

The Impact of Technophobia on Vertical Farms

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Abstract: Today's rapidly changing economic and social environment requires many new and sustainable solutions for the agricultural sector, in particular in terms of achieving higher yields and conserving arable land. However, the latest technologies and innovative ideas could answer these issues and even support a smooth transition into a green economy. The current work studies one of the best solutions—consumer acceptance. Even though vertical farming is relatively widely researched, the potential clients are seldom analysed. The applied systematic literature review (PRISMA) approach revealed various vital characteristics related to the consumers based on academic publications. According to the selected studies' results, consumers' adoption of innovative technology is most influenced by prior knowledge of vertical farming and the importance of sustainability. Some studies found further correlations between age and gender regarding adoption, while others did not investigate these or found their role irrelevant. Most consumers found vertical farming "too artificial" and identified this as a major inhibiting factor. However, further investigation has shown that appropriate and informative marketing could significantly increase the understanding of the concept and, through this, the acceptance and widespread practical application of the innovation. In addition, the authors want to use the current work to highlight the unsettled state of vertical management. It can be concluded that new regulations could increase confidence in vertical farming, which could be further supported by the theoretical model developed in this study, thus allowing the creation of a fully traceable product chain.

Keywords: vertical farming; acceptance; traceability; systematic review

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1. Introduction

The world's population is constantly growing. Adequate food supply for people can be ensured by bringing new areas into agricultural production and/or intensifying production on existing land. At the same time, the quality of water, soil, and air needed for production is limited, and existing resources are often highly polluted [1–4]. These challenges are faced most by China, India, and countries on the African continent [5,6]. In more developed areas of the world, such as Europe, consumers' preferences for food have changed, which could contribute to the transformation of agriculture [7–9]. This change is partly due to the EU's Green Deal (similar to the United Nations' Sustainable Development Goals), which encourages Member States and their citizens to go green [10–12]. The Sustainable Development Goals (SDGs) are interconnected aims. They were defined to provide a more sustainable and equitable future for the globe's population. The 17 SDGs could be considered frameworks for governments, civil societies, private sectors, and individuals to evaluate their green operations and improve their sustainable run through these assets. Although the problems related to agriculture in various locations (especially in developed and developing countries) seem pretty different, vertical farming can offer solutions to these. Vertical farming is a type of indoor farming that increases the resource and land-use efficiency within horticulture. This form of plant cultivation is conducted by

a vertically stacked irrigation system in addition to natural or artificial light [13]. The plants are cultivated in a soil-free environment and watered by hydroponic or aeroponic technology. This approach's advantages are yield consistency, isolation from pathogens, urban agriculture, shorter food supply chain, seasonal independence, higher nutrient content and product consistency, growing crops not suited to local conditions, and high profitability [14–17]. With sensors and robotised solutions, vertical farms can become more effective and efficient [18]. Naturally, vertical farming faces difficulties too, such as high start-up and operating costs and long payback periods (the application of renewable resources could significantly influence them) [19–23]. One of the most significant disadvantages of this indoor farming is the limited crop types. Generally, salad leaves and other small leafy vegetables are the most often harvested crops, but strawberries could occasionally be found in vertical farms too. The microgreens' small size allows a high number of plants (vertically and horizontally), and their fast-growing increases the harvest per "season", which positively affects the profit [24,25]. The potential application of GM (Genetically Modified) crops could alleviate the low number of diverse crops [26]; although, it would open up other concerns [27]. In developing countries, somewhat limited resources affect food production [28,29], whereas in wealthier countries, it is influenced by consumer attitudes [30]. In developed countries, consumer attitudes influence public perception, purchasing behaviour, and government policies. Administration operations worldwide support sustainable agriculture and consumption thanks to the SDGs. Therefore, consumer attitudes seem to be one of the core factors that could affect the application and spread of the various sustainable alternatives. Their point of view also influences the form and type of investments in this field [31]. This article aimed to analyse the published scientific works on consumers' acceptance of vertical farm products. The study also reveals concerns regarding the lack of regulation and suggests a theoretical frame enhancing traceability.

2. Materials and Methods

To conduct a comprehensive literature review, a wide range of articles regarding vertical farming were collected from the three most recognised online databases: Scopus, Web of Science, and Science Direct. The used keyword was "vertical farming". In the title, abstract or keywords, this expression had to occur. The involved articles had to be based on a survey, but the limited number of quantitative studies led us to extend with qualitative works too. Only English studies were involved. The references from the studied works were also checked to obtain the broadest spectrum. However, none of them could be involved, which could be caused by the speciality of the topic. The well-known online databases, such as World Bank, Eurostat or OECD, do not collect topic-related information, and relevant non-peer-reviewed reports (grey literature) were not found. From the scientific databases, 814 items completed the formerly presented requirements. The online platform Rayyan was used [32] to conduct the systematic literature review, where the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach was applied. The concept is used to identify the motivation, methodology, and findings of the analysed article [33]. The original idea was released in 2009 [34], but after a decade, in 2020, it was extended [35]. The method starts with the identification of the research question. This step is followed by the search strategy, where the relevant databases are sought. Then, the publications are reviewed based on their titles, abstracts, or full texts. According to the selection criteria, the works are classified. The potential disagreements must be resolved by the authors' discussion or by the involvement of an unbiased colleague. If there is agreement, the data extraction can be started. In the next stage, the authors can go into detail, evaluate the more exact points, and select the most relevant publications regarding the research question. Based on these studies, the data synthesis can be performed and presented. According to the demonstrated points, the below presented (Figure 1) multi-round screening was applied.

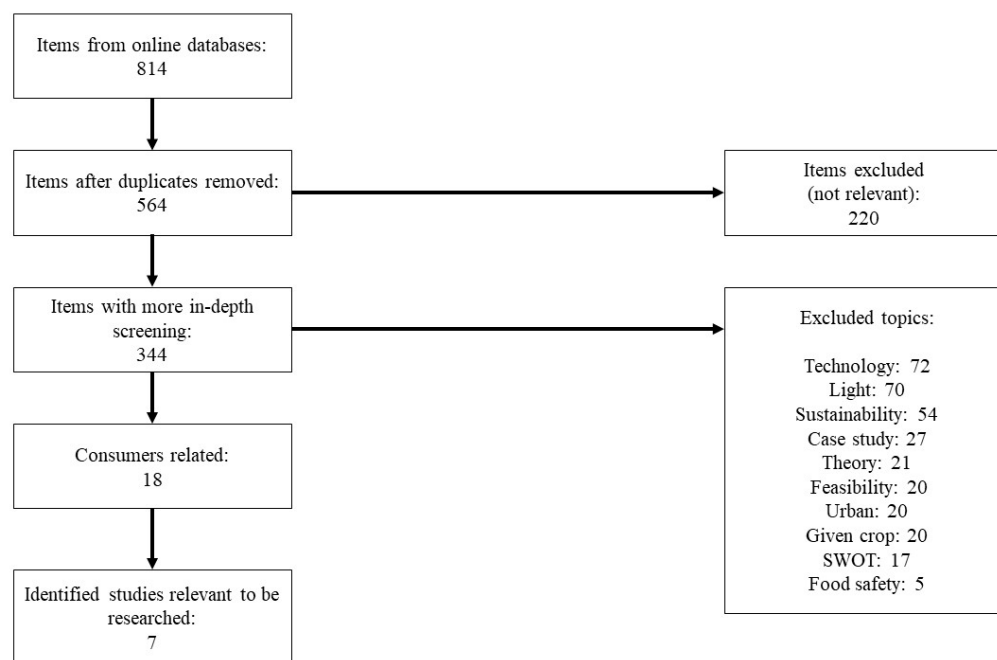


Figure 1. Pathway of the systematic literature review based on the PRISMA concept. Source: Own elaboration, 2023.

The duplicates and irrelevant works were selected by Rayyan. After these were sorted out, 564 research works remained. These formed the basis of the systematic literature review. The abstracts, as the initial screening, were read by the authors. The contradictory opinions were discussed. The screening resulted in 220 excluded articles. Then, the remaining 344 studies were deeply examined to specify the various fields within the topic of vertical farming. This matter is a mix of diverse sciences. In addition, its possible advantages could considerably support the realisation of SDGs that are widely studied nowadays. These could explain why so many articles were involved and later excluded from the current review. The distribution of the leading research directions within vertical farming was the following: technology: 72; light: 70; sustainability: 54; case study: 27; theory: 21; feasibility: 20; urban: 20; given crop: 20; acceptance: 18; SWOT: 17; food safety: 5. At the end of the selection, only seven relevant academic publications were left, which could not be extended with any other reports. The current work covers all the related publications until 19 December 2022.

As mentioned earlier, many scientists consider vertical farming a game changer. Regarding the advantages of this agricultural form, it affects, directly and indirectly, many SDGs. These aims came into force in 2016, and the number of related publications has risen since then. The pandemic also intensified related studies, as seen in Figure 2.

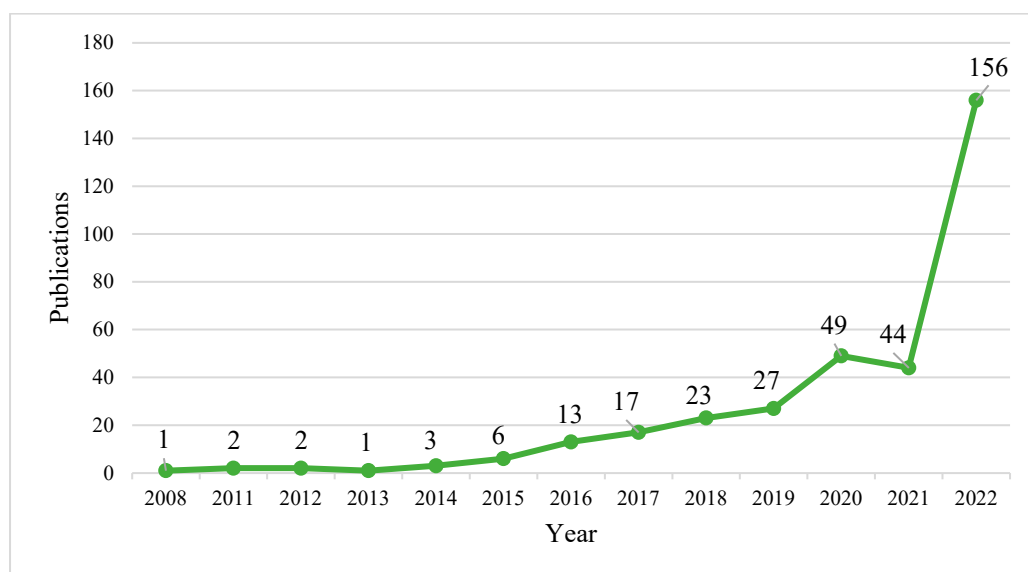


Figure 2. The identified vertical farming studies by year of publication (only items with more in-depth screening). Source: Own elaboration; the collection covers studies available on 19 December 2022, 2023.

3. Results

3.1. Related Reviews

The number of related articles is high, and many reviews have been published too. The mixed approach to the topic provides various research directions within vertical farming. Although the idea is not new, the continuous technical progress allows the efficiency of its operation to be increased through the results of emerging research. Table 1 shows the share of the identified research directions within the topic.

Table 1. Share review articles according to the studied fields.

Sustainability	18
Technology	17
SWOT	5
Indoor farm	5
Light	4
Given crop	3
Theory	3
Urban	3
Food safety	2
Feasibility	1

Source: Own elaboration, 2023.

The analysis of the published reviews revealed the lack of technology acceptance studies, which could be caused by the lack of consumer-related research. This type of indoor farming is still emerging—with excellent prospects—but is used sporadically. Enormous vertical farms can be found around the world (the Arabic and Asian countries, in addition to the USA, operate a lot), and this farming method is more common than it seems. The technology is mature and standardized, which can be ordered through many companies [36]. There are even calculators to estimate the investment, cost, yield, and profit related to vertical farming [37,38]. It is also available in small-scale versions, which could be used for pilot projects or diversification. Despite its maturity and large-scale application, consumer-acceptance-related studies have not been widely published. However, through acceptance, the increased demand would serve not only financial but

environmental aims too. Figure 3 shows how this farming could contribute to the realisation of various Sustainable Development Goals.

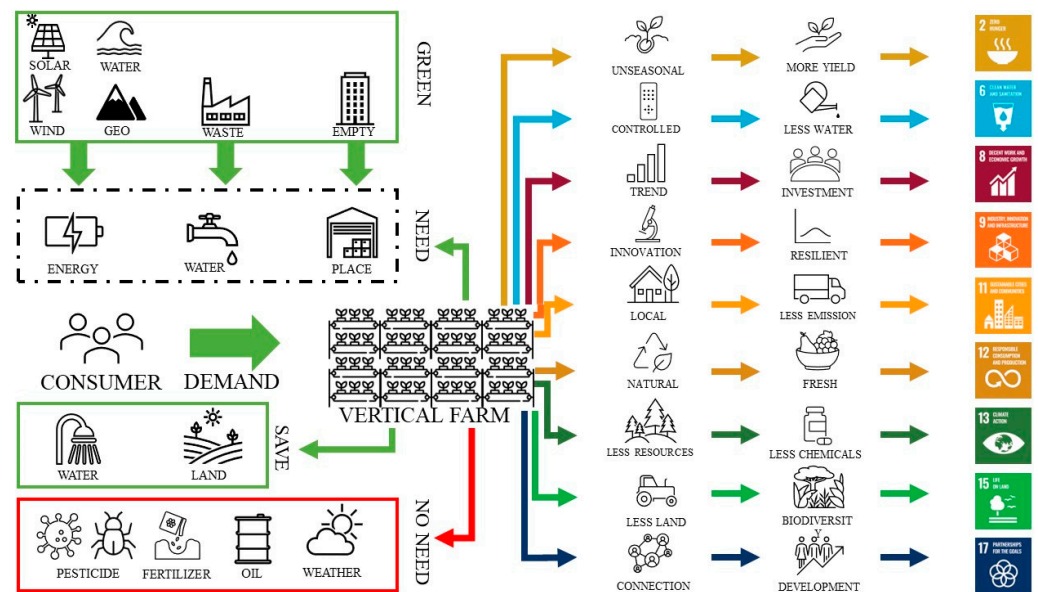


Figure 3. The vertical farms' contribution to the Sustainable Development Goals, Source: Own elaboration, 2023.

The benefits of vertical farming could provide significant support to the residents of (crowded) urban areas, and arid and northern regions since the limited space, resources, and time frame could be replaced by the controlled environment. However, not only could their well-being be improved, but the increased yield and higher food security could eliminate hunger and malnutrition. The shorter the transportation, the less energy and (no) chemicals, which would reduce greenhouse gas emissions and its carbon footprint. The more efficient use of resources is also one of the most significant advantages of vertical farming.

3.2. Academic Papers

The study by Jürkenbeck et al. 2019 [39] analysed the key drivers for the acceptance of vertical farming and the behavioural intention to buy its products or the system itself. The data were collected online in Germany in February 2018. The sample of 482 surveyed mimicked well the German population regarding gender, age, and education and even represented well the number of persons per household and the net household income. The questionnaire measured the socio-demographic features, knowledge, and general attitudes toward agriculture and food on a five-point Likert scale. The researchers applied a between-subjects design. The participants were randomly distributed into one of the three systems (home vertical farm, in-store vertical farm, and indoor vertical farm). The involved received the same brief with a short description of vertical farming and its advantages and disadvantages. Each group member also received another specialised description related to their own (formerly assigned) vertical farm.

The descriptive statistics revealed that more than three-fourths of the respondents had never heard of vertical farming, while the rest were better informed or unsure if they had heard about it. More than 80% found environmental friendliness to be an essential aspect of vertical farming, but around 60% of the respondents were sceptic regarding the decreased fertiliser use in vertical farming. However, nine out of ten considered the systems' reduced pesticide usage beneficial for the environment. Only one-fourth of respondents from the home farm group showed interest in buying the given system because of its features, and the same share found it too artificial. In addition, only one-third of the

participant from this cluster showed a readiness to purchase its products. Half of the in-store group planned to buy the described system despite four out of ten finding it too artificial. Despite all that, 55% of this cluster would buy products from in-store vertical farms. The indoor vertical farm group's respondents showed the highest interest (50.3%) in buying the system because of its features. Nearly all who would purchase the system would buy its products; although, 31% of them found it too artificial.

Based on the semantic differentials, the home vertical farm differs significantly from the other groups in the sustainability evaluation (it seems the worse alternative). In contrast, the indoor version seems the most trendsetting. The authors observed the larger the system, the more positive the assessment of the system is. The R^2 values for the endogenous latent variables and path coefficients revealed that perceived usefulness positively affects the attitude towards buying in all cases. The perceived sustainability had the same impact on the perceived usefulness and the attitude toward buying on the behavioural intention to buy. The study also highlights that a healthy diet, environmental friendliness, and combating hunger affect the purchase decision more than the attitude toward sustainability. In addition, the latter is also influenced positively by perceived usefulness because the respondents found it a new way to produce food locally.

Specht et al.'s 2019 [40] work aimed to study the perception of sustainability, social acceptability, and ethical aspects of the new waves of urban food production. The chosen alternatives were the followings: rooftop greenhouses, vertical farms, indoor farms, aquaponics, insects, and algae. The research was based on the qualitative content analysis of 19 interviews. The interviewees were experts (in practice or research) in their field. Three of them were asked about vertical farming. Mostly the participants were German and American. The 35 min long interviews were conducted in person or online between May and July 2018.

Regarding the studied factors that could hamper the acceptance of vertical farming, only two did not occur. Concerning the production methods and the applied technologies, general scepticism, contrasting images of agriculture, and the rejection of associated technologies could hinder acceptance. At the same time, the potential conflicts between different urban user groups and ethical aspects related to the keeping and killing of animals would not cause any trouble. Regarding the uncertain impacts and relevance, the uncertainties about the potentially positive impacts and the relevance and embeddedness of vertical farming in the cities were highlighted. The barriers to the vertical farms' products could also be the negative connotation of their taste, appearance, and association with health risks. The experts thought the hesitation toward a long-lasting adoption and the image of an elite product could impede vertical farming acceptance.

The research of Kalantari and Akhyani [41] aimed to identify the community acceptance factors of vertical farming in Kuala Lumpur (Malaysia). The mix-method research developed a conceptual framework based on the literature review. This framework was presented to experts (four professors) to identify those factors that most likely affect community acceptance and suggest others if they think so. These interviews were studied through content and frequency analysis. These created the base of a qualitative questionnaire. The main attributes of it were perceived benefit, perceived risk, value and belief, and location, which were measured on a five-point Likert scale. A pilot test was undertaken in April 2019 on 30 participants to test and guarantee the reliability of the questionnaire. The data were collected from May 2019 to June 2019 during the daytime in Kuala Lumpur. At the end of the random selection, 403 participants were involved. The researchers provided a one-page description of vertical farming for each participant (because of the lack of related knowledge).

The application of exploratory factor analysis on the "perceived benefit" defined four factors. One of these is landscape greening, a mix of social, economic, and environmental benefits. Based on the respondents' answers, sustainability creates the environmental benefit factor. The third factor was called economic benefit. This factor included reducing food prices and energy costs, more job opportunities and valuable food. The last factor was

named social benefit, which provides spiritual health for the citizens. Related to the perceived risk, three factors were identified. The surrounding area was concerned with the noises, smells, and conflicts connected to vertical farms. The second factor is called the economic concern of vertical farm implementation. According to the surveyed respondents, the vertical farm requires high investment. The last factor within the concerns was the socio-economical one. Besides the worries about local farmers and property prices, artificial food production appeared here.

The application of exploratory factor analysis on value and belief revealed three components: ecocentric, apathetic, and anthropocentric. The ecocentric component includes the variables related to the preservation of the environment (especially forests). The apathetic factor showed up: not all involved felt responsible for the environment. The anthropocentric component lights up the critical role of humanity. The variables listed here stress that everything could be used but reject what does not provide an advantage for the population. The evaluation of location dimension defined three components. Anywhere meant that the surveyed were not worried about the location, so they could imagine vertical farms even next to their house. The developed area factor involved those variables related to already existing buildings. Many of the respondents found the utilization of empty buildings for this purpose to be ideal. The last “vacant” component highlighted that not all the respondents were worried about green, vacant areas for vertical farming. Probably they found the reconstruction of old buildings more cost-intensive.

The study by Perambalam et al. 2021 [42] investigated consumer acceptance regarding vertical farming in Nordic areas, especially focusing on young customers. The data were collected through surveys from Denmark, Sweden, and Norway. However, the study was limited to Denmark because the lack of respondents from other countries could risk the validity and credibility of the research. The database was established on 111 answers. The first part of the questionnaire focused on demographic questions such as gender, age, education, and income. The following part asked about existing knowledge and attitudes towards vertical farming. (A 3-point scale: “yes”, “maybe”, and “no” was used for these purposes.) The Technology Acceptance Model’s (TAM) questions were randomised to avoid influencing the answers.

Half (51%) of the respondents said they had heard about vertical farming, while the other half (48%) had not. The analysis highlighted the willingness to pay extra for environmentally friendly products (79%), while only 20% of the respondents rejected this. Only 13.5% of the respondents have bought anything from this type of agriculture, while the overwhelming majority (86.4%) have never. The low share of previous experience does not hinder the trust in vertical farming. Generally, the surveyed trust these farms (73.8%) and would purchase their products. Only 16.2% could not trust them. The low share of previous purchasers could be explained by the lack of opportunities because eight out of ten have never seen any vertical farms or their products during shopping. The lack of vertical farms in their region could be the problem’s source, which was chosen the most often (77%). The pricing of their products is divided among the involved. Mostly, the consumers found the price reasonable (41%), 22% found it “maybe” reasonable, and the rest (36%) did not find it appropriate. Even for the respondents that trust vertical farms, the majority think that agriculture’s future is not the vertical farm (66.7%), while 18.9% thought the reverse.

Regarding its future role, the respondents were asked about investment in vertical farming stocks. Only one-fifth showed a willingness to buy it. One-third of the respondents (31,5%) rejected this opportunity, while most did not share their opinion. The TAM model revealed that the perceived sustainability and the subjective norm considerably influence the attitude toward buying.

The research of Ares et al. 2021 [43] aimed to study consumer attitudes to vertical farming in the USA, UK, Singapore, and China. In each country, 637–683 participants were involved with matched gender and age group distributions. After a pilot study (10% of the total sample in each country), the data were collected through an online questionnaire

in April and May 2021. The survey used a seven-point Likert scale and contained three tasks: text highlighting (the core idea of this new methodology is to highlight those aspects from the given text that the respondents ‘like’ and ‘dislike’), attitudinal statements, and choice tasks. The participants were asked about their fruit and vegetable consumption habits and prior knowledge of vertical farming. In the end, demographic and socio-economic questions were found.

In all the countries, the respondents showed a positive attitude towards vertical farming, especially regarding controlled growing conditions, fresh products, and global food supply. These aspects were scored around five (slightly in agreement). A negative attitude was measured (score under four) regarding the location of vertical farms. The surveyed would not prefer them in or near cities; in addition, they would not give back the land (which is not used anymore for agricultural purposes) to nature. Related to the application of robots for planting and harvesting, the scores were measured between 4.1 (UK) and 5.5 (China) (slightly disagree–slightly agree). The respondents were worried about high energy consumption (4.6–5.1). Generally, a positive attitude towards vertical farming was measured in all the countries. However, the Chinese respondents liked it the most, while the UK’s respondents the less.

The text highlighting showed up those aspects that the surveyed liked the most. The highest sentiment scores belonged to the increased yield for salad greens and herbs, controlled growing conditions in nutrient-rich water, supply of fresh products harvested less than 24 h earlier, location in/near cities to reduce transport-related carbon emissions and secure food supply, protection of the environment, and returning agricultural land to nature. The study revealed significant differences between countries, where China differed mainly from the other countries. There the environmental aspects were less critical. Singapore showed the highest interest in vertical stacking (optimal space usage) and in/near city-located vertical farms to reduce the emission of transportation and provide a secure food supply.

Regarding the average sentiment scores, the respondents from the UK and Singapore appreciated vertical farming more positively than the USA and China. The possible premium price and the high energy requirements received the most negative judgment in the analysis. The respondents from UK and Singapore resisted the most against them, while the UK’s surveyed were the most negative regarding the high energy consumption. The authors identified two sentences where the judgements varied across the four countries. The difference is not so high but can be relevant. The UK’s score was negative regarding their trust in the IT system used to oversee and plan production. The USA and China were found to be positive that in some countries fewer fruits and vegetables are grown than would be needed to feed their population, so they rely on imports. In contrast, the same expression was negative for the respondents from the UK and Singapore.

In the choice task, the respondents were asked to indicate which aspects of vertical farming form their overall opinion about this topic the most and least. The highest scores belonged to increased yield, reduction in carbon emissions and availability of fresh fruits and vegetables. The countries did not show any relevant differences in their average importance. The factors that affected the least the surveyed opinion were the premium prices and reliance on robotics and IT systems. In this case, significant differences were measured between China and the rest of the countries. The Chinese respondents saw the application of robotics and IT systems’ role as less important than the role of premium prices.

Three groups were defined based on the cumulated answers of the involved countries (more than 2400 responses). The highest share (63%) showed a positive attitude (positive cluster) towards vertical farming. They were more positive towards the advantages of vertical farming and less negative towards its disadvantages. In their case, only the possible premium price was estimated negatively. Vertical farming was neutral (neutral cluster) for 17% of the whole sample, while 20% was negative (negative cluster) related to this topic. For the neutral respondents, the statements’ values varied between positive and negative. In the negative group, only one sentiment was positively indicated (the average

sentence sentiment scores were always negative), the one that writes about the return of formerly used agricultural land to nature. The authors analysed the diverse groups, where statistically significant differences were found in the distribution of diverse clusters according to country, gender, educational level, and working status. The positive group involved mostly respondents from Singapore and China. There were more men and full-time workers with higher educational levels than in the other two groups. Statistically significant differences in age group and household composition were not found in the three clusters. In addition, the clusters did not differ regarding the involvement in household grocery shopping or fruit and vegetable consumption. The study highlights that the positive cluster's members heard about vertical farming previously with a higher probability (70%) than the others (57–59%).

The work of Zhou et al. 2022 [44] focused on the social acceptance of indoor agritecture (“agri”culture + archi“ecture”) among consumers and experts in Shanghai (China). This mixed-method research included a survey to analyse the potential consumers' acceptance and perceptions of vertical farms. The questionnaire contained 31 questions divided into five parts. The main topics were current food-purchasing behaviour, environmental perceptions of vertical farming, participation willingness and marketing opportunities, planning-related questions, and demographical questions. The data were collected between October and November 2013. The authors could involve randomly 941 respondents, but after data-cleaning and digitalizing, 713 answers were left, which created the basis for the analyses.

The respondents showed high (84%) acceptance regarding developing a vertical farm in Shanghai. Since a binary scale was used for this question, a polychoric correlation matrix had to be applied to analyse the connections between the variables. The statistical test revealed that the distance to the current food shopping location, younger age, lower income, and gender (females more likely to accept) were closely related to the acceptance of vertical farming. However, the household size, the distance between the respondents' homes to the city centre, and the level of education were not correlated with the acceptance level. Those respondents, who would not accept vertical farms, were asked about its reason. Mostly the artificial aspect of the system was named, but the preference of conventional agriculture was often chosen. The lack of interest in the topic was also a significant reason behind the rejection. However, the farm's economic viability, potential food safety risks, the potential indirect influence of the poor megacity environment on a vertical farm, and the sufficiency of the food supply from neighbouring provinces were chosen too. Eco-technical questions were asked to identify the most and the least accepted environmental practices. According to the respondents, feeding aquatic animals within a vertical farm is the most acceptable (82.3%), while a closed vertical farm is the least accepted (47.5%). Two out of ten involved accepted all the technologies and their underlying ideas, while eight out of ten agreed with half of the diverse approaches. A moderate polychoric correlation (0.524) was measured between the acceptance of cultivation practices and the overall acceptance of vertical farming. Almost 60% of the involved considered vertical farming a great tool to increase the balance between human development and nature.

The authors also studied the willingness to purchase the products of vertical farming. Only 2.8% rejected this opportunity. The respondents would be ready to buy fruits and vegetables (these were the most commonly indicated, above 75%) and even pay higher prices for organic products if they embody high quality. The overwhelming majority (90%) shopped in supermarkets and markets. A robust statistical relationship was not measured between travel distance for shopping and willingness to buy multiple products from vertical farms. Based on the respondents, food purchasing is mainly influenced by quality, taste, price, brand, and special offers. Organic products are not represented in the top five, but they were averagely higher ranked than brands and special offers. It means fewer consumers prefer these products, but those who do pay a lot of attention to this feature. Nearly everyone (97.3% of respondents) wanted to improve their food shopping

experiences. The most wanted improvements were “more fresh food products” (62.6%) and “more organic food” (59.9%).

The study also involved 20 experts for semi-structured interviews. These 60–90 min long discussions were held between May and July 2016, focusing on the broader concept of agritecture. The interviewees were asked about the potentials and drawbacks of agritecture. The experts stressed the promoting role of time-saving, increased food safety, and extra food source aspects. These could make vertical farming more accepted. Regarding the economic factors, the maturity of the technology and the high investment (which would create a high price for its products) could impede acceptance. At the same time, the positive ecological impact and the optimization of resources could support the acceptance.

The work of Jaeger et al., 2022 [45], used text highlighting to measure the attitudes toward purchasing from vertical farms. This study involved 837 respondents from the UK. The quota sampling is defined 50:50 gender and age group split (younger 18–39 years, older 40–65 years old). The participants had to define English as their primary language and be involved in a minimum of twice a week in grocery shopping. The data collection was realised through text highlighting, a survey based on a seven-point Likert scale, and a questionnaire regarding Food Technology Neophobia (FTN: is a 13-point scale to identify who may resist food made using new technologies). The authors asked the participants about their former knowledge of vertical farming and fruit and vegetable consumption (frequency and proportion of organic fruits and vegetables). The data collection was closed with socio-economic questions. After a pilot test (10%), the data were collected in February 2021.

The general analysis of the text highlighted showed that the expressions related to the growing conditions (such as controlled environment, regulated light, hydroponic, and nutrient-rich water) and consumer benefits (freshly harvested, supplied daily) were liked. In contrast, the respondents disliked mostly the technology-related sentences, such as IT systems, automation, and robots, in addition to the “inside” approach of vertical farming. The previous observation changed slightly when the text was extended with a separate part for pros and contras (related to vertical farming). The same sentences were liked, but this time benefits were more frequently chosen than the growing conditions, and the negative aspects were less frequently disliked than the consumer disadvantages. In the general description, the highest sentiment score was connected to the following sentences: plants grown in fully controlled environments, use of hydroponic systems, and vertical stacking for optimal space use. Whereas if we study the extended pros and contras, the most positively evaluated were those features that are the key advantages of vertical farming: being near cities to reduce carbon emissions, securing food supply, high yield, and return of agricultural land to nature.

The classification of respondents identified three groups. The positive group was the greatest (63%), and the rest was shared nearly equally between the neutral and the negative group. These names cover well the general attitude of the respondents towards vertical farming because the positive group found all the “like” expressions positive, the negative group found all the “dislike” expressions negative, and the neutral find them mixed. Regardless of the group membership, high energy use and premium pricing were negative for everyone. When the general attitude of the whole sample was studied, the authors found around 60% thought vertical farming was a good idea and would try its products. Similar to the cluster’s result, the remaining 40% was shared nearly equally among the neutral and rejecting respondents. The whole sample, like the clusters, showed disagreement regarding the premium price. The study also observed that heterogeneity was related to the potential negative impact of vertical farming, similar to the energy consumption of this farming aspect. It is important to stress the generally positive attitude of UK respondents towards food safety (through vertical farming). The analysis of the connection between Food Technology Neophobia and attitude towards acceptance of vertical farming showed that the positive respondents had lower, the neutral higher, and the negative consumer had the highest scores in FTN. A significant difference was measured

regarding the frequency of purchasing organic fruits and vegetables. The positive group showed a greater tendency than the others. However, conventional fruit and vegetable consumption frequency did not reflect the same. A significant difference was highlighted between the positive group and previous knowledge about vertical farming. Regarding gender, age, education, and income, the three groups did not differ systematically. One significant exception should be mentioned. The women seem to be more frequently classified in the negative group than in the positive.

4. Discussion

Most of the reviewed articles revealed the artificial aspect of vertical farming. The missing acceptance of the controlled environment from the consumers' side could hinder the widespread use of vertical farms. To see the investors' vertical farming as a good business and not just a promise, the consumers would have to show a stable demand, interest, and openness towards this new sustainable farming method. The studies showed a connection between the former knowledge of vertical farming and acceptance of it (and its products). Generally speaking, this alternative form of farming is not widely known, which tends to lead to rejection, and marketing can therefore play a huge role in positioning "new" products. The regulation of the European Parliament and Council [46] sets out food traceability, but sharing this information with consumers is not mandatory. Since more product information could be provided by vertical farming (thus no need to trust in the classical sense), it could enhance the consumers' trust. However, this niche has not yet been exploited [36].

Unfortunately, the lack of regulation could further decrease openness and acceptance. In the European Union, the products of vertical farms cannot be labelled organic because the regulation demands soil [47]. While in the USA, the same products can be sold as organic, even though there are serious debates about this regulation [48]. Supposedly, the producers see the consumers' sceptical attitude, which leads them to hide the (extra) production information. Instead of implementing data sharing and extensive marketing campaigns, they (could) simply market their products as conventional. From the business aspect, hiding the extra information means less risk because the formerly indicated actions require a huge amount of money, but their payback is uncertain. Although with vast investment, those fruits and vegetables that are cultivated in vertical farms (e.g., in the USA) could be marketed under diverse "types" (with various pros and contras).

As Table 2 shows, there are considerable gaps in analysing new product types. In addition, marketing-related studies are also missing. These directions would merit more (scientific) attention. The willingness to pay for extra product information would be worth studying, with a particular focus on vertical farms' products.

Table 2. Alternatives to market the products of vertical farms (out of the EU).

Type	conv.	org.	v.f. + conv.	v.f. + org.	conv. + trac.	org. + trac.	v.f. + conv. + trac.	v.f. + org. + trac.	v.f. + org. + trac.
Acceptance	High e.	High [49]	Low [50]	Low e.	High e.	High e.	Low e.	Low e.	High e.
Certificate	No [51]	Yes [51]	No [51]	Yes [51]	No [51]	Yes [51]	No [51]	Yes [51]	No [51]
Demand	High [52]	High [53]	Low e.	Low e.	High [54]	High [55]	Low e.	Low e.	High [52]
Investment	Average [56]	High [57]	High [58]	High [59]	Extra [60]	Extra [61]	Extra e.	Extra e.	Average [56]
Marketing effort	Low e.	Average [62]	High e.	High e.	High e.	High e.	Extra e.	Extra e.	Low e.
Price	Low [63]	Average [64]	High [65]	High e.	Extra [66]	Extra [67]	Extra e.	Extra e.	Low [63]

Notes: conv: conventional, org: organic, v.f: vertical farm, trac: traceability, e: estimated. The estimated values were concluded from the other product types' features and trends. Source: Own elaboration, 2023.

Those consumers who do not know and understand the operation of this indoor farming could be convinced by the totally traceable products. In this case, a complex and

developed traceability system could be implemented through smart and standardized solutions. This system could serve the highest level of product control (for the certification) and quality goods (through the information) since there is proven demand for traceable products [61,68–70]. Various articles also revealed the consumers' willingness to pay an extra price for the extra product information [71–73]. Numerous works have analysed the diverse methods for implementing the ideal data sharing in traceability systems [74–76]. However, it is not obligatory to base a vertical farm on IoT, but the possibility is given [77–79]. Smart farming solutions could reduce failures [18], and their implementation could open up the highest level of traceability [80]. The various schematic diagrams of the IoT-based approach have been disclosed [81–84], which literally establishes the traceability system's physical requirements. The generated data uploaded in the cloud need to be shared—with the proper rights—with the customers, as shown in Figure 4. Initially, this farming method was built to shorten the supply chain (sell it where you produce it), but minimal transportation and even storage could be involved [85,86]. In this case, the application of scanners or other tools with similar functions (connected to the cloud and referred to as logistics in the figure) has to be included to provide access to all the production and logistic information from farm to fork.

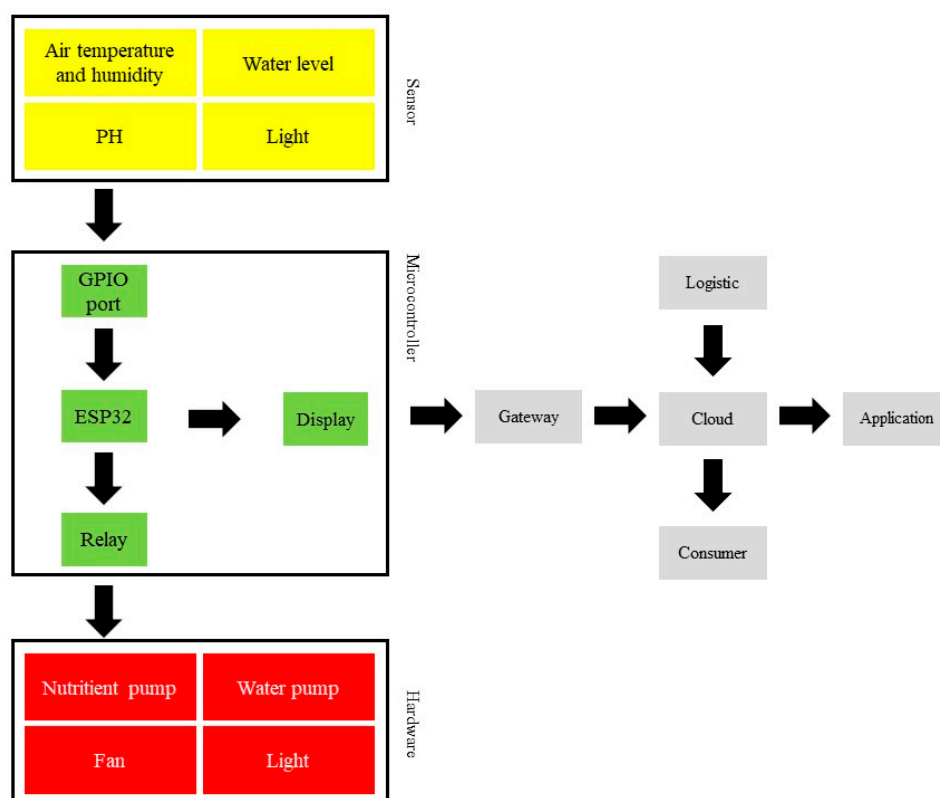


Figure 4. A possible schematic diagram to standardise the farm-to-fork traceability in vertical farms. Source: based on [87], Notes: GPIO: it connects microcontrollers to other electronic devices. ESP32: complete standalone system or a slave device to a host MCU (with integrated Wi-Fi and Bluetooth), Relay: an electrically operated switch. Own elaboration, 2023.

The presented schematic diagram could provide a standard and the basics of a “new” product. It could be beneficial for the Association for Vertical Farming, founded in 2013 in Germany as a leading global non-profit organization, to enable the exchange and cooperation for developing the vertical farming industry [88]. Although it has existed for ten years, until now, only one organisation has been registered (Control Union UK a few months ago) with its help to certify and label vertical farms and their products [89]. Simultaneously with the certification, the regulation of vertical farming should be started. The

authors want to highlight the disordered situation of vertical farming with the current work. If it were considered organic or was given its own category, this would strengthen the knowledge and acceptance of its products. However, the current grey zone is not ideal.

In fact, the biggest driver for the development of vertical farms depends on economic benefits. The investment costs of these farms are generally higher than those of conventional farmers. However, the advantages of lower transport costs, water and energy savings, and resilience to climatic variations mean that vertical farms can be more economical in the long term. Operational costs can be high, especially due to the energy needed to feed crops properly, but the use of automated systems and artificial intelligence can help reduce costs and make operations more efficient.

5. Conclusions

Nowadays, the political, economic, and sociocultural environment is changing rapidly. The pandemic highlighted how fragile the global (food) supply chains are, and that local agricultures are not self-sufficient. The United Nations announced the Sustainable Development Goals to reduce climate change. Since agriculture is one of the core sectors, it affects many of those aims. Technological progress is visible in agriculture too. The maturity of the automated solutions provides an IoT-based controlled environmental approach for the sustainable development of food production. The so-called vertical farming is neither widespread nor widely known. This could be why consumers' acceptance of this new aspect is not so high and has not been deeply analysed. The reviewed publications highlighted the importance of previous knowledge related to vertical farming. More studies measured the connection between that and acceptance of this method. The eco-friendly approach also supported the willingness to purchase from vertical farms. The published scientific works do not agree about the impact of age and gender on the acceptance of vertical farming. However, the too-artificial approach embodied by vertical farms is considered a disadvantage and a reason for rejecting its products. Even the studies found sustainability an important buzzword, based on the respondents, vertical farming will not be the future's agriculture. Publicizing awareness-raising materials, national/international campaigns, and the engagement of influencers could lead to better public awareness and knowledge. The clarified regulations by the local/worldwide organisations could increase trust and traceability, which seem decisive factors. These actions can contribute to the understanding, acceptance, and uptake of vertical farming. In addition, this alternative's cost-effectiveness and risk-resistance features could significantly enhance sustainability. However, the existing regulation enables the product information to be hidden, instead of increasing its sharing. The developed framework provides a theoretical base for vertical farms to maximize the traceability of their products. Although the lack of regulations and certifications also should be solved to support the development of vertical farming and sustainability. Different regions depend to different degrees on vertical agricultural plantations, and the prices of plantations vary in diverse regions, which may lead to differences in the concept of vertical farms. Further research should pay particular attention to and analyse these anomalies.

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