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Analysis of the Operational Efficiency of Agritourism Farms Integrating Green Restaurants and Organic Farming

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Given the limited agricultural production resources, a pivotal concern in the context of sustainable agriculture development concentrates on strengthening agricultural productivity by integrating the concepts of agricultural circular economy into the agricultural production model, thereby achieving maximum economic benefits through optimizing farms' operational efficiency. This study aims to investigate how agricultural farm operators' recycling of agricultural waste for compost in organic farming impacts the production efficiency of organic farming, the market efficiency of green res-taurants and the overall operating efficiency of agritourism farms. To achieve this, this study em-ployed a dynamic network data envelopment analysis (DEA). This study focuses on the top 30 agritourism farms in Taiwan with organic certification and garnered positive online reviews. The results revealed that the highest operating expenses of agritourism farms are for organic fertilizers, which greatly affects their overall efficiency. Recycling agricultural waste for organic compost not only effectively reduces production costs but also significantly improves the overall operating effi-ciency of agritourism farms. The COVID-19 pandemic has severely impacted the overall operating efficiencies of the green restaurants in Taiwan's agritourism farms.The result also showed the only thing that was unaffected by the pandemic was the production efficiency of organic farming, which implies that the public's demand for sustainable agriculture and organic and healthy crops re-mained consistent. Agritourism farms fully utilize their circular economic resources and offer a comprehensive farm-to-fork supply chain of organic crops, which not only stabilizes the food supply but also reduces pollution, lowers operating costs, and stimulates the operating efficiency of farms, ultimately promoting agricultural sustainability.

Keywords: agritourism farms; food supply chain; sustainable agriculture

1. INTRODUCTION

To shorten the distance from agricultural production to the table, reduce the carbon footprint of food transportation, and promote the recycling of agricultural waste, high-tech automated organic agriculture is an effective solution to climate change and the scarcity of agricultural resources worldwide. This study focuses on how to effectively enhance the operational efficiency of agritourism farms and maintain a sustainable living environment, thereby boosting farmers' economic benefits and meeting people's health needs.

Sustainable development is one of the most critical global issues nowadays. All industries are committed to transforming themselves to adapt to evolving develop-ment trends, in addition to initiatives focused on green energy and carbon reduction. It's also important for all industries to take more dimensions into account. De Salvo et al. [1] pointed out that comprehensive social cost–benefit analysis of wind farm pro-jects should take into account not only the negative effects on the integrity of local landscape assets but also the positive effects on global environmental issues such as the contribution to the reduction of global warming. Take agriculture, for example. It has evolved from a primary industry to a service industry to keep up with the chang-ing times. Farms strive to reinforce their attractiveness by going beyond simply selling products. Ammirato [2] argued that farmers are consistently looking for 'new ways' of doing business to increase their competitive advantage in the global market, improve their income sources, expand farm activities, 'use' modern and innovative agricultural products, and develop new customer niches. Such a shift has driven the rise of agri-culture-related travel patterns. D'Alessandro [3] proposed the concept of green tour-ism, a type of tourism promoted by operators who pay special attention to the rela-tionship between tourist activity and nature. This type of tourism involves adopting operational strategies in a spirit of harmony and respect. Additionally, Ammirato et al. [4] considered rural tourism as a growing market offering rural communities growth opportunities arising from the emerging trends in tourism demand, paying more at-tention to cultural values, foods, and countryside experiences. Tregua et al. [5] argued that agritourism serves as a valuable tool for promoting local regions and their unique cuisine, leading to local economic development. Agriculture has evolved from being a primary industry to a tertiary industry, driven by its own tangible and intangible re-sources, which are used to further improve revenues. According to [6], agritourism has statistically significant and positive effects on farm profitability. However, its benefits still need further study. Brune et al. [7] pointed out that COVID-19 impacted all sectors of the tourism industry revealing previously unknown strengths and weaknesses. The impact of the COVID-19epidemic on agritourism farm profitability need to be explored. Veeck et al. [8] proposed that agritourism often generates limited revenue, which may significantly increase cash flow. Arru et al. [9] pointed out that the results of their study on economic performance of agritourism showed controversial performance but basically highlight the difficulty agritourist farmers have both remunerating their work at market price levels and being profitable. Therefore, to exploring the operational efficiency of agricultural farms is one of the purpose of the study.

Based on the above literature, foods or cuisines play a vital role in agricultural transformation, affirming the findings of [10] which state that hotels, restaurants, and catering firms can carry out activities on a large scale. The restaurants in agritourism farms offer locally produced ingredients to their consumers to promote the concept of green consumption, which aligns with the idea of slow food. This strategy fosters trust among consumers to expand the farms' revenue. With respect to Tuscan's research on agritourism, Fanelli [11] argued that restaurants are the primary reason for people to visit agritourism farms. The experience offered in the restaurant leaves the most last-ing impression on the visitors of Tuscan agritourism facilities. Dragulanescu et al. [12] analyzed Italian agritourism farms with restaurant business and concluded that 13.8% of restaurant farms were authorized only to offer restaurant services, 72.6% offer ac-commodation, 26% combine restaurant with food tasting experiences, and 58% supply other activities (e.g., horseback riding, hiking, sports, and courses). Farms offering res-taurants experienced a higher growth rate (+ 3.6%) compared to the overall growth rate (+ 2.1%). This underscores the significant role that restaurants play in agritourism. Furthermore, agritourism farms are more likely to implement a "from farm to table" model, which was stressed in the European Union's white paper on food safety. Hence, this study also aims to understand the influence of green restaurants on the economic efficiency of agritourism farms.

Organic farming aligns with the principle of sustainable natural resource utiliza-tion and natural environment damage reduction. This is achieved by abandoning the use of chemical fertilizers and synthetic pesticides. In 2014, the International Federa-tion of Organic Agriculture (IFOAM) suggested four revised principles for the organic industry--"Health, Ecology, Fairness, and Care," emphasizing systematic natural cy-cles, promoting innovative thinking in traditional agriculture, and proposing technol-ogy for promoting ecological balance and harmonious coexistence with human beings. Most agritourism farms are small and are likely to engage in organic farming [13]. Ac-cording to [14], organic agricultural tourism provides agriculturists an opportunity to generate income from agricultural products, create new activities or products for dis-tribution, and add more value to their products. Khanal et al. [15] discovered a synergy between agritourism and organic farming decisions and between agri-environmental conservation efforts and agritourism activities.

Organic farming is not free from limitations. Thus, it is worth investigating whether it can exert a positive impact on revenue. Canter et al. [16] noted that in or-ganic farms, the cultivation of certain medicinal herbs can be challenging due to spe-cific ecological requirements. From the relevant literature, it shows that green restau-rants play significant role in agritourism farm. Apart from that, the benefits and the cost of organic farming have yet to be explored. Therefore, the main objective of this study is to analyze the production efficiency of the organic farming stage, the market efficiency of the green restaurant, and the total operational efficiency of the leisure farm by using the dynamic network DEA when the agritourism farms operator con-verts the agricultural waste and restaurant food waste into the organic farming pro-duction mode after treatment and reuse.

This study primarily analyzes the value of the organic production department (production function), the green restaurant department (living function), and the reuse of agricultural waste generated by operations between the two departments (ecological function) in agritourism farms. Empirical results indicate that agritourism farms with higher operational efficiency typically feature ecological functional tours and high-tech automated organic production departments. These farms also integrate food farming education and green restaurant management, emphasizing the science and technology of agritourism farm production, agricultural life and cultural characteristics, and environmental and ecological education. Additionally, it was found that the overall operating efficiency of agritourism farms that recycle agricultural waste on a larger scale is higher. This suggests that these farms fully leverage their characteristic functions and optimally configure and utilize all inputs, outputs, and resource energy, thereby effectively improving operational efficiency and economic benefits.

2. LITERATURE REVIEW

2.1 Agritourism Farms and Operational Efficiency

Due to socioeconomic development and industrial structure change, agriculture has transformed from being a primary industry to a diversified industry. In addition to producing crops, agriculture now plays a role in food production. According to [17], agriculture has been recognized as an important element in reducing poverty and promoting rural development. Additionally, agriculture fosters more diverse benefits through its integration of local industries, culture, and natural ecology. Choo and Park [18] asserted that a growing number of farms have started adopting multiple non-agricultural activities to increase household sales and societal benefits. The de-velopment of agritourism farms aligns with the transformation mentioned above in agriculture. According to [19], agritourism allows agricultural entrepreneurs to diver-sify their income while also promoting the concept of agriculture multifunctionality. Roman [20] asserted that agritourism is a subset of rural tourism that encompasses leisure activities, including active forms of recreation, for individuals or groups. It typically operates in an agricultural farm that offers various recreational and tourist services, either during peak season or throughout the entire calendar year. The value of agritourism farms covers agricultural conservation, leisure, and sightseeing activities derived from special local cultures. Whitt et al. [21] noted that agritourism helps U.S. farmers and ranchers generate revenue from recreational or educational activities by offering services, such as farm tours, camping, or horseback riding. Agritourism also has the potential to revitalize rural economies, promote agricultural awareness among the public, and preserve agricultural heritage. Efficiency count from the perspective of agritourism farm operators. Arru et al. [22] used DEA approach to investigate tech-nical efficiency related to agritourism and recreational functions in Sardinia. Their findings suggested that efficiency can improve if technical inputs are adequately used. The study estimated that the margins for improving the efficiency are larger for recre-ational services and that technical factors contribute to efficiency with a different magnitude as well. Li et al. [23] pointed out that the efficiency of agrotourism integra-tion in China is relatively high and tourism significantly promotes agriculture . Changjiang [24] argues that the production level and development scale of leisure ag-riculture in Anhui Province are not optimal. These gaps are mainly reflected in the difference in pure technical efficiency. [18] found that the length of time in business, the number of employees, the type of tourism program, availability of attractions, availability of financial resource, and availability of business/marketing plan have a positive impact on the performance of agritourism farms.From the above literature, it is clear that using input variables and output variables from the agricul-tural and tourism systems to analyze the efficiency of agrotourism is a reasonable way of analyzing. According to [25], agritourism can be considered a viable alternative ag-ricultural enterprise for enhancing farm income and sustainability. Schilling [6] ar-gued that improving a farm's financial performance is generally a primary motive be-hind the development of agritourism enterprises. Hence, agritourism can be defined as a transformation of agricultural business and economic activity that integrates pro-duction, life, and ecology. However, agritourism still faces some challenges. According to [6], existing assessments of the income impacts of agritourism are not based on di-rect empirical observation but on qualitative farm operator assessments, which deter-mine how agritourism shapes farm profitability. Hoppe [26] noted that the lack of re-sources among small farms causes them to struggle financially. It can be seen that agritourism farms are limited in human, material and financial resources. How to share the existing resources and effective development and management of resources is worth exploring further. For example, this paper focuses on the impact of reusing agricultural waste and restaurant food waste in recreational farms and converting them into organic farming production models on the operational efficiency of agritourism. Hung et al. [27] asserted that previous studies on the determinants of agritourism farm performance are inconclusive. Moreover, the key success factors of high and low performance may differ. A diverse set of factors influences the profita-bility of agritourism farms. Therefore, the operational efficiency of agritourism is worth investigating.

2.2 Green restaurants and organic farming

The European Union countries first proposed the concept of Multifunctionality of Agriculture (MFA) due to the development of global agriculture. Belletti [28] argued that MFA ranges from primary food production to meeting social requirements that had not previously been recognized in the agricultural industry, such as biodiversity recovery, environmental decontamination, amenity restoration, cultural resource uti-lization, and food security. In fact, agritourism also promotes a lot of green economies. For instance, Broccardo et al. [29] asserted that agritourism must create sustainable value in ecological, social, or economic terms with respect to ecological functions, such as air purification, carbon sequestration, and environmental and species conservation. Currently, agritourism prioritizes the promotion of production, living, and ecology, while the concepts of green and environmental protection are interpreted in different ways. Consistent with the literature mentioned above, Ammirato and Felicetti [30] argued that agricultural sustainability pertains to the use of land and natural resources in such a way that: 1. Natural resources, habitats, landscapes, and biodiversity are also available in the future, considering the biophysical nature of agricultural production and its close dependence on the specific characteristics of local ecosystems (environ-mental dimension); 2. Resources are used in efficient ways, contributing to the devel-opment of rural territories (economic dimension); 3. Job opportunities are ensured, as well as access to resources and services provided by farmers (social dimension).

The integration and operation of green restaurants in agritourism farms have en-vironmental, economic, and social benefits. Lorenzini [31] defines green restaurants as restaurants that are created or operated in an environmentally friendly way, aiming to reduce the impact of their operations on the environment. Gilg et al. [32] pointed out that green restaurant focuses on three Rs (reduce, reuse, recycle) and two Es (energy and efficiency). Therefore, green restaurants engage in a variety of green practices to promote environmental protection and provide consumers with a leisure experience. At present, it has gradually become a trend and social responsibility of the catering industry to provide catering services with a low environmental impact. For instance, the Green Restaurant Association (GRA) has been committed since 1990 to push for-ward green restaurants, allowing it to establish a complete green restaurant evaluation system [33]. The GRA standards aim to provide a transparent way to measure each restaurant's environmental accomplishments. Eight evaluation criteria are covered: energy, water, waste, reusables & disposables, chemicals & pollution, food, building & furnishing, and education & transparency.

Organic farming promotes environmental friendliness and ecological conserva-tion while providing consumers with healthy and safe agricultural products. Addi-tionally, recycling chicken and duck manure and spoiled agricultural products or composting farm waste highlights a sustainable way of reusing farm waste, which matches the goal of the agricultural circular economy. According to [34], using micro-bial fermentation technology in organic farming can not only recycle and reuse agri-cultural waste but also create a new cycle of low-input, zero-pollution, high-yield, and high-value agriculture that would promote sustainable recycling of green resources. Green restaurants are often combined with organic farming to meet certain business philosophies and consumer expectations. Lin et al. [35] explored the critical success factors of green restaurants and discovered that food quality, product cooking tech-nology, environmental protection, service quality, green food marketing, and val-ue-added green food assessment factors, such as the six dimensions, produce quality, as the most important facet. However, organic restaurants still face some challenges today. Poulston and Yiu [36] noted that poor government support, supply difficulties, price premiums, and poor market demands were the prevalent barriers to the devel-opment of organic dining. Therefore, this study examines how the operators of agritourism farms manage the recycling of agricultural waste and analyzes the influence of the production efficiency of organic farming, the market efficiency of green restaurants, and the overall operating efficiency of agritourism farms.

3. RESEARCH METHOD

3.1 Modeling

The COVID-19 pandemic has shifted the public's attention to including organic and healthy products in their dietary choices and consumption patterns. As a result, more farms are adopting more eco-friendly and organic farming methods. In Taiwan, agritourism farms provide consumers with a one-stop food supply chain that offers eco-friendly agricultural products, as well as organic, healthy, and creative cuisines cooked freshly in their green restaurants. This farm-to-fork approach mitigates carbon emissions linked to environmental pollution while simultaneously reducing excessive packaging, processing, and transportation of products. In terms of eco-friendly farm-ing, farms adopt composting techniques to manage wastes, including biological resi-dues, animal excreta, expired agricultural products, and food waste from green res-taurants. By adjusting factors, such as car-bon-nitrogen ratio, water content, and venti-lation, the waste materials undergo compost-ing (fermentation) to produce organic fer-tilizers. The sustainable use of agricultural waste can reduce operating costs, reinforce the food supply chain, enhance the overall operating efficiency, and maintain a favor-able operating cycle between producers and consumers. Moreover, such practice aligns with the trends of sustainable and organic farming and green catering, promotes the concept of green and healthy food, and contributes to the development of an agricul-tural circular economy. Figure 1 shows the waste composting process and the concept of circular agriculture observed by Taiwanese agritourism farms.

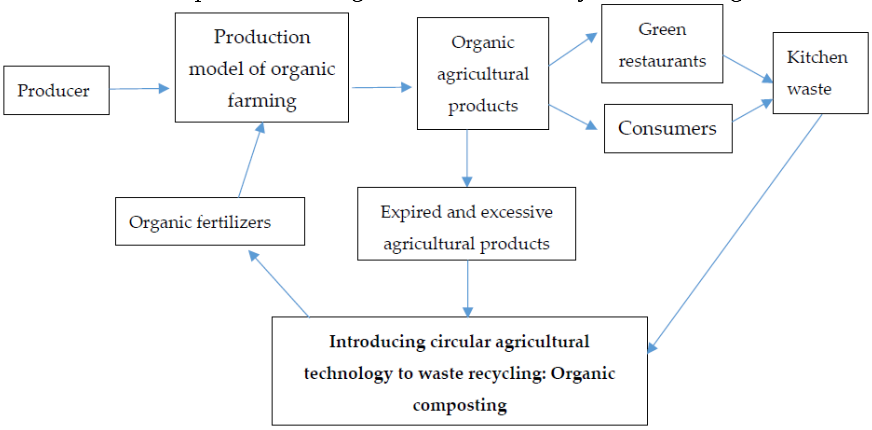

Figure 1. Waste recycling and circular agriculture of Taiwanese agritourism farms

The management skills, resources, and business conditions of the production de-part-ments and the operating efficiency of agritourism farms differ between the two phases. This study mainly focuses on the production efficiency of organic farming in Phase 1. It also delves into the market efficiency of green restaurants and the overall operating effi-ciency of agritourism farms upon integration in Phase 2. The inputs in Phase 1, which focuses on organic farming, include water source equipment, environ-mental maintenance for eco-friendly farming, and organic composting of farm waste. The primary output of this phase is the output of organic crops. Then, the output of organic crops in Phase 1 (intermediate output) serves as the input for the green res-taurant in Phase 2. In conjunction with common farm resources, the market efficiency of the green restaurant in Phase 2 was evaluated. Lastly, the overall operating effi-ciency of the agritourism farm was analyzed by integrating eco-friendly farming and the green restaurant.

This study primarily discusses the operating efficiency of agritourism farms and ana-lyzes how the integration of organic farming in Phase 1 and green restaurant oper-ations in Phase 2 influences the overall operating efficiency of agritourism farms. The findings of this study provide a strategic reference for optimizing the allocation of re-source inputs and outputs within agritourism farms. Figure 2 shows the inputs and outputs of each de-partment, highlighting the interconnection of the operations be-tween the departments. Specifically, Link 1->2 signifies that a portion of the outputs of Department 1 serves as part of the inputs of Department 2. Similarly, Link 1->3 and Link 2->3 have the same pattern, denoting the respective flows of inputs between the departments.

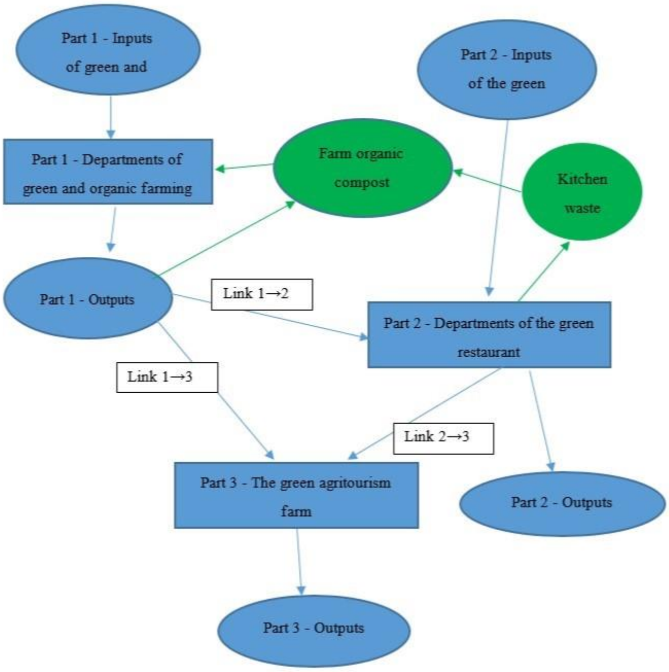

Figure 2. DEA model of a green agritourism farm

3.2 The multi-departmental DEA model

This study primarily analyzes the agritourism farm's operational inefficiencies spurred by the supply chain and resource-sharing relationship between the organic production department and the green restaurant department.

As indicated in the literature, Zha et al. [37] and Amir et al. [38] explored a two-stage process involving shared inputs, while Fukuyama et al. [39], Magbouli et al. [40], and Nematizadeh and Nematizadeh (2021) proposed a two-stage model encompassing the causes of inefficiency.

Kalantari et al. [41] introduced the network dynamic range adjustment model (RAM) to assess supply chain sustainability, where the model measures the optimal allocation of inputs and outputs under fixed efficiency. Further et al. [42] developed a network dynamic SBM model to evaluate the operational efficiency of sustainable supply chains that adjusts input and output amounts and generates new efficiency values. Amin et al. [43] designed a two-stage DEA model to gauge the potential benefits of mergers, while Mogadas et al. [44] progressed the NDEA model to bolster supply chain sustainability through the network relationship structure's effectiveness. Arbabi et al. [45] employed a leader-follower approach and proposed an NDEA model for a two-stage production process.

Due to the supply chain and resource-sharing relationship between the agritourism farm's organic production department and the green restaurant department, this paper employs the MNDEA model to estimate the operating efficiency of the two department stages. This approach circumvents the mutual offset issue of efficiency and inefficiency between the two production stages and enhances the ability to discern the relative performance magnitude among various agritourism farm departments. Hence, this study's MNDEA model can deliver results that measure a more comprehensive degree of inefficiency.

This study developed a multi-departmental DEA model based on the directional distance function of [46], which combines the MDEA model created by [47] and the network model proposed by [48].

The possible sets of agritourism farms are outlined below, and the DEA model was developed based on the traditional vector function and Russell's vector function. Suppose there are K agritourism farms, $\mathrm{DM}U_k(k = 1, \ldots, K)$. Each of them engages in two production phases: organic farming and green restaurant operations. Specifically, the phase of organic farming utilizes specific $X_{vk}^{B}(v = 1, \ldots, V)$ and common $X_{ck}^{BF}(c = 1, \ldots, C)$ factors. The intermediate output is represented by $z_{rk}(r = 1, \ldots, R)$. Due to the common factors, X_{ck}^{BF}, it is further assumed that U_{ck} represents the proportion of these factors allocated to the phase of organic farming. The remaining common factors, $(1 - U_{ck})X_{ck}^{BF}$, were used in the phase of green restaurant operations together with the intermediate input $\mathrm{z}(-1)_{rk}$, which emerged from the previous phase were used to produce the final output, $y_{mk}^{F}(m = 1, \ldots, M)$. Under the constant returns to scale (CRS), two possible production sets of the two production phases were established, T^B and T^F. The possible production set, T^B, in the phase of organic farming is as follows:

$$
\begin{gathered}
T^B = \left\{(x, z, y): \sum_{k=1}^{k} \lambda_k^B X_{vk}^B \leq X_v^B, v = 1, \ldots, V \right\} \\
\sum_{k=1}^{k} \lambda_k^B \mu_c X_{ck}^{BF} \leq \mu_c X_c^{BF}, c = 1, \ldots, C \\
0 < \mu_c < 1, c = 1, \ldots, C \\
\sum_{k=1}^{k} \lambda_k^B z_{rk} \geq z_r, r = 1, \ldots, R \\
\lambda_k^B \geq 0, k = 1, \ldots, K
\end{gathered}
\tag{1}
$$

The possible production set, T^F, in the phase of green restaurant operations is as follows:

$$T^F = \left\{ \begin{array}{l} (x, z(-1), y): \sum_{k=1}^{k} \lambda_k^F z(-1)_{rk} \leq z(-1)_r, r = 1, \ldots, R \\ \sum_{k=1}^{k} \lambda_k^F (1-\mu_c) X_{ck}^{BF} \leq (1-\mu_c) X_c^{BF}\ c = 1, \ldots, C \end{array} \right\}$$

$$0 < \mu_c < 1, c = 1, \ldots, C$$

$$\sum_{k=1}^{k} \lambda_k^F y_{mk}^F \geq y_m^F, m = 1, \ldots, M$$

$$\lambda_k^F \geq 0, k = 1, \ldots, K$$

(2)

where λ^B and λ^F are the respective intensity variables of the two phases of organic farming and green restaurant operations, and the weights of the manufacturers' inputs and outputs with efficient boundaries corresponding to the k-th DMU when efficiency is measured.

After the efficiency boundaries were established based on the production sets in Equations (1) and (2), the gap between the production sets of agritourism farms and the efficiency boundaries was compared using a vector function to calculate the farms' technical efficiency. In the phase of organic farming, a graph-oriented approach was used to measure the efficiency, representing the operating efficiency of the agritourism farms based on the lowest inputs and the largest outputs. In the phase of green restaurant operations, the outputs of the previous phase were regarded as the intermediate inputs. Thus, the best outputs were determined based on the intermediate outputs of the previous phase and the inputs of the green restaurants. The method used for efficiency measurement was semi-graph-oriented. Drawing on these two orientations, the MNDEA model for measuring the overall efficiency of the k'-th (K' = 1, …, K) agritourism farm was constructed as follows:

$$D^{BF^*}(x, y, z; g^B, g^F) = D^{BF} = \max_{\lambda,\beta,\mu} \left(\beta_{k`}^B + \beta_{k`}^F\right)/2 \qquad (3)$$

s.t.

Constraint equations for the organic farming phase:

$$\sum_{k=1}^{k} \lambda_k^B X_{vk}^B \leq \left(1 - \beta_{k`}^B\right) X_{vk`}^B, v = 1, \ldots, V \qquad (3\text{-}1)$$

$$\sum_{k=1}^{k} \lambda_k^B \mu_{ck`} X_{ck}^{BF} \leq \left(1 - \beta_{k`}^B\right) \mu_{ck`} X_{ck`}^{BF}, c = 1, \ldots, C \qquad (3\text{-}2)$$

$$\sum_{k=1}^{k} \lambda_k^B z_{rk} \geq \left(1 - \beta_{k`}^B\right) z_{rk`}, r = 1, \ldots, R \qquad (3\text{-}3)$$

$$\lambda_k^B \geq 0, k = 1, \ldots, K \qquad (3\text{-}4)$$

Constraint equations for the green restaurant operations phase:

$$\sum_{k=1}^{k} \lambda_k^F z(-1)_{rk} \leq z(-1)_{rk`}, r = 1, \dots, R \quad (3\text{-}5)$$

$$\sum_{k=1}^{k} \lambda_k^F (1 - \mu_{ck`}) X_{ck}^{BF} \leq (1 - \beta_{k`}^F)(1 - \mu_{ck`}) X_{ck`}^{BF}, c = 1, \dots, C \quad (3\text{-}6)$$

$$\sum_{k=1}^{k} \lambda_k^F y_{mk}^F \geq (1 + \beta_{k`}^F) y_{mk`}^F, m = 1, \dots, M \quad (3\text{-}7)$$

$$\lambda_k^F \geq 0, k = 1, \dots, K \quad (3\text{-}8)$$

$$L_c < \mu_c < U_c,\ c = 1, \dots, C \quad (3\text{-}9)$$

In the above model, $g^B = (-g_x, g_z)$ and $g^F = (-g_x, g_y)$ are the direction vectors of the two production phases of the directional distance function. In this paper, $g^B = (-x_{k`}, z_{k`})$ and $g^F = (-x_{k`}, y_{k`})$ are set; the sample observation values are taken as the direction of the efficiency measurement. β^B, β^F represent the values of the directional output distance function for the k'-th DMU under the constraint equations of (3-1) ~ (3-4) for the organic farming phase and the constraint equations of (3-5) ~ (3-8) for the green restaurant operations phase, respectively. Since the values of these functions represent the magnitude of the increase in outputs and the decrease in inputs that should be provided by the DMUs, they can be used to illustrate the extent of the inefficiency in the operation of the DMUs. On the other hand, Eq. (3-9) represents the constraint equation that if there is an output, there must be a factor input, where L_c, U_c represent the upper and lower limits of μ_c.

Under the above-mentioned nonlinear constraints of Equations (3-1) ~ (3-9), the nonlinear mathematical programming method is used to obtain the objective function value β^{BF}, which is the average of the solution values of β^B and β^F. Thus, it can be interpreted as the aggregate or the overall technical inefficiency measure of the k'-th DMU. Its value is always greater than or equal to 0.

Under the nonlinear constraints of Equations (3), nonlinear mathematical programming was used to obtain the objective function value, β^{BF}, which is the average of β^B and β^F. Thus, it can be interpreted as the aggregate or the overall technical inefficiency measure of the k'-th agritourism farm, which is always greater than or equal to 0. When $\beta^{BF} = 0$, the k'-th agritourism farm achieves efficiency in both phases of organic farming and green restaurant operations. In other words, when $\beta^B = \beta^F = 0$, it displays the best overall operating efficiency. However, when $\beta^{BF} > 0$, at least one phase of the k'-th farm is efficient; thus, its inputs and outputs should be adjusted.

Although the mathematical model in Eq. (3) above can calculate the relative efficiency of the overall operation of each DMU and analyze which phase of the production department of the inefficient DMU is in trouble, its efficiency is based on proportionality and does not take into account the inefficiencies of non-zero differences. Thus, the calculated efficiency values may be biased. In order to overcome this problem, this paper adopted the Russell directional distance function proposed by Fukuyama and Weber [49] to modify the above model into the Russell multi-departmental network model, as follows:

$$\vec{D}^{RBF}(x, z, y; g) = \beta^{RBF} = \max_{\lambda,\beta,\mu} \frac{1}{2}\left(\frac{1}{3V}\sum_{v=1}^{v} \beta_{vk`}^{B_x} + \frac{1}{3C}\sum_{c=1}^{c} \beta_{ck`}^{B_s} \frac{1}{3R}\sum_{R=1}^{R} \beta_{rk`}^{z}\right) + \frac{1}{2}\left(\frac{1}{2C}\sum_{c=1}^{c} \beta_{ck`}^{F_s} + \frac{1}{2M}\sum_{M=1}^{M} \beta_{mk`}^{F_y}\right) \quad (4)$$

s.t.

Constraint equations for the organic farming phase:

$$\sum_{k=1}^{k} \lambda_k^B X_{vk}^B \leq (1-\beta_{k`}^{B}) X_{vk`}^B, v = 1, \ldots, V \tag{4-1}$$

$$\sum_{k=1}^{k} \lambda_k^B \mu_{ck`} X_{ck}^{BF} \leq \left(1-\beta_{k`}^{B_s}\right) \mu_{ck`} X_{ck`}^{BF}, c = 1, \ldots, C \tag{4-2}$$

$$\sum_{k=1}^{k} \lambda_k^B z_{rk} \geq \left(1-\beta_{k`}^{B_z}\right) z_{rk`}, r = 1, \ldots, R \tag{4-3}$$

$$\lambda_k^B \geq 0, k = 1, \ldots, K \tag{4-4}$$

Constraint equations for the green restaurant operations phase:

$$\sum_{k=1}^{k} \lambda_k^F z(-1)_{rk} \leq z(-1)_{rk`}, r = 1, \ldots, R \tag{4-5}$$

$$\sum_{k=1}^{k} \lambda_k^F (1-\mu_{ck`}) X_{ck}^{BF} \leq \left(1-\beta_{ck`}^{F_s}\right)(1-\mu_{ck`}) X_{ck`}^{BF}, c = 1, \ldots, C \tag{4-6}$$

$$\sum_{k=1}^{k} \lambda_k^F y_{mk}^F \geq \left(1+\beta_{mk`}^{F_y}\right) y_{mk`}^F, m = 1, \ldots, M \tag{4-7}$$

$$\lambda_k^F \geq 0, k = 1, \ldots, K \tag{4-8}$$

$$L_c < \mu_c < U_c,\ c = 1, \ldots, C \tag{4-9}$$

If the importance of different phases of different production departments or different inputs and outputs are considered to vary, this objective function (4) can be adjusted to $\beta^{RBF} = \max_{\lambda,\beta,\mu} W_B \left(\frac{w_x^B}{V}\sum_{v=1}^{v}\beta_{vk`}^{B_x} + \frac{w_s^B}{C}\sum_{c=1}^{c}\beta_{ck`}^{B_s}\frac{w_Z^B}{R}\sum_{R=1}^{R}\beta_{rk`}^{z}\right) + w_F\left(\frac{w_s^F}{C}\sum_{c=1}^{c}\beta_{ck`}^{F_s} + \frac{w_y^F}{M}\sum_{M=1}^{M}\beta_{mk`}^{F_y}\right)$, where W_B and w_F represent the weights of the importance of the two phases, w_x, w_s, and w_y represent the weights of the importance of specific factors, common factors and outputs, respectively, which are all the exogenous variables set by the evaluator. In this study, in the objective function of Eq. (4), it is assumed that $W_B = w_F = \frac{1}{2}, w_x = w_s = w_y = \frac{1}{3}, w_s^F = w_y^F = \frac{1}{2}$, which means that different phases of production or inputs and outputs are given the same weight. That is to say, the efficiency of each of them is of equal importance to the DMU.

From the comparison of the MNDEA model of the objective functions (3) and (4) with the constraint equations, it can be observed that their structures are the same. The only difference lies in that the efficiency measure is adjusted from the directional distance function to Russell's directional distance function so that in the MNDEA model, the inputs and outputs of the two phases of the departments of organic farming and green restaurant operations have the same weight in terms of efficiency measurement. If the inputs and outputs in the two departments are adjusted to be non-radial to measure efficiency, then the outputs β of each of the inputs in the constraint equations for the organic farming department (4-

1) ~ (4-4) and the constraint equations for the green restaurant department (4-5) ~ (4-9) will differ.

According to this model, a specific part of the objective function, $\frac{1}{3V}\sum_{v=1}^{v}\beta_{vk`}^{B_x}+\frac{1}{3C}\sum_{c=1}^{c}\beta_{ck`}^{B_s}\frac{1}{3R}\sum_{R=1}^{R}\beta_{rk`}^{z}=\beta^{RB}$, which is obtained from the optimal solution, can be used to measure the degree of inefficiency of the phase of organic farming. Meanwhile, $\frac{1}{2C}\sum_{c=1}^{c}\beta_{ck`}^{F_s}+\frac{1}{2M}\sum_{M=1}^{M}\beta_{mk`}^{F_y}=\beta^{RF}$ can be used to gauge the inefficiency degree of the phase of green restaurant operations. The average of these two is the overall inefficiency of the k'-th agritourism farm.

4. EMPIRICAL ANALYSIS OF THE OPERATING EFFICIENCY OF AGRITOURISM FARMS

4.1 Characteristics and the input and output variables of agritourism farms

The samples of this study included Top 30 agritourism farms in Taiwan. The rankings are based on online comments, organic certification, and green restaurant operations. Data were obtained from publicly available financial statements from 2019 to 2022, in line with the accounting procedures and financial reporting standards for agricultural consortia on the Taiwan Organic Information Portal. Table 1 presents the characteristics of the 30 agritourism farms.

Table 1. Characteristics of the 30 agritourism farms

DMU	Agritourism farm	County	Characteristics
D1	King Bao Leisure Farm	Yilan	It offers an organic farming environment where consumers can experience farming activities, purchase organic fresh fruits and vegetables, and enjoy creative cuisine in the green restaurant.
D2	Hong Qi Organic Farm	Pingtung	Hsu Tien, the owner of the farm, has been committed to organic farming since he retired from the educational sector. He uses non-polluting mountain spring water and certified fertile soil for “integrated rice and duck farming.”
D3	Jaodaotian Leisure Farm	Yilan	The restaurant, the outdoor space, and the farmland are green, low in carbon emissions, safe, and healthy.

D4	Yam Vine Organic Farm	Taoyuan	A variety of root fruits and vegetables, as well as herbs, are organically grown and directly supplied to ORGANICYAM restaurants or the farm's workshop. In the event of volume production, these items are also supplied to the farm's stores so that customers can purchase the freshest and seasonal organic vegetables.
D5	Kangzhuang Leisure Agriculture Area	Taoyuan	The Kangzhuang Leisure Agriculture Area, home to both Hokkien and Hakka ethnic groups, is a unique leisure area that embraces diverse cultures and observes abundant ecological resources and natural sceneries.
D6	Bei Hsin Leisure Farm	New Taipei City	Managed by Mr. Lien-Sheng Chien, recipient of the Outstanding Agricultural Professionals Award, this farm is the first legal organic agritourism farm in New Taipei City, offering organically certified fruits and vegetables, as well as organic creative dishes.
D7	Shangrila Leisure Farming	Yilan	This farm grows Chamaecyparis formosensis, a symbolic tree of immortality in Taiwan. Grown at a high altitude, this plant can absorb phytoncide from the millennial forest. Customers can savor organic cuisines on this farm.
D8	Sen Lon Leisure Farming	Nantou	Organic mushrooms are a major feature of this agritourism farm. This farm also covers self-production and self-marketing, leisure and recreation, and natural education. Visitors can partake in firsthand mushroom growth experiences and indulge in food tasting.
D9	Jia-Feng Organic Farm	Hualien	Adhering to the three principles—"protecting the earth, cherishing lives, and respecting nature," this farm warmly welcomes consumers with organic vegetables and fruits that offer benefits to both physical and mental well-being.
D10	Ladybug Organic Farm	Taichung	In pursuit of organic and healthy food options, this farm offers customers with farm-to-table experience.
D11	Formosa Organic Farm	Taoyuan	No chemical fertilizers, no pesticides, fruits and vegetables, and the company's environmental and ecological philosophy is implemented.

D12	Songmanyuan Organic Farm	Yilan	The constant occurrence of food safety issues made Song Manyuan decide to grow organic vegetables on his own.
D13	Beixin Organic Leisure Farm	Taipei	In addition to producing organic fruits and vegetables, the farm also plans many rural experience activities
D14	Jiudou Village Organic Farm	Taoyuan	An ecological farm that combines rural culture and green restaurants
D15	Chengnan Organic Farm	Miaoli	Organic farmers grow fruits and vegetables, providing fresh, safe and healthy agricultural products to green restaurants and the public.
D16	Dayu organic farm	Tainan	Adhering to the concept of "environmentally friendly and sustainable management" to provide food safety
D17	Liangshan Organic Farm	Taoyuan	No pesticides or chemical fertilizers are used in the cultivation process.
D18	Yazhi Organic Farm	Hsinchu	We insist on not using chemical fertilizers or drugs in order to produce safe, healthy and delicious ingredients.
D19	Niupu Organic Farm	Taipei	Organic and low-carbon production process
D20	Guanfang Organic Farm	Tainan	A farm that provides high quality organic sprouts.
D21	Xiangri Organic Farm	Taipei	A farm that provides organic vegetable feasts and rural experiences
D22	Dongfeng Organic Farm	Yilan	Farms that incorporate agricultural waste reuse
D23	Biluo Village Organic Farm	Taoyuan	The farm promotes the concepts of organic agriculture and ecological conservation
D24	Dajin organic farm	Yilan	The water quality is good, the soil is not polluted, and the quality of the fruits and vegetables produced is well received.
D25	Jujube Healthy Organic Farm	Yilan	The farm’s pursuit of a friendly environment is beneficial to the health of human body, land and soul.
D26	Liangchen Organic Farm	Taoyuan	The farm is a greenhouse organic farming method
D27	Lishan Organic Farm	Taipei	The farm emphasizes that every vegetable eaten is healthy and non-toxic
D28	Yulin Organic Farm	Taipei	The farm hopes to bring the production end and the consumer end closer so that the organic market can be sustainable.
D29	Chaoyang Organic Farm	Yunlin	An organic farm that brings happiness to farmers through green energy

D30	Xinlu Farm	Organic	Hualien	Play in the water and pick wild vegetables at the farm, and then participate in hot pot cooking

This study employed the DEA model to analyze the operating efficiency of agritourism farms. The common inputs considered are labor costs and land rents. In Phase 1, the inputs for organic farming covered organic resources and materials, organic fertilizers, as well as soil and water maintenance costs. Meanwhile, the output of this phase is the organic crops. In Phase 2, the inputs related to green restaurant operations consist of the output of organic crops (intermediate output) and the operating costs of green restaurants. The output generated by green restaurants is represented by earnings per share (EPS). The net profit was utilized as a carry-over from one year to the next to measure the overall operating efficiency of agritourism farms. Table 2 presents the variables of agritourism farms.

Table 2. Definitions of the input and output variables of agritourism farms

	Variable	Definition	Unit (US)
Common inputs	Labor cost	Annual personnel cost of the agritourism farm	1,000
	Land rent cost	Annual land rent cost of the agritourism farm	1,000
Inputs for organic farming in Phase 1	Covered organic resources and materials	Pesticides and soil amelioration costs	1,000
	Organic fertilizers cost	Waste recycling cost of the agritourism farm	1,000
	Soil and water maintenance cost	Land and water maintenance cost	1,000
Intermediate output	Output of organic crops	Annual output of organic farming	1,000
Inputs of green restaurant operations in Phase 2	Operating expenses	Utilities and material costs	1,000
Interdepartmental link	Operating income	Annual income of the agritourism farm	1,000
Final output	EPS	EPS of the agritourism farm	US
Inter-period-carry over	Profit	Net profit of the agritourism farm	1,000

The researchers of this study used the DEA-SOLVER Professional 16.0 statistical software and the DEA model to analyze the operating efficiency of agritourism farms, as well as the operating efficiency of the supply chain integration of organic farming and green restaurants, with the aim of optimizing the allocation of inputs and outputs within these farms.

4.2 Descriptive statistics of agritourism farms

Among the top 30 agritourism farms in Taiwan ranked based on online comments in 2022, labor costs accounted for the highest proportion of all inputs, averaging US$ 5536,000 per year and with a standard deviation of 8.76. In terms of the inputs for Phase 1 of organic farming, the organic composting cost was the highest, averaging US$ 9,860 per year and with a standard deviation of 4.01. The average annual output of the agritourism farms amounted to US$ 60,583, indicating their small business scale. Meanwhile, the average annual operating expenses of green restaurants was US$ 11,620, with a standard deviation of 1.52. On the other hand, the average annual profit of the farms stood at US$ 46,260, with a standard deviation of 8.12. The descriptive statistics suggest that despite its relatively high cost, composting plays a vital role in addressing waste pollution and improving soil fertility, thus supporting organic cultivation. Taiwan's green agritourism is distinguished by its small-scale operation, refined management, and a business model rooted in local resources. It also serves as a platform for educating the public on food safety and agriculture, contributing to the sustainable development of ecology and rural cultures.

Table 3. Descriptive statistics of agritourism farms

	Variables	Average (USD1,000)	Minimum (USD1,000)	Maximum (USD1,000)	Standard deviation
Common inputs	Labor cost	55.36	27.95	86.30	8.76
	Land rent cost	6.21	4.09	12.19	1.27
Inputs for organic farming in Phase 1	Covered organic resources and materials	7.81	5.66	14.23	1.89
	Organic fertilizers cost	9.86	6.32	17.32	4.01
	Soil and water maintenance cost	5.21	3.45	9.31	1.64
Intermediate output	Output of organic crops	60.58	34.22	109.53	12.18
Inputs of green restaurant operations in Phase 2	Operating expenses	11.62	7.17	17.62	1.52
Interdepartmental link	Operating income	129.58	85.87	197.62	11.81
Final output	EPS	0.00026	0.00011	0.00036	0.00002

Inter-period-carry over	Profit	46.26	30.51	55.12	8.12

Based on the empirical results of this study, the average inefficiency of the overall operations of the 30 agritourism farms was 0.16, suggesting 16% room for improvement. Meanwhile, the average inefficiency of organic farming was 0.13. On the other hand, the average inefficiency of green restaurant operations was 0.19, suggesting 19% room for improvement. Based on the above three inefficiencies, organic farming technology, which represents a relative advantage of the agritourism farms in Phase 1, had a low inefficiency. However, the high inefficiency of green restaurants can be attributed to the lack of professional managers and chefs, suggesting the need for agritourism farms to make strategic adjustments in their green restaurant operations.

As shown in Table 4, the agritourism farm with the highest overall operating inefficiency was D3, with an inefficiency value of 0.27. Meanwhile, D2 has the lowest overall operating inefficiency, with an inefficiency value of 0.00, which means it is the most efficient. In the context of organic farming, the most inefficient was D25, while D2, D5, D8 and D14 were the most efficient. In terms of green restaurant operations, the most inefficient was D3, while D2 stood out as the most efficient. The above results and the descriptive statistics of the agritourism farms demonstrate that, due to its organic composting technology, D2 not only effectively recycled waste and strengthened soil fertility but also earnestly developed healthy and creative cuisine. Additionally, hiring professional chefs and managers also assisted D2 in achieving the highest efficiency, implying that regardless of organic farming or green restaurant operations, D2's inputs and outputs were optimally arranged.

Table 4. Inefficiencies of the overall operations, organic farming, and green restaurant operations of agritourism farms

DMU	Inefficiency of overall operations	Inefficiency of organic farming	Inefficiency of green restaurant operations
D1	0.15	0.16	0.21
D2	0.00	0.00	0.00
D3	0.27	0.18	0.28
D4	0.15	0.10	0.18
D5	0.21	0.00	0.25
D6	0.14	0.08	0.14
D7	0.15	0.09	0.20
D8	0.11	0.00	0.16
D9	0.20	0.15	0.26
D10	0.16	0.08	0.23
D11	0.12	0.07	0.18
D12	0.11	0.06	0.15
D13	0.14	0.04	0.10
D14	0.06	0.00	0.05
D16	0.10	0.03	0.08
D17	0.21	0.18	0.20

D18	0.14	0.16	0.15
D19	0.18	0.22	0.23
D20	0.19	0.10	0.17
D21	0.13	0.08	0.11
D22	0.23	0.18	0.21
D23	0.13	0.21	0.17
D24	0.20	0.16	0.22
D25	0.19	0.23	0.20
D26	0.21	0.18	0.21
D27	0.15	0.12	0.16
D28	0.25	0.23	0.23
D29	0.21	0.16	0.19
D30	0.24	0.21	0.26
Average	0.16	0.13	0.19
Maximum	0.26	0.23	0.28
Minimum	0.00	0.00	0.00
Standard deviation	0.021	0.011	0.026

4.3 Impact of the COVID-19 pandemic on the inefficiency of agritourism farm operations

This study explores the impact of the COVID-19 pandemic on the inefficiency of agritourism farm operations. The sample period was divided into two: during the pandemic (2019-2021) and after the pandemic (2022). Table 5 presents similar types of operating efficiencies in the two sub-periods. Based on the results of the non-parametric Kruskal-Wallis test (K-W test), the overall efficiency of the agritourism farms and the market efficiency of Phase 2 in green restaurant operations demonstrated statistically significant differences at the significant level during and after the pandemic. H values were 6.82 and 7.98, respectively, indicating that the COVID-19 pandemic severely impacted the overall operating efficiency of agritourism farms and the market efficiency of green restaurant operations. The primary reason for this was the necessity to prevent gatherings, leading the tourists to opt for takeout orders instead of dining in the green restaurants or visiting the farms. Interestingly, the efficiency of organic farming in Phase 1 was not affected by the pandemic and stayed below the significant level. H value was lower than the critical value of 5.99, suggesting that tourists attached more importance to organic and healthy agricultural products during the pandemic, resulting in a strong product demand.

Table 5. Inefficiencies of agritourism farm operations and the K-W test

Period	Inefficiency of overall operations				Inefficiency of organic farming				Inefficiency of green restaurant operations			
	Average	Standard deviation	Minimum	Maximum	Average	Standard deviation	Minimum	Maximum	Average	Standard deviation	Minimum	Maximum

2019-2022	0.16	0.021	0.00	0.26	0.13	0.011	0.00	0.18	0.19	0.026	0.00	0.28
2020-2021 (during the pandemic)	0.22	0.022	0.00	0.31	0.15	0.009	0.00	0.11	0.38	0.031	0.05	0.46
2022 (post-pandemic)	0.12	0.025	0.00	0.28	0.11	0.013	0.00	0.17	0.18	0.025	0.00	0.23
H value of the Kruskal-Wallis test	6.82*				3.96				7.98*			

* Significant at the significance level of α <0.05.

4.4 Tobit regression analysis

According to the descriptive statistics presented in this study, the main factors affecting the operating efficiency of agritourism farms included the composting cost of waste recycling, the quantity of certified organic crops, the educational qualifications of farm managers, and the impact of the COVID-19 pandemic. Regression analysis was conducted in conjunction with the operating inefficiency of the selected agritourism farms and the four variables. The dependent variable in this study was the inefficiency of the overall operations of the agritourism farms, ranging between 0 and 1. Therefore, Tobit regression was performed using the SHAZAM statistical software.

Since the most important factor affecting the organic farming of agritourism farms was organic composting cost, this study considered the organic composting cost, the quantity of certified organic crops, the educational qualifications of farm managers, and the impact of the COVID-19 pandemic (a dummy variable, with 1 representing the pandemic period in 2020, and 0 representing the post-pandemic period in 2022) as the explanatory variables. Meanwhile, the inefficiency of the agritourism farms represents the dependent variable. Due to the unilateral restriction of yi in the Tobit regression analysis, it was necessary to calculate the natural logarithm of the opposite of the inefficiency and convert it to the lower limit of yi, which was 0. In this context, a higher value of yi corresponds to better efficiency. Therefore, a positively estimated parameter indicated a positive effect on efficiency. Table 6 presents the results of the Tobit regression analysis.

Table 6. Results of the Tobit regression analysis (the values in parentheses are t-values)

Variable	Constant	Organic fertilizers cost	Number of certified organic crops	Educational background manager	Impact of the of COVID-19 pandemic
Coefficient value	0.125 (1.661*)	-0.261 (-1.862*)	0.225 (1.655*)	0.265 (1.705*)	-0.306 (-2.106**)

* means p < 0.05 and ** p < 0.01.

Table 6 shows that the t-values of all the explanatory variables at the significant level were significant, while the coefficients of the two explanatory variables were negative, implying a negative influence on the operating efficiency. Specifically, the coefficient of the impact of the COVID pandemic, -0.306, was the highest, emphasizing that the pandemic has a substantial influence on the overall operating efficiency of agritourism farms. This result was consistent with the non-parametric analysis. The result echoes the arguments of Nicola et al. [50] that the global crash of demand from hotels and restaurants caused the prices of agricultural goods to drop by 20%. Roman & Grudzień [51] also found that the massive impact of the COVID-19 pandemic on agritourism. From the relevant literature, the impact of COVID pandemic on operating efficiency of agritourism farms can be verified.

Another variable that negatively influenced the operating efficiency was the organic composting cost. While it played a crucial role in converting waste into organic fertilizers to improve soil fertility, it also contributed to operating inefficiencies in agritourism farms. Therefore, composting technology must be improved to reduce costs. The results of this study are the same as those of previous studies. For example,Viaene et al. [52] pointed out that the shortage of woody biomass, strict regulation, considerable financial and time investment, and lack of experience and knowledge are hindering on-farm composting.In other words, mastery of composting technology and related knowledge is one of the major cost factor. Durán-Lara et al. [53] holds the same view and pointed that biopesticides based on microorganisms can be quite expensive compared to synthetic pesticides. They often do not work as quickly and they have to be applied more frequently, making them a tough sell in some markets. From the relevant literature, it is clear that how to reducing composting costs has become an important issue for farms. Lim et al. [54] made the same argument and found that omposting has been considered as a non-financially friendly/low revenue process, as the high requirement on land area and processing time are non-parallel with the relatively low selling price of mature compost. It can be seen that the high cost of composting is still one of the important issues facing farms. Meanwhile, the variables that positively influenced the operating efficiency of the agritourism farms included the educational qualifications of farm managers and the quantity of certified organic crops. Higher educational background among farm managers and more certified organic crops resulted in greater operating efficiency. The meaning is that when consumers purchase organic agricultural products, the organic certification label or validation mark will be regarded as the source of quality signals. Relevant studies also hold this view. For example, Oya et al. [55] argued that there are positive effects on prices and income from the sale of produce is higher for certified farmers. Khanal et al. [56] pointed out that the marginal impact of participation in certified organic food production is higher for farms generating higher sales and net cash income. From this, we can see certified organic food production help to enhance the value of agritourism farms and good for operating efficiency.

5. Conclusion and Recommendation

The empirical results of this study show that the COVID-19 pandemic has significantly reduced the operational efficiency of green restaurants and the overall operational efficiency of agricultural farms. The main reason is that people are unwilling to engage in leisure activities and tourism to avoid the risk of gathering in groups during the epidemic. Interestingly, due to the impact of the epidemic, people paid more attention to organic, healthy agricultural products and sustainable environmental protection, resulting in the operational efficiency of the organic farming department of agricultural farms not being affected. On the other hand, this study found that organic agriculture on agricultural farms with large-scale composting technology can efficiently process and recycle farm waste, stimulate soil nutrient recycling, reduce the cost of dependence on external fertilizers, stabilize soil fertility, and maintain high biodiversity.These factors have improved the management efficiency of agritourism farms. Overall, agritourism farms not only provide consumers with healthier food choices, but also stabilize green supply and value chains. These chains promote mutual trust between organic producers and consumers, are the most direct economic manifestation of eco-friendly organic agriculture, and promote the sustainable development of the natural environment and ecology.

The resources for organic agricultural production are very limited. Therefore, it is important in sustainable agricultural development to reduce costs, convert agricultural waste into agricultural resources, increase agricultural productivity, maximize the efficiency of the farm and obtain the maximum economic benefits through the introduction of the organic farming mode in an agricultural circular economy. According to the statistics and empirical analysis results of this study, the D2 agritourism farm made the highest investment in organic compost and produced the most organic compost, which enhanced the fertility and capacity of the land, increased the organic crop yield, and resulted in the highest efficiency of the organic farming phase (with the inefficiency value of 0). In addition, the increase in the organic crop yield indirectly reduced the cost of green restaurant operations, increasing the latter's efficiency (with the inefficiency value of 0). In summary, the D2 agritourism farm had the largest scale of organic composting for agricultural waste treatment. Although there were many expired and damaged crops in the agritourism farm and lots of kitchen waste in the green restaurant, the organic composting process allowed the agricultural waste to be recycled and produced the highest overall operating efficiency of the agritourism farm. On the contrary, the D3 agritourism farm had the smallest scale of organic composting, resulting in the lowest operating efficiency (with the highest inefficiency value). In conclusion, the full recycling and high mobility of all resources in agritourism farms and the conversion of agricultural wastes into useful agricultural resources enable the organic production department and the green restaurant department in agritourism farms to provide a complete supply chain of organic crops, reduce the distance from the production end (Farm) to the consumption end (Fork), and enhance the operating efficiency of agritourism farms.

The results of this study revealed that the COVID-19 pandemic significantly affected the overall operating efficiency of agritourism farms. Moreover, the quantity of certified crops positively influenced the operating efficiency of such farms. Therefore, agritourism farm operators should adjust their business strategies appropriately, particularly in the post-pandemic era, where the connection between people and the environment takes on even greater significance. Agritourism farms provide visitors with the simplest form of tourism, enabling them to immerse themselves in the culture of the land through slow travel and slow food. Therefore, it is also suggested that agritourism farm operators prioritize local agricultural characteristics and reduce activities or plans that have a weaker connection to the local environment. For instance, the agritourism farms surrounding Sanyi Township, Miaoli County, Taiwan, which is adjacent to the Hakka ethnic group, may offer cultural experiences to visitors, such as blue dyeing and face painting. The Taomi Agricultural Leisure Area, Puli Town, and Nantou County in Taiwan may support and promote local agriculture by offering picnic services in Taomi Village.

Brands can be developed to enhance the value of the local economy, environment, and culture. When combined with organic certifications, agritourism farms are more likely to achieve an iconic status and be recognized as a tourist attraction by travel agencies or individual travelers.

This study further reveals that organic composting cost is a major factor influencing the operating efficiency of agritourism farms. Therefore, agritourism farm operators are expected to improve their knowledge and practical skills of the circular economic model covering agriculture, food, and ecology. Long-term improper composting can lead to negative reactions in soil properties, while proper composting can improve the organic matter, diversify microorganisms, and reinforce crop productivity. Regarding specific practices, hardware facilities may purchase small shredders to shred crop branches and leaves, provided that it is aligned with the operating costs. Meanwhile, fast composting machines can be procured to accelerate the curing of microorganisms. On the other hand, the production and application of composting should be comprehensively understood among software facilities. An appropriate amount of fertilizers can be applied during crop planting or before sowing to strengthen soil fertility. These strategies can effectively reduce the organic composting cost.

From related literature, it is understood that most of the previous research on green restaurants focused on consumer behavior. Studies beyond the consumption pattern of green restaurants are relatively scarce. However, 'production' and 'consumption' represent a transformation process between humans and natural resources. During the consump-tion process, people should pay more attention to the finiteness of Earth's resources and environmental destruction. Thus, from a macro and long-term perspective, the focus should lean towards 'sustainable consumption'. This article contributes by integrating the organic farming methods of agritourism farms, providing a green supply value chain that promotes mutual trust between the organic production and consumption ends of green restaurants. On the other hand, insisting on organic production is not necessarily the best strategy for green restaurants at leisure farms. Therefore, this article analyzes the factors affecting the operational efficiency of agritourism farms. It is found that the cost of organic compost plays a vital role in the profitability of agritourism farms, an aspect which pre-vious related literature has explored less. The suggestions provided in this article will contribute to the cost control strategies of future agritourism farm operations.

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