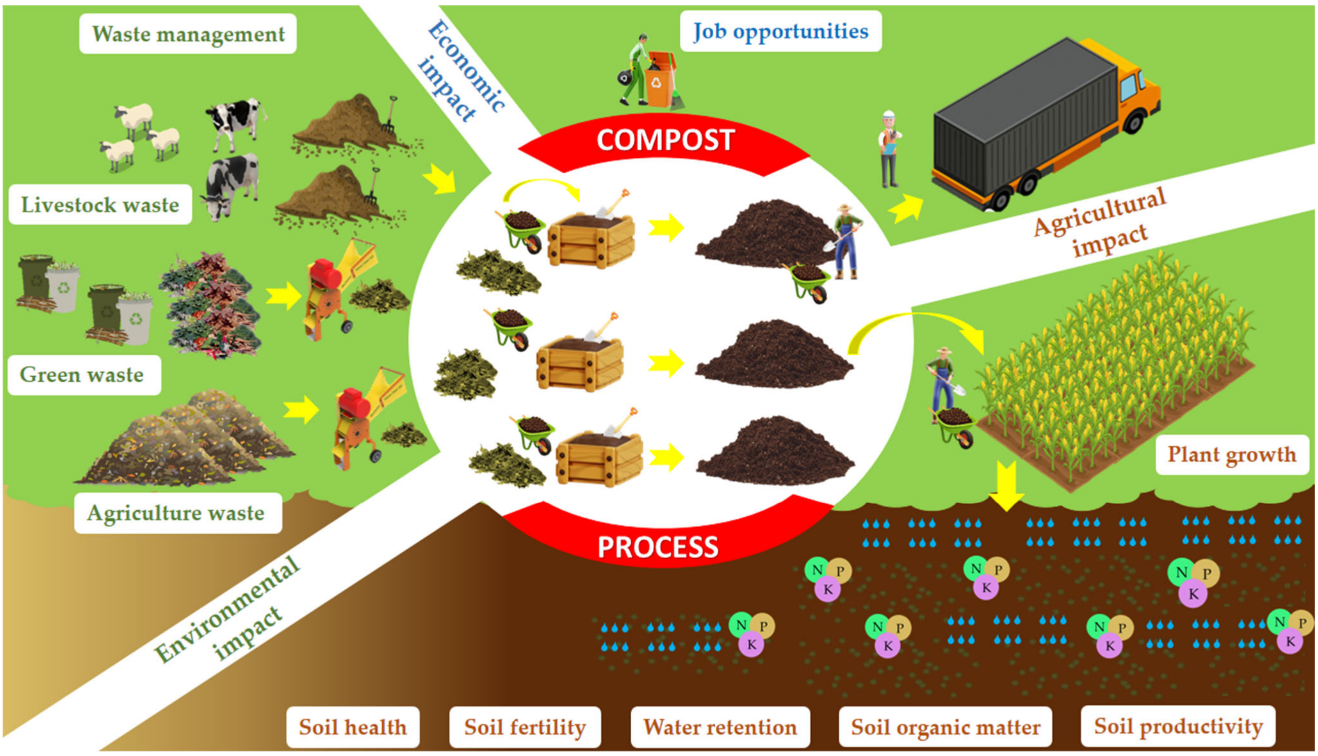

Figure 5. Illustration of compost impact on soil and environmental parameters.

Recent research underscores the significant benefits of compost derived from various raw materials on crop and plant growth [105]. Particularly, Goldan et al. [11] demonstrated the advantages of manure-based compost for soil health by improving soil structure, aeration, water retention capacity, infiltration capacity, and porosity. This compost enriches the nutrient cycle and provides a slow-release mechanism of nutrients, available to plants as needed [106]. As a result, compost enhances crop productivity and soil fertility, contributing to the maintenance of healthy, balanced ecosystems [107]. This sustainable approach reduces the need for chemical fertilizers for 2–3 years, thereby offering a cost-effective solution within the agricultural sector [11].

In a study conducted in 2023, Aouass et al. [108] conducted a comparative analysis of synthetic fertilizers versus organic compost on broccoli crop yields in the arid regions of Morocco. The research concluded that compost serves as a slow-release source of nutrients, significantly promoting the nitrogen use effectively of the crops over time. The study suggested that applying the appropriate dosage of compost can serve as a sustainable alternative to synthetic fertilizers, providing an effective alternative to synthetic fertilizers and offering more sustainable nutrient management in arid agricultural environments. This approach promotes nutrient recycling, prevents toxicity in soils and plants, and reduces the risk of water contamination caused by nutrient oversupply and leaching. Furthermore, it helps conserve essential resources, particularly phosphorus, a non-renewable element of growing concern due to its loss through erosion and infiltration into groundwater causing serious problems like eutrophication [43,59].

The application of compost has demonstrated numerous benefits, including enhanced soil fertility, increased CS, improved nutrient availability for crops, and mitigation of salt stress [46,68]. Even in challenging conditions such as those presented by calcareous soils, compost demonstrated potential as an efficacy soil amendment for enhancing soil fertility and crop productivity. The study by Manirakiza and Şeker [33] underscored that compost improves soil fertility by increasing OM content, enriching exchangeable cations, and enhancing the availability of macro and micronutrients. Additionally, compost positively influences the physical and morphological characteristics of the plants [8]. Its slow-release nutrient property is advantageous in calcareous soils, where the high pH levels often result in reduced nutrient availability and lower crop yield.

The study by Cao et al. [109] explores the role of OA in enhancing soil organic carbon levels, thereby contributing to significant CS. The study highlights biochar for its long-term stability and effectiveness in locking carbon into the soil, making it a critical tool for sustained carbon storage. Other amendments such as compost also play a vital role in improving soil fertility and CS, though they operate with different dynamics and time frames. The application of these OA has been shown to elevate CS rates by 13.3% to 33.6%, showcasing their potential to mitigate climate change through soil management practices [96].

A study by Azim et al. [8] investigated the dual benefits of composting tomato by-products in semi-arid regions such as Morocco in enhancing soil fertility and facilitating CS. The study highlighted the role of compost in enhancing OM levels in the soil, thereby enhancing agricultural productivity and improving soil health and structure. This enrichment of soil not only boosts crop yield but also plays a significant role in sequestering atmospheric CO_2, thus mitigating GHG and supporting sustainable agricultural practices [107,110,111].

Compost has been recognized for its effective mechanisms in stress mitigation, particularly in enhancing plant resilience under adverse conditions. In research by Elbagory [22], the role of liquid extract of compost and effective microorganisms in mitigating salt stress in wheat plants was thoroughly examined. Compost tea, an aqueous extract obtained by soaking or fermenting compost in water for several days, produces a liquid concentrate rich in easily available nutrients, beneficial microorganisms, and organic compounds, significantly improves soil fertility, and enhances plant resilience to various stresses, including diseases and salinity [59,112]. This enrichment is achieved through multiple pathways, by improving nutrient uptake, promoting stronger root development, and enhancing enzymatic and antioxidant activity. Together, these effects strengthen plants' ability to withstand salt stress and combat diseases, making compost tea a valuable tool in sustainable agriculture [113–116].

Produced through a highly valuable process, compost improves soil characteristics such as structure and porosity while simultaneously enriching the supply of nutrients essential for crop growth [117]. It accelerates plant growth, resulting in increased CO_2 uptake, further contributing to agricultural productivity [13,15]. Whether applied in solid or liquid form, compost contributes to healthier soil, supporting sustainable agriculture practices. In countries like Morocco, date palm cultivation is a crucial part of the agricultural landscape but faces significant challenges related to soil and plant health [118]. To address these issues, Hakimi et al. [119] conducted a study evaluating the effects of various forms of compost on date palm growth and soil quality in oasis areas. Their finding confirmed the vital role of OA in promoting robust plant growth and enhancing soil conditions. The study found that compost not only increases soil OM and supports slow-release nutrients but also the liquid extract of compost, providing quicker nutrient availability and easier applications. These organic strategies demonstrate their potential for long-term agricultural sustainability aligning with world efforts to address climate change [120].

3.4.3. Economical Impact

The growing public demand for high-quality food products from organic and sustainable agriculture practices has intensified, reflecting a large shift in public opinion toward environmentally responsible consumption [121]. In this context, agricultural producers must adopt eco-friendly and sustainable practices, prioritizing environmental stewardship and ensuring that final products are high quality [5].

Investing in improved agricultural practices is essential for producing qualitative products, though it usually requires a higher initial investment from farmers [108]. Economically, the use of inorganic fertilizers (IOF) may appear more cost-effective in the short term compared to OF. However, this perspective underestimates the economic potential of OW as a valuable lost resource [16]. By transforming waste into a resource, farmers can reduce their dependency on IOF and create a sustainable long-term revenue stream [13].

A study conducted at Kean University by Mu et al. [56] provides a comprehensive economic analysis of an in-vessel composting system, demonstrating its potential for cost-saving over time. The research revealed that long-term financial benefits are achieved through reduced waste disposal fees, decreased transportation costs, and the production of valuable resources, which can be utilized on campus or sold to the public to generate additional revenue [13]. The study revealed substantial ecological and economic benefits of the composting process. The benefits were in the reduction of USD 0.02 per MJ in fossil fuel usage, a decrease of USD 36/ton CO_2 eq. in GHG emissions, a reduction of USD 4/ton N eq. in eutrophication, and a savings of USD 661/ton of SO_2 eq. in acidification. Additionally, the net income from vegetables grown using the compost was estimated at USD 5.26/Kg, as well as a notable saving of USD 27.164 in waste disposal costs.

A study by Pergola et al. [46] examined on-farm compost production in an Italian farm, revealing that the cost of producing 1 ton of compost ranges from USD 9 to USD 145/m^2, depending on many factors, such as technology, infrastructure, energy consumption, and transportation fees. The study concluded that on-farm compost is generally more cost-effective than commercially available compost. By reducing reliance on expensive IOF, composting lowers input costs and offers a more affordable means of enhancing soil fertility [1]. Additionally, this process diminishes the environmental impact associated with IOF and contributes to improved crop yields and higher-quality products, ultimately boosting farmer profitability [13,46].

Recent studies have consistently highlighted the economic challenges associated with IOF, particularly for small-scale farmers in low and middle-income countries, as noted by Guo et al. [76]. These challenges underscore the benefits of composting agricultural waste and livestock manure, which has been recognized as both an environmentally friendly and cost-effective OA, as highlighted by Ayilara et al. [1]. Furthermore, Jjagwe et al. [122] identified vermicomposting as the most economical technology due to its low operational costs and high returns on investment. Their findings demonstrated that vermicomposting results in a notable annual net cash flow of USD 2.305 and an annual benefit of USD 3.516, making it a particularly advantageous approach for enhancing sustainable agricultural productivity while maintaining economic feasibility.

In Morocco, a study by Azim et al. [8] highlights the significant economic potential of composting horticultural waste, estimating that the process could generate approximately

USD 13 million worth of nitrogen, phosphorus, and potassium. Despite this potential, diagnostics indicate that the OW generated over 1 million tons of DM annually, with the majority of the porting diverted to landfills or incineration [7]. This potential is exacerbated by the low level of consciousness among farmers regarding composting practices [123,124]. Recently, Majbar et al. [5] found that only 10% of farmers are informed about composting, including its benefits and production methods. Consequently, the economic and environmental advantages of composting remain underutilized, mainly due to insufficient engagement and a lack of understanding of the composting process in this region.

4. Conclusions

Improper WM poses significant risks to environmental integrity and public health, leading to pollution and the spread of harmful pathogens. Transitioning to more sustainable methods, such as composting, offers a safer and more effective alternative.

By recycling OW, composting reduces landfill dependency, enriches soil through available nutrients, enhances soil fertility, and promotes sustainable agricultural practices. Despite the challenges and complications of OW composting, this study provides a detailed synthesis of the effective role of composting technology in agricultural soil health and underscores the complexity of composting processes, emphasizing the necessity for thorough evaluation and making ecological strategic decisions.

In a circular agricultural model, the recycling of AW, whether alone or through co-composting with other organic materials, plays an essential role in promoting sustainability in arid and semi-arid regions characterized by poor soil conditions. This practice is crucial for countries like Morocco, where encouraging farmers to integrate compost into their agricultural systems could significantly mitigate environmental challenges, such as climate change, groundwater pollution, and soil degradation. However, there is a notable lack of comprehensive long-term research data assessing the impact of agricultural waste on soil health and productivity in these regions, underscoring the need for more studies to fully understand the long-term benefits of composting in such challenging environments.

The primary objective of composting is to reduce using IOF, with a future goal of eliminating chemical inputs from crop production. To achieve this, further studies are needed to investigate the potential of co-composting agricultural waste with plants possessing anti-nematicidal, viricidal, bactericidal, and fungicidal properties, which could serve as natural alternatives to conventional herbicides and insecticides in crop management. Additionally, increasing farmer's awareness and confidence in using OA derived from their waste is crucial, as the current lack of detailed and comprehensive data on these aspects may deter interest and adoption among the farming community.

In conclusion, future research must crucially address the economic aspects of composting, as this is a fundamental consideration for the adoption of sustainable agricultural practices globally. The economic viability of composting, including cost benefits and potential returns, plays an essential role in its adoption and implementation. Addressing these concerns will be pivotal in optimizing composting processes and promoting the transition toward more sustainable agricultural management.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agriculture14122356/s1, Table S1: Selected papers in the literature.

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References

1. Ayilara, M.; Olanrewaju, O.; Babalola, O.; Odeyemi, O. Waste Management through Composting: Challenges and Potentials. *Sustainability* **2020**, *12*, 4456. [CrossRef]
2. Bernal, M.P.; Alburquerque, J.A.; Moral, R. Composting of Animal Manures and Chemical Criteria for Compost Maturity Assessment. A Review. *Bioresour. Technol.* **2008**, *100*, 5444–5453. [CrossRef] [PubMed]
3. Glick, B.R. Using Soil Bacteria to Facilitate Phytoremediation. *Biotechnol. Adv.* **2010**, *28*, 367–374. [CrossRef]
4. Liu, X.; Xie, Y.; Sheng, H. Green Waste Characteristics and Sustainable Recycling Options. *Resour. Environ. Sustain.* **2023**, *11*, 100098. [CrossRef]
5. Majbar, Z.; El Madani, F.-Z.; Khalis, M.; Lahlou, K.; Ben Abbou, M.; Majbar, E.B.; Bourhia, M.; AL-Huqail, A.A.; El Askary, A.; Khalifa, A.S.; et al. Farmers' Perceptions and Willingness of Compost Production and Use to Contribute to Environmental Sustainability. *Sustainability* **2021**, *13*, 13335. [CrossRef]
6. Jahangir, M.M.R.; Islam, S.; Nitu, T.T.; Uddin, S.; Kabir, A.K.M.A.; Meah, M.B.; Islam, R. Bio-Compost-Based Integrated Soil Fertility Management Improves Post-Harvest Soil Structural and Elemental Quality in a Two-Year Conservation Agriculture Practice. *Agronomy* **2021**, *11*, 2101. [CrossRef]
7. Azim, K.; Soudi, B.; Boukhari, S.; Perissol, C.; Roussos, S.; Thami Alami, I. Composting Parameters and Compost Quality: A Literature Review. *Org. Agr.* **2017**, *8*, 141–158. [CrossRef]
8. Azim, K.; Komenane, S.; Soudi, B. Agro-Environmental Assessment of Composting Plants in Southwestern of Morocco (Souss-Massa Region). *Int. J. Recycl. Org. Waste Agric.* **2017**, *6*, 107–115. [CrossRef]
9. Azim, K.; Faissal, Y.; Soudi, B.; Perissol, C.; Roussos, S.; Thami Alami, I. Elucidation of Functional Chemical Groups Responsible of Compost Phytotoxicity Using Solid-State 13C NMR Spectroscopy under Different Initial C/N Ratios. *Environ. Sci. Pollut. Res.* **2018**, *25*, 3408–3422. [CrossRef] [PubMed]
10. Devkota, M.; Devkota, K.P.; Kumar, S. Conservation Agriculture Improves Agronomic, Economic, and Soil Fertility Indicators for a Clay Soil in a Rainfed Mediterranean Climate in Morocco. *Agric. Syst.* **2022**, *201*, 103470. [CrossRef]
11. Goldan, E.; Nedeff, V.; Barsan, N.; Culea, M.; Panainte-Lehadus, M.; Mosnegutu, E.; Tomozei, C.; Chitimus, D.; Irimia, O. Assessment of Manure Compost Used as Soil Amendment—A Review. *Processes* **2023**, *11*, 1167. [CrossRef]
12. Fernandes, P.; Pinto, R.; Correia, C.; Mourão, I.; Moura, L.; Brito, L.M. Impact of Kiwifruit Waste Compost on Soil Bacteriome and Lettuce Growth. *Agriculture* **2024**, *14*, 1409. [CrossRef]
13. Oueld Lhaj, M.; Moussadek, R.; Mouhir, L.; Mdarhri Alaoui, M.; Sanad, H.; Iben Halima, O.; Zouahri, A. Assessing the Evolution of Stability and Maturity in Co-Composting Sheep Manure with Green Waste Using Physico-Chemical and Biological Properties and Statistical Analyses: A Case Study of Botanique Garden in Rabat, Morocco. *Agronomy* **2024**, *14*, 1573. [CrossRef]
14. Chabbi, N.; Labbassi, S.; Afi, C.; Chafiki, S.; Telmoudi, M.; Tiouidji, F.E.; Wifaya, A.; Bouharroud, R.; Tahiri, A.; Qessaoui, R.; et al. Mineral and Organic Fertilizers' Effect on the Growth of Young Argane Trees (*Argania spinosa* L.) and Soil Properties under Vulnerable Conditions. *Plants* **2024**, *13*, 2026. [CrossRef] [PubMed]
15. Sanad, H.; Moussadek, R.; Mouhir, L.; Oueld Lhaj, M.; Dakak, H.; El Azhari, H.; Yachou, H.; Ghanimi, A.; Zouahri, A. Assessment of Soil Spatial Variability in Agricultural Ecosystems Using Multivariate Analysis, Soil Quality Index (SQI), and Geostatistical Approach: A Case Study of the Mnasra Region, Gharb Plain, Morocco. *Agronomy* **2024**, *14*, 1112. [CrossRef]
16. García Castellanos, B.; García García, B.; García García, J. Economic and Environmental Effects of Replacing Inorganic Fertilizers with Organic Fertilizers in Three Rainfed Crops in a Semi-Arid Area. *Sustainability* **2023**, *15*, 16897. [CrossRef]
17. Bhattacharyya, P.; Chakrabarti, K.; Chakraborty, A.; Nayak, D.C.; Tripathy, S.; Powell, M.A. Municipal Waste Compost as an Alternative to Cattle Manure for Supplying Potassium to Lowland Rice. *Chemosphere* **2007**, *66*, 1789–1793. [CrossRef]
18. López-Cano, I.; Roig, A.; Cayuela, M.L.; Alburquerque, J.A.; Sánchez-Monedero, M.A. Biochar Improves N Cycling During Composting of Olive Mill Wastes and Sheep Manure. *Waste Manag.* **2016**, *49*, 553–559. [CrossRef] [PubMed]
19. Kumar, M.; Ou, Y.-L.; Lin, J.-G. Co-Composting of Green Waste and Food Waste at Low C/N Ratio. *Waste Manag.* **2010**, *30*, 602–609. [CrossRef] [PubMed]
20. Adugna, G. A Review on Impact of Compost on Soil Properties, Water Use and Crop Productivity. *Acad. Res. J. Agric. Sci. Res.* **2016**, *4*, 93–104. [CrossRef]
21. Kelley, A.; Wilkie, A.C.; Maltais-Landry, G. Food-Based Composts Provide More Soil Fertility Benefits Than Cow Manure-Based Composts in Sandy Soils. *Agriculture* **2020**, *10*, 69. [CrossRef]
22. Elbagory, M. Reducing the Adverse Effects of Salt Stress by Utilizing Compost Tea and Effective Microorganisms to Enhance the Growth and Yield of Wheat (*Triticum aestivum* L.) Plants. *Agronomy* **2023**, *13*, 823. [CrossRef]

23. Abdelilah, M.; OUFDOU, K.; Boutasknit, A.; Anas, R.; Tahiri, A.-I.; Ben-Laouane, R.; Ait-El-Mokhtar, M.; Anli, M.; Mitsui, T.; Wahbi, S.; et al. *Use of Organic and Biological Fertilizers as Strategies to Improve Crop Biomass and Yields and Physicochemical Parameters of Soil*; Springer: Singapore, 2019; pp. 247–288. ISBN 9789811386596.
24. Antil, R.S.; Raj, D.; Abdalla, N.; Inubushi, K. Physical, Chemical and Biological Parameters for Compost Maturity Assessment: A Review. In *Composting for Sustainable Agriculture*; Springer: Cham, Switzerland, 2014; Volume 3, pp. 83–101, ISBN 978-3-319-08004-8.
25. Cao, L.; Luo, G.; Tsang, D.C.W.; Chen, H.; Zhang, S.; Chen, J. A Novel Process for Obtaining High Quality Cellulose Acetate from Green Landscaping Waste. *J. Clean. Prod.* **2018**, *176*, 338–347. [CrossRef]
26. Kan, X.; Yao, Z.; Zhang, J.; Tong, Y.W.; Yang, W.; Dai, Y.; Wang, C.-H. Energy Performance of an Integrated Bio-and-Thermal Hybrid System for Lignocellulosic Biomass Waste Treatment. *Bioresour. Technol.* **2017**, *228*, 77–88. [CrossRef]
27. López, M.; Soliva, M.; Martínez-Farré, F.X.; Bonmatí, A.; Huerta-Pujol, O. An Assessment of the Characteristics of Yard Trimmings and Recirculated Yard Trimmings Used in Biowaste Composting. *Bioresour. Technol.* **2010**, *101*, 1399–1405. [CrossRef] [PubMed]
28. Götze, R.; Boldrin, A.; Scheutz, C.; Astrup, T.F. Physico-Chemical Characterisation of Material Fractions in Household Waste: Overview of Data in Literature. *Waste Manag.* **2016**, *49*, 3–14. [CrossRef]
29. Karnchanawong, S.; Mongkontep, T.; Praphunsri, K. Effect of Green Waste Pretreatment by Sodium Hydroxide and Biomass Fly Ash on Composting Process. *J. Clean. Prod.* **2017**, *146*, 14–19. [CrossRef]
30. Zhang, S.; Wen, J.; Hu, Y.; Fang, Y.; Zhang, H.; Xing, L.; Wang, Y.; Zeng, G. Humic Substances from Green Waste Compost: An Effective Washing Agent for Heavy Metal (Cd, Ni) Removal from Contaminated Sediments. *J. Hazard. Mater.* **2018**, *366*, 210–218. [CrossRef] [PubMed]
31. Soobhany, N.; Mohee, R.; Garg, V.K. Inactivation of Bacterial Pathogenic Load in Compost against Vermicompost of Organic Solid Waste Aiming to Achieve Sanitation Goals: A Review. *Waste Manag.* **2017**, *64*, 51–62. [CrossRef] [PubMed]
32. Gómez-Brandón, M.; Lazcano, C.; Domínguez, J. The Evaluation of Stability and Maturity during the Composting of Cattle Manure. *Chemosphere* **2008**, *70*, 436–444. [CrossRef]
33. Manirakiza, N.; Şeker, C. Effects of Compost and Biochar Amendments on Soil Fertility and Crop Growth in a Calcareous Soil. *J. Plant Nutr.* **2020**, *43*, 3002–3019. [CrossRef]
34. Medina, J.; Monreal, C.; Barea, J.M.; Arriagada, C.; Borie, F.; Cornejo, P. Crop Residue Stabilization and Application to Agricultural and Degraded Soils: A Review. *Waste Manag.* **2015**, *42*, 41–54. [CrossRef] [PubMed]
35. Onwosi, C.O.; Igbokwe, V.C.; Odimba, J.N.; Eke, I.E.; Nwankwoala, M.O.; Iroh, I.N.; Ezeogu, L.I. Composting Technology in Waste Stabilization: On the Methods, Challenges and Future Prospects. *J. Environ. Manag.* **2017**, *190*, 140–157. [CrossRef]
36. Tabrika, I.; Azim, K.; Mayad, E.H.; Zaafrani, M. Composting of Tomato Plant Residues: Improvement of Composting Process and Compost Quality by Integration of Sheep Manure. *Org. Agric.* **2019**, *10*, 229–242. [CrossRef]
37. Zhang, L.; Sun, X. Improving Green Waste Composting by Addition of Sugarcane Bagasse and Exhausted Grape Marc. *Bioresour. Technol.* **2016**, *218*, 335–343. [CrossRef] [PubMed]
38. Sortino, O.; Montoneri, E.; Patanè, C.; Rosato, R.; Tabasso, S.; Ginepro, M. Benefits for Agriculture and the Environment from Urban Waste. *Sci. Total Environ.* **2014**, *487*, 443–451. [CrossRef] [PubMed]
39. Brito, L.M.; Coutinho, J.; Smith, S.R. Methods to Improve the Composting Process of the Solid Fraction of Dairy Cattle Slurry. *Bioresour. Technol.* **2008**, *99*, 8955–8960. [CrossRef] [PubMed]
40. Liu, L.; Wang, S.; Guo, X.; Zhao, T.; Zhang, B. Succession and Diversity of Microorganisms and Their Association with Physicochemical Properties during Green Waste Thermophilic Composting. *Waste Manag.* **2018**, *73*, 101–112. [CrossRef]
41. Kong, Y.; Zhang, J.; Yang, Y.; Liu, Y.; Zhang, L.; Wang, G.; Liu, G.; Dang, R.; Li, G.; Yuan, J. Determining the Extraction Conditions and Phytotoxicity Threshold for Compost Maturity Evaluation Using the Seed Germination Index Method. *Waste Manag.* **2023**, *171*, 502–511. [CrossRef]
42. Amir, S.; Merlina, G.; Pinelli, E.; Winterton, P.; Revel, J.-C.; Hafidi, M. Microbial Community Dynamics during Composting of Sewage Sludge and Straw Studied through Phospholipid and Neutral Lipid Analysis. *J. Hazard. Mater.* **2008**, *159*, 593–601. [CrossRef] [PubMed]
43. Sánchez, Ó.J.; Ospina, D.A.; Montoya, S. Compost Supplementation with Nutrients and Microorganisms in Composting Process. *Waste Manag.* **2017**, *69*, 136–153. [CrossRef] [PubMed]
44. Cesaro, A.; Conte, A.; Belgiorno, V.; Siciliano, A.; Guida, M. The Evolution of Compost Stability and Maturity during the Full-Scale Treatment of the Organic Fraction of Municipal Solid Waste. *J. Environ. Manag.* **2019**, *232*, 264–270. [CrossRef]
45. Raj, D.; Antil, R.S. Evaluation of Maturity and Stability Parameters of Composts Prepared from Farm Wastes. *Arch. Agron. Soil Sci.* **2012**, *58*, 817–832. [CrossRef]
46. Pergola, M.; Persiani, A.; Palese, A.M.; Di Meo, V.; Pastore, V.; D'Adamo, C.; Celano, G. Composting: The Way for a Sustainable Agriculture. *Appl. Soil Ecol.* **2018**, *123*, 744–750. [CrossRef]
47. Villar, I.; Alves, D.; Garrido, J.; Mato, S. Evolution of Microbial Dynamics during the Maturation Phase of the Composting of Different Types of Waste. *Waste Manag.* **2016**, *54*, 83–92. [CrossRef] [PubMed]
48. Makan, A.; Assobhei, O.; Mountadar, M. Effect of Initial Moisture Content on the In-Vessel Composting under Air Pressure of Organic Fraction of Municipal Solid Waste in Morocco. *Iran. J. Environ. Health Sci. Eng.* **2013**, *10*, 3. [CrossRef] [PubMed]
49. Voběrková, S.; Vaverková, M.D.; Adamcová, D. Enzyme Production During Composting of Aliphatic–Aromatic Copolyesters in Organic Wastes. *Environ. Eng. Sci.* **2017**, *34*, 177–184. [CrossRef]

50. El Fels, L.; Lemee, L.; Ambles, A.; Hafidi, M. Identification and Biotransformation of Lignin Compounds during Co-Composting of Sewage Sludge-Palm Tree Waste Using Pyrolysis-GC/MS. *Int. Biodeterior. Biodegrad.* **2014**, *92*, 26–35. [CrossRef]
51. Lim, L.Y.; Bong, C.P.C.; Lee, C.T.; Klemes, J.J.; Sarmidi, M.R.; Lim, J.S. Review on the Current Composting Practices and the Potential of Improvement Using Two-Stage Composting. *Chem. Eng. Trans.* **2017**, *61*, 1051–1056. [CrossRef]
52. Gavilanes-Terán, I.; Jara-Samaniego, J.; Idrovo-Novillo, J.; Bustamante, M.A.; Moral, R.; Paredes, C. Windrow Composting as Horticultural Waste Management Strategy—A Case Study in Ecuador. *Waste Manag.* **2015**, *48*, 127–134. [CrossRef] [PubMed]
53. Chew, K.W.; Chia, S.R.; Yen, H.-W.; Nomanbhay, S.; Ho, Y.-C.; Show, P.L. Transformation of Biomass Waste into Sustainable Organic Fertilizers. *Sustainability* **2019**, *11*, 2266. [CrossRef]
54. Hassen, A.; Belguith, K.; Jedidi, N.; Cherif, A.; Cherif, M.; Boudabous, A. Microbial Characterization during Composting of Municipal Solid Waste. *Bioresour. Technol.* **2001**, *80*, 217–225. [CrossRef]
55. Yin, Z.; Zhang, L.; Li, R. Effects of Additives on Physical, Chemical, and Microbiological Properties during Green Waste Composting. *Bioresour. Technol.* **2021**, *340*, 125719. [CrossRef]
56. Mu, D.; Horowitz, N.; Casey, M.; Jones, K. Environmental and Economic Analysis of an In-Vessel Food Waste Composting System at Kean University in the U.S. *Waste Manag.* **2017**, *59*, 476–486. [CrossRef] [PubMed]
57. Huang, L.; Gu, M.; Yu, P.; Zhou, C.; Liu, X. Biochar and Vermicompost Amendments Affect Substrate Properties and Plant Growth of Basil and Tomato. *Agronomy* **2020**, *10*, 224. [CrossRef]
58. Katiyar, R.B.; Sundaramurthy, S.; Sharma, A.K.; Arisutha, S.; Pratap-Singh, A.; Mishra, S.; Ayub, R.; Jeon, B.-H.; Khan, M.A. Vermicompost: An Eco-Friendly and Cost-Effective Alternative for Sustainable Agriculture. *Sustainability* **2023**, *15*, 14701. [CrossRef]
59. Zhou, Y.; Xiao, R.; Klammsteiner, T.; Kong, X.; Yan, B.; Mihai, F.-C.; Liu, T.; Zhang, Z.; Kumar Awasthi, M. Recent Trends and Advances in Composting and Vermicomposting Technologies: A Review. *Bioresour. Technol.* **2022**, *360*, 127591. [CrossRef]
60. Goyal, S.; Dhull, S.K.; Kapoor, K.K. Chemical and Biological Changes during Composting of Different Organic Wastes and Assessment of Compost Maturity. *Bioresour. Technol.* **2005**, *96*, 1584–1591. [CrossRef] [PubMed]
61. Rashad, F.M.; Saleh, W.D.; Moselhy, M.A. Bioconversion of Rice Straw and Certain Agro-Industrial Wastes to Amendments for Organic Farming Systems: 1. Composting, Quality, Stability and Maturity Indices. *Bioresour. Technol.* **2010**, *101*, 5952–5960. [CrossRef] [PubMed]
62. Wichuk, K.M.; McCartney, D. Compost Stability and Maturity Evaluation—A Literature Review. *J. Environ. Eng. Sci.* **2013**, *8*, 601–620. [CrossRef]
63. Zemánek, P. Evaluation of Compost Influence on Soil Water Retention. *Acta Univ. Agric. Silvic. Mendel. Brun.* **2011**, *LIX*, 227–232. [CrossRef]
64. Sanad, H.; Mouhir, L.; Zouahri, A.; Moussadek, R.; El Azhari, H.; Yachou, H.; Ghanimi, A.; Oueld Lhaj, M.; Dakak, H. Assessment of Groundwater Quality Using the Pollution Index of Groundwater (PIG), Nitrate Pollution Index (NPI), Water Quality Index (WQI), Multivariate Statistical Analysis (MSA), and GIS Approaches: A Case Study of the Mnasra Region, Gharb Plain, Morocco. *Water* **2024**, *16*, 1263. [CrossRef]
65. He, Z.; Yang, X.; Kahn, B.A.; Stoffella, P.J.; Calvert, D.V. Plant Nutrition Benefits of Phosphorus, Potassium, Calcium, Magnesium, and Micronutrients from Compost Utilization. *Compost. Util. Hortic. Crop. Syst.* **2001**, *15*, 307–320. [CrossRef]
66. Ejileugha, C.; Onyegbule, U.O.; Osuoha, J.O. Use of Additives in Composting Promotes Passivation and Reduction in Bioavailability of Heavy Metals (HMs) in Compost. *Rev. Environ. Contam. Toxicol.* **2024**, *262*, 2. [CrossRef]
67. Bouhia, Y.; Hafidi, M.; Ouhdouch, Y.; Lyamlouli, K. Olive Mill Waste Sludge: From Permanent Pollution to a Highly Beneficial Organic Biofertilizer: A Critical Review and Future Perspectives. *Ecotoxicol. Environ. Saf.* **2023**, *259*, 114997. [CrossRef]
68. Sanad, H.; Oueld Lhaj, M.; Zouahri, A.; Saafadi, L.; Dakak, H.; Mouhir, L. Groundwater Pollution by Nitrate and Salinization in Morocco: A Comprehensive Review. *J. Water Health* **2024**, *22*, 1756–1773. [CrossRef]
69. Kouchou, A.; El Ghachtouli, N.; Duplay, J.; Ghazi, M.; Elsass, F.; Thoisy, J.C.; Bellarbi, M.; Ijjaali, M.; Rais, N. Evaluation of the Environmental and Human Health Risk Related to Metallic Contamination in Agricultural Soils in the Mediterranean Semi-Arid Area (Saiss Plain, Morocco). *Environ. Earth Sci.* **2020**, *79*, 131. [CrossRef]
70. Zhang, J.; Chen, G.; Sun, H.; Zhou, S.; Zou, G. Straw Biochar Hastens Organic Matter Degradation and Produces Nutrient-Rich Compost. *Bioresour. Technol.* **2016**, *200*, 876–883. [CrossRef] [PubMed]
71. Amirahmadi, E.; Ghorbani, M.; Moudrý, J.; Bernas, J.; Mukosha, C.E.; Hoang, T.N. Environmental Assessment of Dryland and Irrigated Winter Wheat Cultivation under Compost Fertilization Strategies. *Plants* **2024**, *13*, 509. [CrossRef] [PubMed]
72. Zhao, Y.; Li, W.; Chen, L.; Meng, L.; Zhang, S. Impacts of Adding Thermotolerant Nitrifying Bacteria on Nitrogenous Gas Emissions and Bacterial Community Structure during Sewage Sludge Composting. *Bioresour. Technol.* **2023**, *368*, 128359. [CrossRef] [PubMed]
73. Reyes-Torres, M.; Oviedo-Ocaña, E.R.; Dominguez, I.; Komilis, D.; Sánchez, A. A Systematic Review on the Composting of Green Waste: Feedstock Quality and Optimization Strategies. *Waste Manag.* **2018**, *77*, 486–499. [CrossRef] [PubMed]
74. Ozi, F.Z.; Boutaleb, N.; Hadidi, M.; Bahlaouan, B.; Bennani, M.; Silkina, A.; El Antri, S. Production of Bio-fertilizer by Biotransformation of Poultry Waste Enriched with Molasses and Algae. *Environ. Qual. Manag.* **2023**, *32*, 123–134. [CrossRef]
75. Mana, A.A.; Allouhi, A.; Ouazzani, K.; Jamil, A. Feasibility of Agriculture Biomass Power Generation in Morocco: Techno-Economic Analysis. *J. Clean. Prod.* **2021**, *295*, 126293. [CrossRef]

76. Guo, L.; Wu, G.; Li, C.; Liu, W.; Yu, X.; Cheng, D.; Jiang, G. Vermicomposting with Maize Increases Agricultural Benefits by 304%. *Agron. Sustain. Dev.* **2015**, *35*, 1149–1155. [CrossRef]
77. Zgallai, H.; Zoghlami, R.I.; Annabi, M.; Zarrouk, O.; Jellali, S.; Hamdi, H. Mitigating Soil Water Deficit Using Organic Waste Compost and Commercial Water Retainer: A Comparative Study under Semiarid Conditions. *Euro-Mediterr. J. Environ. Integr.* **2024**, *9*, 377–391. [CrossRef]
78. Huang, M.; Zhu, Y.; Li, Z.; Huang, B.; Luo, N.; Liu, C.; Zeng, G. Compost as a Soil Amendment to Remediate Heavy Metal-Contaminated Agricultural Soil: Mechanisms, Efficacy, Problems, and Strategies. *Water Air Soil Pollut.* **2016**, *227*, 359. [CrossRef]
79. El Moussaoui, H.; Bouqbis, L. Interactive Effect of Biochar and Bio-Compost on Starting Growth and Physiologic Parameters of Argan. *Sustainability* **2022**, *14*, 7270. [CrossRef]
80. Arslan Topal, E.I.; Ünlü, A.; Topal, M. Effect of Aeration Rate on Elimination of Coliforms during Composting of Vegetable–Fruit Wastes. *Int. J. Recycl. Org. Waste Agric.* **2016**, *5*, 243–249. [CrossRef]
81. Jiang, X.; Wang, J. Biological Control of Escherichia Coli O157:H7 in Dairy Manure-Based Compost Using Competitive Exclusion Microorganisms. *Pathogens* **2024**, *13*, 361. [CrossRef] [PubMed]
82. Abdellatif, S.M.; El-Hadidi, Y.M.; El-Kasemy, S. Effect of Aeration Rates and Mechanical Stirring System on Compost Production from Some Farm Wastes. *J. Soil Sci. Agric. Eng.* **2021**, *12*, 831–838. [CrossRef]
83. Farooq, Q.U.A.; McComb, J.; Hardy, G.E.S.J.; Burgess, T.I. Soil Amendments for Management of Phytophthora Root Rot in Avocado and Their Impact on the Soil Microbiome. *J. Plant Pathol.* **2024**, *106*, 439–455. [CrossRef]
84. Garau, M.; Pinna, M.V.; Nieddu, M.; Castaldi, P.; Garau, G. Mixing Compost and Biochar Can Enhance the Chemical and Biological Recovery of Soils Contaminated by Potentially Toxic Elements. *Plants* **2024**, *13*, 284. [CrossRef] [PubMed]
85. Gabhane, J.; William, S.P.; Bidyadhar, R.; Bhilawe, P.; Anand, D.; Vaidya, A.N.; Wate, S.R. Additives Aided Composting of Green Waste: Effects on Organic Matter Degradation, Compost Maturity, and Quality of the Finished Compost. *Bioresour. Technol.* **2012**, *114*, 382–388. [CrossRef]
86. Sanad, H.; Moussadek, R.; Dakak, H.; Zouahri, A.; Oueld Lhaj, M.; Mouhir, L. Ecological and Health Risk Assessment of Heavy Metals in Groundwater within an Agricultural Ecosystem Using GIS and Multivariate Statistical Analysis (MSA): A Case Study of the Mnasra Region, Gharb Plain, Morocco. *Water* **2024**, *16*, 2417. [CrossRef]
87. Wang, Q.; Wang, Z.; Awasthi, M.K.; Jiang, Y.; Li, R.; Ren, X.; Zhao, J.; Shen, F.; Wang, M.; Zhang, Z. Evaluation of Medical Stone Amendment for the Reduction of Nitrogen Loss and Bioavailability of Heavy Metals during Pig Manure Composting. *Bioresour. Technol.* **2016**, *220*, 297–304. [CrossRef] [PubMed]
88. Lin, H.; Sun, W.; Yu, Y.; Ding, Y.; Yang, Y.; Zhang, Z.; Ma, J. Simultaneous Reductions in Antibiotics and Heavy Metal Pollution during Manure Composting. *Sci. Total Environ.* **2021**, *788*, 147830. [CrossRef] [PubMed]
89. Duan, Y.; Yang, J.; Guo, Y.; Wu, X.; Tian, Y.; Li, H.; Awasthi, M.K. Pollution Control in Biochar-Driven Clean Composting: Emphasize on Heavy Metal Passivation and Gaseous Emissions Mitigation. *J. Hazard. Mater.* **2021**, *420*, 126635. [CrossRef] [PubMed]
90. Peng, W.; Li, X.; Xiao, S.; Fan, W. Review of Remediation Technologies for Sediments Contaminated by Heavy Metals. *J. Soils Sediments* **2018**, *18*, 1701–1719. [CrossRef]
91. Yousif Abdellah, Y.A.; Shi, Z.-J.; Luo, Y.-S.; Hou, W.-T.; Yang, X.; Wang, R.-L. Effects of Different Additives and Aerobic Composting Factors on Heavy Metal Bioavailability Reduction and Compost Parameters: A Meta-Analysis. *Environ. Pollut.* **2022**, *307*, 119549. [CrossRef] [PubMed]
92. Chen, Y.; Xu, Y.; Qu, F.; Hou, F.; Chen, H.; Li, X. Effects of Different Loading Rates and Types of Biochar on Passivations of Cu and Zn via Swine Manure Composting. *J. Arid Land* **2020**, *12*, 1056–1070. [CrossRef]
93. Liu, H.; Wang, L.; Zhong, R.; Bao, M.; Guo, H.; Xie, Z. Binding Characteristics of Humic Substances with Cu and Zn in Response to Inorganic Mineral Additives during Swine Manure Composting. *J. Environ. Manag.* **2022**, *305*, 114387. [CrossRef] [PubMed]
94. Li, R.; Wang, J.J.; Zhang, Z.; Shen, F.; Zhang, G.; Qin, R.; Li, X.; Xiao, R. Nutrient Transformations during Composting of Pig Manure with Bentonite. *Bioresour. Technol.* **2012**, *121*, 362–368. [CrossRef]
95. Villaseñor, J.; Rodríguez, L.; Fernández, F.J. Composting Domestic Sewage Sludge with Natural Zeolites in a Rotary Drum Reactor. *Bioresour. Technol.* **2011**, *102*, 1447–1454. [CrossRef] [PubMed]
96. Umair Hassan, M.; Huang, G.; Munir, R.; Khan, T.A.; Noor, M.A. Biochar Co-Compost: A Promising Soil Amendment to Restrain Greenhouse Gases and Improve Rice Productivity and Soil Fertility. *Agronomy* **2024**, 1583. [CrossRef]
97. Guidini Lopes, I.; Wiklicky, V.; Ermolaev, E.; Lalander, C. Dynamics of Black Soldier Fly Larvae Composting—Impact of Substrate Properties and Rearing Conditions on Process Efficiency. *Waste Manag.* **2023**, *172*, 25–32. [CrossRef]
98. Attiogbe, F.K.; Ayim, N.Y.K.; Martey, J. Effectiveness of Black Soldier Fly Larvae in Composting Mercury Contaminated Organic Waste. *Sci. Afr.* **2019**, *6*, e00205. [CrossRef]
99. Maaouane, M.; Dobrović, S.; Zouggar, S.; Krajačić, G. Alternative Municipal Solid Waste Management Systems in Morocco: Energy Savings and GHG Emission Reduction. In Proceedings of the Sustainability in Energy and Buildings 2020; Littlewood, J., Howlett, R.J., Jain, L.C., Eds.; Springer: Singapore, 2021; pp. 55–73.
100. Pardo, G.; Moral, R.; Aguilera, E.; Del Prado, A. Gaseous Emissions from Management of Solid Waste: A Systematic Review. *Glob. Change Biol.* **2015**, *21*, 1313–1327. [CrossRef] [PubMed]
101. Wei, Y.; Li, J.; Shi, D.; Liu, G.; Zhao, Y.; Shimaoka, T. Environmental Challenges Impeding the Composting of Biodegradable Municipal Solid Waste: A Critical Review. *Resour. Conserv. Recycl.* **2017**, *122*, 51–65. [CrossRef]

102. Jiang, Y.; Liu, J.; Huang, Z.; Li, P.; Ju, M.; Zhan, S.; Wang, P. Air Bag Bioreactor to Improve Biowaste Composting and Application. *J. Clean. Prod.* **2019**, *237*, 117797. [CrossRef]
103. Andraskar, J.; Yadav, S.; Kepley, A. Challenges and Control Strategies of Odor Emission from Composting Operation. *Appl. Biochem. Biotechnol.* **2021**, *193*, 2331–2356. [CrossRef] [PubMed]
104. Li, H.; Zhang, T.; Tsang, D.C.W.; Li, G. Effects of External Additives: Biochar, Bentonite, Phosphate, on Co-Composting for Swine Manure and Corn Straw. *Chemosphere* **2020**, *248*, 125–927. [CrossRef] [PubMed]
105. Waqas, M.; Hashim, S.; Humphries, U.W.; Ahmad, S.; Noor, R.; Shoaib, M.; Naseem, A.; Hlaing, P.T.; Lin, H.A. Composting Processes for Agricultural Waste Management: A Comprehensive Review. *Processes* **2023**, *11*, 731. [CrossRef]
106. Moral, R.; Paredes, C.; Bustamante, M.A.; Marhuenda-Egea, F.; Bernal, M.P. Utilisation of Manure Composts by High-Value Crops: Safety and Environmental Challenges. *Bioresour. Technol.* **2009**, *100*, 5454–5460. [CrossRef] [PubMed]
107. Masmoudi, S.; Magdich, S.; Rigane, H.; Medhioub, K.; Rebai, A.; Ammar, E. Effects of Compost and Manure Application Rate on the Soil Physico-Chemical Layers Properties and Plant Productivity. *Waste Biomass Valorization* **2020**, *11*, 1883–1894. [CrossRef]
108. Aouass, K.; Kenny, L. Nitrogen Use Efficiency and Yield of Broccoli Crop Fertilized with Compost and Synthetic Fertilizer in Arid Region of Morocco. *Bulg. J. Agric. Sci.* **2023**, *29*, 277–284.
109. Cao, H.; Liu, J.; Ma, S.; Wu, X.; Fu, Y.; Gao, Y. Selection of Suitable Organic Amendments to Balance Agricultural Economic Benefits and Carbon Sequestration. *Plants* **2024**, *13*, 2428. [CrossRef] [PubMed]
110. Cabañas-Vargas, D.D.; Sánchez-Monedero, M.A.; Urpilainen, S.T.; Kamilaki, A.; Stentiford, E.I. Assessing the Stability and Maturity of Compost at Large-Scale Plants. *Ingenieria* **2005**, *9*, 25–30.
111. Tabrika, I.; Mayad, E.H.; Furze, J.N.; Zaafrani, M.; Azim, K. Optimization of Tomato Waste Composting with Integration of Organic Feedstock. *Environ. Sci. Pollut. Res.* **2021**, *28*, 64140–64149. [CrossRef]
112. Langsdorf, A.; Volkmar, M.; Holtmann, D.; Ulber, R. Material Utilization of Green Waste: A Review on Potential Valorization Methods. *Bioresour. Bioprocess.* **2021**, *8*, 19. [CrossRef]
113. Mengqi, Z.; Shi, A.; Ajmal, M.; Ye, L.; Awais, M. Comprehensive Review on Agricultural Waste Utilization and High-Temperature Fermentation and Composting. *Biomass Conv. Biorefinery* **2023**, *13*, 5445–5468. [CrossRef]
114. Zhang, L.; Sun, X. Using cow dung and spent coffee grounds to enhance the two-stage co-composting of green waste. *Bioresour. Technol.* **2017**, *245*, 152–161. [CrossRef] [PubMed]
115. Liu, K.; Price, G.W. Evaluation of Three Composting Systems for the Management of Spent Coffee Grounds. *Bioresour. Technol.* **2011**, *102*, 7966–7974. [CrossRef]
116. Tabrika, I.; Mayad, E.H.; Zaafrani, M.; Guilli, M.E.; Azim, K. Optimization of Solid Phosphate Sludge Composting by Integration of Horticultural Waste. *Org. Agric.* **2020**, *11*, 319–325. [CrossRef]
117. Bojarski, W.; Czekała, W.; Nowak, M.; Dach, J. Production of Compost from Logging Residues. *Bioresour. Technol.* **2023**, *376*, 128878. [CrossRef] [PubMed]
118. Aydi, S.; Sassi Aydi, S.; Rahmani, R.; Bouaziz, F.; Souchard, J.P.; Merah, O.; Abdelly, C. Date-Palm Compost as Soilless Substrate Improves Plant Growth, Photosynthesis, Yield and Phytochemical Quality of Greenhouse Melon (*Cucumis melo* L.). *Agronomy* **2023**, *13*, 212. [CrossRef]
119. Hakimi, F.; Sebbar, A.; Bouamri, R.; Sidikou, A.A.H.; El Janati, M.; Bouaziz, A. Effects of Compost and Compost Tea on Soil Properties and Nutrient Uptake of the Moroccan Date Palm Cultivar "Mejhoul" under Organic Cultivation. *J. Ecol. Eng.* **2024**, *25*, 224–240. [CrossRef]
120. Ortiz, C.; Yagüe, M.R.; Valdez, A.S.; Molina, M.G.; Bosch-Serra, À.D. Sustainability of Organic Fertilizers Use in Dryland Mediterranean Agriculture. *Agriculture* **2024**, *14*, 1301. [CrossRef]
121. Bouras, H.; Devkota, K.P.; Mamassi, A.; Loudari, A.; Choukr-Allah, R.; El-Jarroudi, M. Unveiling the Synergistic Effects of Phosphorus Fertilization and Organic Amendments on Red Pepper Growth, Productivity and Physio-Biochemical Response under Saline Water Irrigation and Climate-Arid Stresses. *Plants* **2024**, *13*, 1209. [CrossRef] [PubMed]
122. Jjagwe, J.; Chelimo, K.; Karungi, J.; Komakech, A.J.; Lederer, J. Comparative Performance of Organic Fertilizers in Maize (*Zea mays* L.) Growth, Yield, and Economic Results. *Agronomy* **2020**, *10*, 69. [CrossRef]
123. Helgason, B.L.; Larney, F.J.; Janzen, H.H. Estimating Carbon Retention in Soils Amended with Composted Beef Cattle Manure. *Can. J. Soil Sci.* **2005**, *85*, 39–46. [CrossRef]
124. Hirich, E.H.; Bouizgarne, B.; Zouahri, A.; Ibn Halima, O.; Azim, K. How Does Compost Amendment Affect Stevia Yield and Soil Fertility? In Proceedings of the 2nd International Laayoune Forum on Biosaline Agriculture, Virtual, 14–16 June 2022; p. 46.