*Sustainability* **2015**, *7*, 11032-11049; doi:10.3390/su70811032

OPEN ACCESS

*sustainability*

**ISSN 2071-1050**

www.mdpi.com/journal/sustainability

*Article*

# Greenhouse Gas Emissions of Tourism-Based Leisure Farms in Taiwan

**Kuo-Tsang Huang [1] and Jen Chun Wang [2,*]**

[1] Department of Bioenvironmental Systems Engineering, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd., Taipei 10617, Taiwan; E-Mail: huangkt@ntu.edu.tw

[2] Department of Industry Technology Education, National Kaohsiung Normal University, No.62 Shenjhong Rd., Yanchao District, Kaohsiung 82446, Taiwan

* Author to whom correspondence should be addressed; E-Mail: jcwang@nknucc.nknu.edu.tw; Tel.: +886-7-717-2930 (ext. 7612).

Academic Editor: Marc A. Rosen

*Received: 10 June 2015 / Accepted: 10 August 2015 / Published: 12 August 2015*

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**Abstract:** This research is the first attempt of a carbon emission investigation of tourism-based farms. A total of 36 cases were investigated. The result reveals that each tourist returns an average revenue of 28.6 USD and generates an average 10.9 kg-$CO_2$eq per visit of carbon emissions. The average carbon emission density for each land area is 8.2 t/ha·year and is 245 kg/m²·year for each floor area. It is estimated that the overall carbon emissions reach 321,751 tons annually. The tourism-based farms were clustered into five categories, based on their business characteristics. It was found that high-end vacation leisure farms produce 2.46 times the carbon emissions than natural eco-conservation farms. Carbon emissions were 42% higher than the annual average in July and August. A secondary high season is in February, but it is merely higher than the annual average by 8% because of the mild climate. Two significant models for predicting carbon emissions were constructed by stepwise regression. As agriculture administrative authorities in Taiwan gradually have begun admitting the cultivated lands for multi-purpose usage, tourism-based farms have been increasing drastically. This study provides references for both public authorities and farm managers in exploring the issues with regard to carbon emissions and farm sustainability.

**Keywords:** tourism-based farms; energy consumption; carbon emission; low-carbon tourism; farm tourism

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## 1. Introduction

The tourism business is able to stimulate economic development [1]. However, the carbon footprint embodied in the tourism industry includes infrastructure construction, hotel building construction, catering services, transportation *etc.*, which leads to an underestimation of the tourism sector's environmental responsibility [2–4]. There is obvious economic growth for those countries that have endeavored in tourism development [5–8]. However, it is an undisputable truth that tourism businesses will also produce significant amounts of carbon emissions [9]. From the perspective of carbon emission, the relation and interaction between the development of tourism and the climate change has been confirmed and identified. Evidence also showed that the tourism industry has a significant influence on the global greenhouse gas (GHG) emissions [10,11]. The issue of carbon emissions in regard to tourism has been discussed in various countries and regions recently [12–15]. Many countries, such as Spain [16], Turkey [17], and European Union countries [18] whose GDP is largely dominated by tourism industry have revealed empirical evidence of the increased carbon emission burden attributed to the tourism development. A Mediterranean island country, Cyprus, whose condition of limited resources is quite similar to Taiwan, has worried about the increasing carbon emission due to the thriving tourism industry and pointed out that protection measurements in the tourism sector should be enacted [19]. Crete Island in Greece, also facing with similar problems, has turned to harvesting renewable energies from solar power to sustain the energy use by the flourishing hotel industry [20]. In Macau, the carbon emission drastically rose by 100.31% during 2000 to 2010 due to the increasing consumption of energy by the tourism industry, service industry and recreational business [21,22].

In 1989, the Council of Agriculture of Taiwan selected 31 rural areas in which to develop leisure farms for the purpose of creating and promoting agricultural tourism and to help sustain agriculture. Agricultural tourism could generate income, create jobs and encourage retail growth [23]. As of 2014, the total number of legal leisure farms is 250. There are several studies on leisure farms conducted in Taiwan from marketing or visitor profile analyzing perspectives: Chang [23] identified the main factors of products and services provided in the leisure farms and analyzed the visitors' demographic profiles as well as their socio-economic characteristics. Chen *et al.* [24] adopted structured questionnaires to investigate travelers' perceptions of farm tourism and used a popular leisure farm in Taiwan as a site for their case study. Huang [25] tried to revitalize the leisure farm industry by implementing an e-commerce strategy. Wu [26] investigated foreign tourists' intentions in visiting leisure farms. Till now, no studies targeting Taiwan have been aimed at the assessment of environmental impact of leisure farms.

The World Tourism Organization (UNWTO) has noted that Taiwan's tourist arrivals topped all other countries in the North-East Asian region during 2012–2014 [5]. Being favored by numerous tourists visiting from China, the average growth rate of international tourist arrivals has reached 13% over the past three years (2012–2014) [5]. Domestic travel has also been flourishing with a growth rate of 12% on average during the same period. As low carbon tourism is gaining more attention due to rises in energy prices, the balance between tourism growth and GHG emissions should be emphasized in order to achieve a sustainable and environmental friendly future, which would be beneficial for public services, owners or managers of tourism industries, or the consumers. Carbon flow caused by international tourism is usually received by and accounted for in destination countries [27,28], and Taiwan is not an exception. Moreover, Taiwan is an island with limited natural resources that would have more stress on reducing its carbon footprint than continental countries [29,30].

The development of tourism is highly dependent on the natural environment and its resources [1,31,32]. Spanning the 3.6 million hectares of land in Taiwan, 59% is allotted to development-restricted mountainous forest lands, 28% to agriculture lands, and only 13% of the lands constitute urban and rural residential areas, which are occupied by approximately 23 million people. However, since two-day weekends became effective starting in 2000 in Taiwan, many people living in urban areas began flushing into the countryside on weekends for vacation, resulting in 6% of cultivated lands being transformed for recreation purposes in recent decades (2005–2014) [33]. The number of tourism-based farms enormously increased from 76 in 2003 to 493 in 2013. From the viewpoint of farm entrepreneurs, opening a working farm to visitors offers a secondary revenue source, resulting in some lands originally cultivated for food production to inevitably become transformed for recreational use to meet tourists' needs. Producing sufficient food for a growing population, within the context of climate change and natural resource constraints, presents major challenges for the future [34]. $CO_2$ emissions associated with land use change are already related to the conversion of natural ecosystems into managed ecosystems for food and feed [35]. With the already existing agricultural land being insufficient to sustain the domestic food demand, the recent agriculture to leisure business land transformations have not only heightened $CO_2$ emissions but worsened the problem of limited land resources for food cultivation.

As all processes involved in producing agricultural products require energy and water, the sources of carbon emissions are various, but international studies on carbon emissions from farms have only mainly focused on those actually involved in agricultural production. In contrast to the resulting narrow, negatively biased view toward farmland, it should be considered that crops/plants grown on farms are capable of capturing carbon dioxide by the photosynthesis process. While different kinds of crops have different capabilities in regards to GHG (greenhouse gas) emissions reduction [34,36], it is, in fact, the vegetation coverage rate that is considered the most crucial indicator in improving the eco-environment [37]. Therefore, in terms of alleviating carbon emissions, it would be beneficial if cultivated lands were simply not transformed for recreational facility use. Taiwan is now facing a major dilemma due to the fact that the fast developing tourism-based farms are gradually eroding the already limited cultivation lands. The purpose of this study is to provide an in-depth discussion on the impact of carbon emissions generated by these tourism-based farms by means of energy auditing. Although the disclosure of GHG emissions may not be a primary concerning factor for people in choosing their destinations, the GHG emission disclosure delivers information for the administrative authority to understand the overall environmental impact of this industry, and take measures in seeking national GHG emissions equilibrium from nation-wide perspectives.

## 2. Background and Methodology

### *2.1. The GHG Emissions Auditing Approach*

A bottom up approach from detail energy auditing to GHG emission conversion was adopted in the study. One limitation of this method is that it requires robust and well documented energy pay bills or usage records to accomplish the auditing process; however, not all the leisure farms will document these energy data in detail. To audit all the leisure farms is impractical by the bottom up auditing approach. Overall, 36 cases were selected for this study. The primary GHG emissions are that of carbon dioxide ($CO_2$), nitrous oxide ($N_2O$), methane ($CH_4$), ozone ($O_3$), sulphur hexafluoride ($SF_6$), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs) [38]. Among them, the GHGs expected to be generated by the energy use of hotels include $CO_2$, $CH_4$, and $N_2O$. Therefore, the scope of a GHG emission audit should involve all of these three gases ($CO_2$, $CH_4$, and $N_2O$) instead of $CO_2$ only. Table 1 summarizes the GHGs generated by different kinds of energy consumption according to local energy efficiency. In fact, both the use of electric power and fossil fuels will indirectly/directly emit GHGs, which not only pollute our environment but also contribute to global warming. According to the report announced in 2012 by the Bureau of Energy of Taiwan, every kilowatt of electricity usage is equivalent to 0.532 kg of $CO_2$ emissions. In the fifth assessment report on climate change in 2013, the past changes in atmospheric GHG concentrations were determined with very high confidence exceeding the most unprecedented range of concentrations ever recorded [35]. Typically, GHG emissions are reported in units of carbon dioxide equivalents ($CO_2$eq) and the total GHG emissions of a given case can be evaluated via Equation (1) by referencing the various energy emission factors ($\alpha$) given in Table 1.

$$E_{GHG} = \sum_i \sum_j E_{i,j} \cdot \alpha_{i,j} \tag{1}$$

where $E_{GHG}$ is total GHG emissions in kg-$CO_2$eq, $i$ denotes a given energy type, $j$ denotes each GHG and $\alpha_{i,j}$ denotes the emission factor for $j$-type GHGs of $i$-type energy and s of $i$-type energy.

**Table 1.** Greenhouse gas (GHG) emissions generated by different energy resources.

| Energy Type | Unit | GHGs | Emission Factor ($\alpha$) [a] | kg-$CO_2$eq [b] |
|---|---|---|---|---|
| Liquefied petroleum gas (LPG) | L | $CO_2$ | 1.75 kg-$CO_2$/L | 1.75 |
| | | $CH_4$ | $2.78 \times 10^{-5}$ kg $CH_4$/L | $5.84 \times 10^{-4}$ |
| | | $N_2O$ | $2.78 \times 10^{-6}$ kg $N_2O$/L | $8.62 \times 10^{-4}$ |
| Liquefied natural gas (LNG) | $m^3$ | $CO_2$ | 2.66 kg-$CO_2$/$m^3$ | 2.66 |
| | | $CH_4$ | $1.24 \times 10^{-4}$ kg $CH_4$/$m^3$ | $2.60 \times 10^{-3}$ |
| | | $N_2O$ | $2.49 \times 10^{-5}$ kg $N_2O$/$m^3$ | $7.72 \times 10^{-3}$ |
| Heavy fuel | L | $CO_2$ | 2.98 kg-$CO_2$/L | 2.98 |
| | | $CH_4$ | $1.16 \times 10^{-4}$ kg $CH_4$/L | $2.44 \times 10^{-3}$ |
| | | $N_2O$ | $2.31 \times 10^{-5}$ kg $N_2O$/L | $7.16 \times 10^{-4}$ |
| Light fuel | L | $CO_2$ | 2.73 kg-$CO_2$/L | 2.73 |
| | | $CH_4$ | $1.44 \times 10^{-4}$ kg $CH_4$/L | $3.02 \times 10^{-3}$ |
| | | $N_2O$ | $1.44 \times 10^{-4}$ kg $N_2O$/L | $4.46 \times 10^{-2}$ |
| Electricity | kWh | $CO_2$eq | 0.532 kg-$CO_2$eq/kWh | 0.532 |

[a] Per unit energy emits GHG [39]. The factors are calculated by Bureau of Energy, Taiwan, according to the local energy efficiency; [b] Kilogram of carbon dioxide equivalent. The conversion factors are 1 kg-$CO_2$ = 1 kg-$CO_2$eq, 1 kg $CH_4$ = 21 kg-$CO_2$eq, and 1 kg $N_2O$ = 310 kg-$CO_2$eq, respectively [38].

### *2.2. Description of the Studied Samples*

Because of the limited natural destinations in Taiwan, leisure farms became a new thriving holiday destination to provide a getaway or retreat especially for urban people. Leisure farms provide a variety of services and activities to choose from. Activities such as in-farm dining, fruit picking experience, livestock raising experience, horse riding, flower viewing, tea or coffee tasting, *etc*. can usually be seen in leisure farms. Furthermore, some larger cases will provide areas or fields for physical training/exercising, lodging, picnicking, camping, bicycling, leisure boating, or even have pools for healing spa treatment. Some leisure farms provide courses to learn or visit the making/producing process of agricultural products, such as rice cake, wine, beer, bee honey, milk, essential oil, tea, coffee, *etc*. The types of recreational facilities a leisure farm provides are quite diverse. The average length of the stay of tourists varies with the location of the leisure farm. Basically, although suburban leisure farms provide accommodation facilities, people seldom lodge in those farms. A couple of hours' stay or a day visit with an in farm dining experience is usually the case. For remote farms, especially for those located in mountainous areas, around 70% of the tourists will usually spend two days with an overnight stay, and some will choose to stay for three days. Few people, usually retired people, will spend more than a week's or a month's long stay in leisure farms.

As of 2014, the total number of leisure farms is 250. The geographical distribution of these farms is nearly randomly distributed across the Taiwan Island, from suburban areas, rural areas to mountainous areas. To conduct a general investigation of all cases is labor intensive and time consuming, which is considered impractical. Therefore, the 36 cases discussed in the studies were randomly selected based on their geographical distribution. The administrative authority of leisure farms in Taiwan is the Council of Agriculture. There is no official classification and definition of leisure farms. Therefore, for research convenience and to derive useful results, we clustered them based on the business types of farms. As depicted in Figure 1, there are 36 tourism-based farms studied, which are evenly distributed across the island of Taiwan. There are five cases located in the northern area, six cases in the central region, nine cases in the south, eight cases in the east, and eight in the mountainous area. None of the cases are located in metropolitan areas. The altitude of each case is tabulated in Table 2, ranging from 50 m to 2300 m. The sizes of the farms range from small suburban farms with occupied land areas below three hectares to large forest conservation and high-altitude fruit planting farms occupying over 700 hectares.

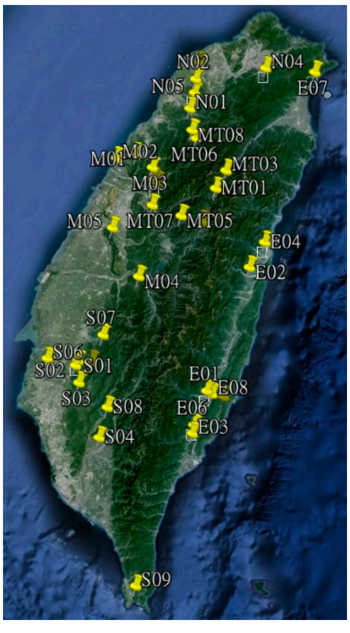


**Figure 1.** Distribution of the 36 studied cases.

**Table 2.** Information of the 36 leisure farms.

| Sample | Land Areas (ha) | Total Building Floor Areas ($m^2$) | Altitude (m) | Ticket Price (USD) | Revenue per Year (1000 USD) | No. of Lodging Rooms | No. of Guests per Year (1000) | Energy (MWh) |
|---|---|---|---|---|---|---|---|---|
| N01 | 70 | 3026 | 500 | 11.7 | 7392 | 0 | 489 | 2965 |
| N02 | 27 | 3996 | 200 | 12 | 2129 | 32 | 114 | 1727 |
| N03 | 15 | 1985 | 200 | 3.3 | 2550 | 0 | 136 | 714 |
| N04 | 12 | 966 | 400 | 6.7 | 7118 | 3 | 378 | 2023 |
| N05 | 3 | 1990 | 100 | 15 | 1868 | 33 | 103 | 1142 |
| M01 | 50 | 5861 | 50 | 6.7 | 6989 | 62 | 300 | 3688 |
| M02 | 35 | 5962 | 60 | 5 | 5371 | 51 | 205 | 3354 |
| M03 | 64 | 1762 | 300 | 1 | 4803 | 4 | 160 | 3152 |
| M04 | 100 | 1785 | 515 | Free | 1171 | 62 | 39 | 1299 |
| M05 | 1 | 1193 | 200 | 3.3 | 2263 | 0 | 105 | 690 |
| M06 | 135 | 955 | 370 | 3.3 | 2452 | 30 | 80 | 1301 |
| S01 | 106 | 9605 | 300 | 5 | 8294 | 120 | 229 | 3976 |
| S02 | 33 | 5892 | 200 | 11.7 | 2626 | 60 | 134 | 1794 |
| S03 | 120 | 24,697 | 200 | 8.3 | 8935 | 240 | 420 | 5825 |
| S04 | 8 | 3288 | 400 | 3.3 | 561 | 40 | 20 | 739 |
| S05 | 50 | 4019 | 277 | 3.3 | 6245 | 52 | 222 | 1693 |
| S06 | 4 | 1008 | 60 | 3.3 | 1056 | 0 | 38 | 153 |
| S07 | 6 | 1953 | 450 | Free | 2182 | 0 | 83 | 600 |
| S08 | 23 | 2469 | 210 | 6 | 1199 | 63 | 49 | 1511 |
| S09 | 48 | 3558 | 150 | 6.7 | 10,368 | 34 | 386 | 5876 |
| E01 | 400 | 6128 | 100 | Free | 2502 | 70 | 55 | 1856 |
| E02 | 726 | 15,600 | 50 | 11.7 | 22,036 | 130 | 245 | 9775 |
| E03 | 72 | 3557 | 300 | 3.3 | 11,424 | 0 | 357 | 4689 |
| E04 | 3.3 | 2008 | 350 | 3.3 | 1268 | 24 | 51 | 1557 |
| E05 | 615 | 3469 | 400 | 0 | 3367 | 30 | 98 | 1688 |
| E06 | 1 | 1895 | 500 | 2.7 | 566 | 0 | 27 | 381 |
| E07 | 110 | 6014 | 81 | Free | 15,891 | 97 | 318 | 6725 |
| E08 | 53 | 4140 | 350 | 1.7 | 1057 | 16 | 254 | 577 |
| MT01 | 800 | 7980 | 2300 | 2.3 | 7877 | 90 | 156 | 2756 |
| MT02 | 760 | 12,050 | 1750 | 5.3 | 24,983 | 103 | 1,149 | 6721 |
| MT03 | 700 | 11,296 | 2000 | 5.3 | 14,644 | 105 | 379 | 3722 |
| MT04 | 224 | 10,060 | 600 | 8.3 | 7827 | 112 | 258 | 2783 |
| MT05 | 100 | 9960 | 770 | 5 | 6120 | 98 | 183 | 2131 |
| MT06 | 13 | 7644 | 1923 | Free | 3056 | 78 | 63 | 1317 |
| MT07 | 8 | 640 | 750 | 5 | 490 | 8 | 13 | 348 |
| MT08 | 150 | 850 | 1300 | Free | 2823 | 10 | 93 | 786 |

The majority of the owners of these farms make their living by providing services for tourists as their major revenue. The services provided include accommodations, restaurants, or vending of special local products and souvenirs. Except for three cases in the east region, these farm owners still make their living primarily with agricultural crops and livestock, one case for vegetables and fruits, and three cases located in the mountains sell high-altitude fruits, with agricultural products grown on farms in all the other cases meant to serve the need of visiting tourists or nearby suburban residents. The types of farm entrance fees deviates a lot. There are those with high-priced entrance fees that typically have coupons for in-farm purchases, and there are also farms with no entrance fee to encourage people to come. The revenue earned and the numbers of tourists also have large discrepancies due to the large deviation in farm sizes. Generally, the farms whose locations are near the urban area and are easily accessible usually have more visiting tourists and have achieved large economies of scale. The availability of accommodation services, on the other hand, is quite different from the variation seen in their marketing strategies. In general, large and remote farms usually provide accommodation services for vacation purposes while small and suburban farms simply do not provide accommodation. Since it is not allowed to use firewood in Taiwan, the energy audit process includes electricity, liquid petroleum gas (LPG), and fuel (heavy fuel and light fuel). The type of fuel used on Taiwanese leisure farms are light fuel and heavy fuel oils. The light fuel includes diesel fuels for electric generators and agricultural machines/vehicles, and gasoline for car vehicles. The heavy fuel oil is primary used by boilers for water heating purpose to supply domestic hot water. The total energy consumption varies much with the sizes of farms, as shown in Table 2.

## 3. Energy Audit Results of the Studied Leisure Farms

### *3.1. Analysis of Annual Carbon Emission of Leisure Farms*

The annual energy consumption and carbon emissions of the 36 studied farms are tabulated in Table 3. The annual average use of electricity, LPG, and fuels are 2254 MWh, 93 MWh, and 209 MWh, respectively, for each farm. The estimated annual expenditure of energy fares is circa 193,058 USD, which is 3.3% of the total revenue. This energy-revenue percentage is similar to that of bed-and-breakfast accommodations (3.0%) but is far lower than other types of Taiwanese hotels, which for international hotels is 4.9%, for tourist hotels is 5.7%, and for general hotels is 7.7% [40]. The primary source of energy demands is electricity for most cases. As most apparatuses or equipment use electricity as their primary energy input, the annual expenditure for electricity consumption comprises 90% of the total energy fares. LPG is primarily used for culinary purposes and hot water supplies for the accommodation units. Fuel is the main energy type used by central water heating systems and also for emergency power generators as well as agricultural mechanical equipment. The purchase of electricity comprises 95% on average of the total energy expenditure in seven cases with no accommodation services, but it comprises only 82% in six cases providing more than 100 accommodation units. Furthermore, as there is high demand in fuels for heating water, the average electricity fare expenditure is about 81% of the total energy fare for the eight cases located in the high altitude mountain area. Therefore, it is obvious that the main source of the GHG emissions is coming from the consumption of electricity, which on average comprises 94% of the total GHG emissions. The annual average GHG emission of each farm is 1287 tons (t).

**Table 3.** GHGs emission statistics of the studied cases.

| Sample(n) | Electricity (MWh) | LPG (MWh) | Fuel (MWh) | Electricity Usage Ratio (%) | GHGs by Electricity (t) | GHGs by LPG (t) | GHGs by Fuel (t) | Total GHGs (t) |
|---|---|---|---|---|---|---|---|---|
| **North(5)** | | | | | | | | |
| Avg. | 1604 | 85 | 26 | 94% | 853 | 22 | 8 | 883 |
| Max. | 2667 | 298 | 129 | 98% | 1419 | 76 | 39 | 1495 |
| Min. | 680 | 13 | - | 90% | 362 | 3 | 0 | 370 |
| **Middle(6)** | | | | | | | | |
| Avg. | 2092 | 43 | 112 | 94% | 1113 | 11 | 34 | 1158 |
| Max. | 3344 | 118 | 308 | 97% | 1779 | 30 | 94 | 1882 |
| Min. | 670 | 20 | - | 91% | 356 | 5 | 0 | 362 |
| **South(9)** | | | | | | | | |
| Avg. | 2235 | 75 | 153 | 92% | 1189 | 19 | 47 | 1255 |
| Max. | 5814 | 154 | 726 | 99% | 3093 | 39 | 222 | 3109 |
| Min. | 145 | 8 | - | 84% | 77 | 2 | 0 | 79 |
| **East(8)** | | | | | | | | |
| Avg. | 3002 | 136 | 268 | 93% | 1597 | 35 | 82 | 1714 |
| Max. | 8117 | 629 | 1029 | 98% | 4318 | 161 | 314 | 4794 |
| Min. | 371 | 10 | - | 83% | 197 | 3 | 0 | 200 |
| **Mountain(8)** | | | | | | | | |
| Avg. | 2057 | 114 | 399 | 81% | 1094 | 29 | 122 | 1245 |
| Max. | 5643 | 350 | 883 | 90% | 3002 | 90 | 270 | 3314 |
| Min. | 302 | 28 | - | 73% | 161 | 7 | 0 | 172 |

### *3.2. Monthly Electricity Usage of Leisure Farms*

As electricity is the primary energy source used in farms, it is of great interest in this study. The high demand of electricity occurs in July and August, which corresponds to the high seasons for tourism. In summer, the monthly electricity use is 42% higher than the annual average, while the number of monthly visiting tourists is higher than the annual average by 33%. The second high season lies in February because of the traditional Chinese New Year holiday. Although the number of visiting tourists during this period is higher than the annual average by 59%, the electricity use is only 8% higher during the same period. Most farms are not equipped with a heating system because of the relatively mild winter in Taiwan, resulting in the monthly average electricity use in summer months being higher than winter by around 40%. This reveals that energy use in summer is primarily dominated by air-conditioning. Moreover, we observed that electricity use during the summer high season was only higher than the annual average by 13%, which is much lower than that of the low-altitude farms. In fact, energy use peaked in February and was higher than the annual average by 38%. By observing these *in situ* investigated cases, we found that some cases do not come with air conditioning systems, as there is no cooling demand for farms located at altitudes higher than 1000 m all year round. Instead, heating systems are provided in four cases located at altitudes above 2000 m. This finding drove the need to discuss the cases in the mountainous area separately. Furthermore, from a preliminary statistical analysis of all cases, we found that the standard deviation of annual electricity use over the mean was as high as 81%, indicating that there are large discrepancies among the cases in marketing strategies and the sizes that cause large variations in the electricity use.

The percentages illustrated in Figure 2 show the amount of monthly energy consumption compared to the total annual energy use. The peaks were in July and August when the tourism is in high season. The electricity consumption comprised 23.7% of the annual energy use. A second high season apparently lies during Chinese New Year in February, which peaked at 9.1%. Although it is not as much as that in summer months, since energy use does not need to include air conditioning, it was still higher than the adjacent winter months by 70%.

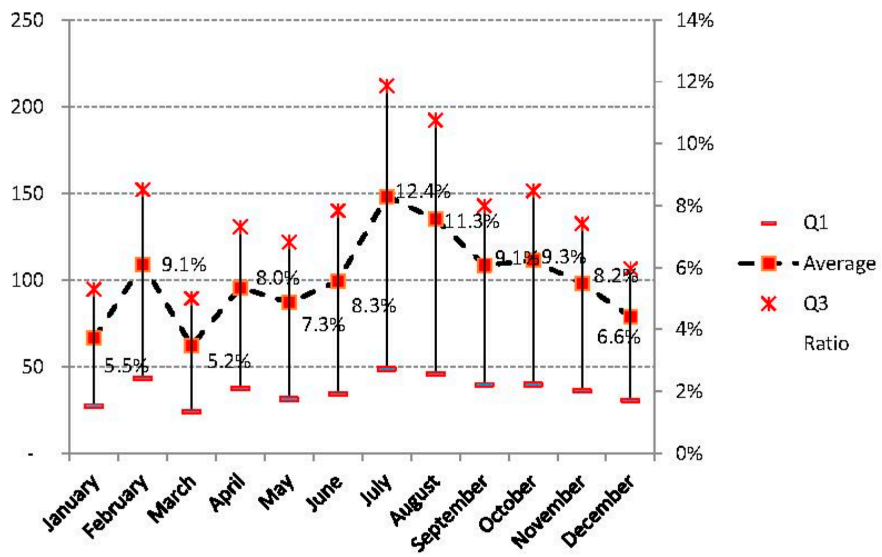


**Figure 2.** Monthly electricity use of all cases (unit in MWh) whereby Q1 is the first quartile and Q3 is the third quartile.

### *3.3. Analysis of Monthly GHGs Emission per Person*

Due to there being different marketing oriented farms, we categorized them into five different types, which include the ecology conservation type (EC, five cases), countryside experience type (CE, six cases), tourism orchard type (TO, seven cases), countryside bed-and-breakfast type (BnB, four cases), and tourism resort type (TR, 14 cases). The EC type farms are oriented toward educating tourists with knowledge of ecology and conservation. The CE type farms aim to provide urban residents experiences of rural country life. The TO type farms profit from the entrance fee for fruit picking. The BnB type farms provide rural country life experiences and fundamental rural accommodation facilities. The TR type farms are usually situated in remote locations and provide luxurious accommodation rooms for vacation. The average GHG emissions per person are shown in Figure 3. Among them, it was the lowest for the EC type farms, which was on average 4.16 kg-$CO_2$eq/person annually, followed by CE type farms 7.66 kg-$CO_2$eq/person, TO type farms 9.39 kg-$CO_2$eq/person, TR type farms 10.02 kg-$CO_2$eq/person and BnB type farms 10.24 kg-$CO_2$eq/person.

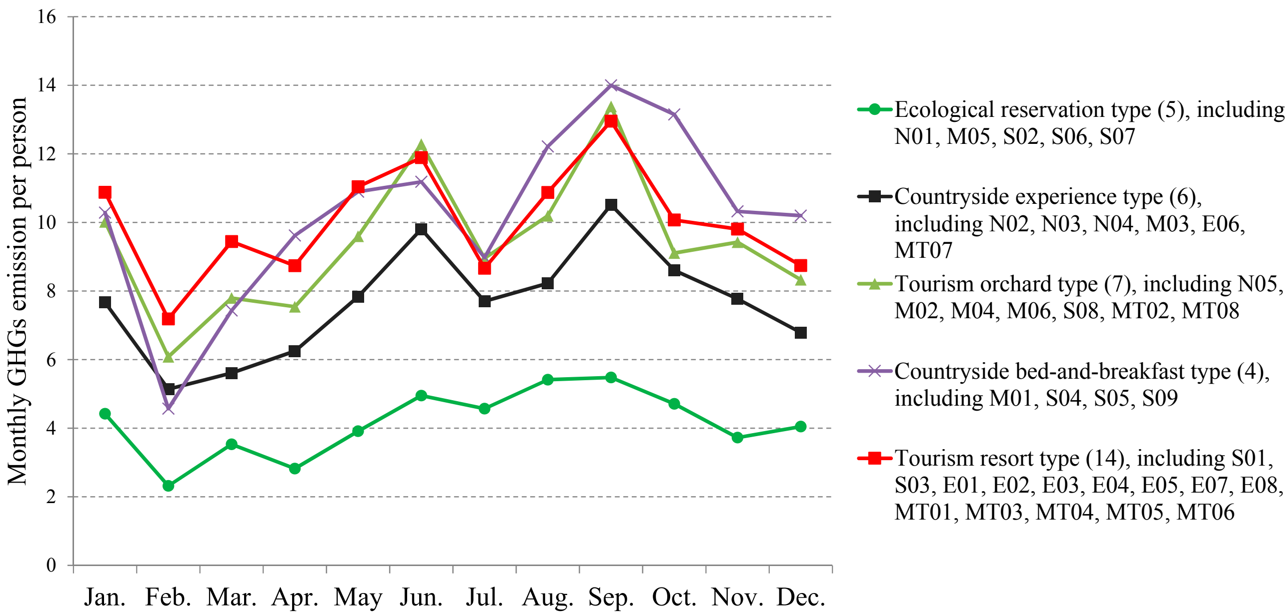


**Figure 3.** Monthly GHGs emission per person of different types of farms (unit in kg-$CO_2$eq/person).

Furthermore, from the monthly analysis revealed in Figure 3, we discovered that the GHG emissions per person in high seasons were not the highest compared to other months due to the fact that there are a higher number of visiting tourists during that period. The GHG emissions per person were even the lowest in February through the year, showing that there are basic energy demands in operating farms.

However, by further scrutinizing the energy data between different types of farms, we found that there were large discrepancies. For instance, although EC farms were the type that had the lowest GHG emissions per person, the S02 case was apparently high because it has 60 vacation wooden villas for accommodation. A similar phenomenon can be observed in CE type farms, e.g., case M03, which was also higher than the others for the same reason. There are cases like this in every type of farm, especially for those whose ratio of lodging visitors over the total number of tourists is high. TR type farms took the lead in higher energy use intensity when compared to BnB type farms. As the sizes and the lodging prices of TR farms are larger and higher than BnB farms, tourists usually tend to lodge in the neighboring inexpensive places and enter the TR farms by purchasing an entrance ticket. As a result, the ratio of lodging visitors over the total number of visitors for TR farms is apparently lower than BnB farms. This is why the GHG emissions per person of TR farms were not expected to be higher than BnB farms. This reveals that GHGs emitted from lodging activity is much higher than that of simply visiting the farms.

Furthermore, electricity use is the primary energy used among all types of leisure farms. It comprised 86%–94% of the total energy, as depicted in Figure 4. LPG and fuel are primarily for domestic hot water supply and for culinary purposes. The annual percentage of LPG and fuel use of TR type farms reached 14%, which was the highest among all types. Ten of these still use traditional heavy fuel boilers for their domestic hot water supplies, resulting in higher consumption of fuels than LPG. The average electricity consumption of TR type farms is 86%, a percentage that corresponds well with the reported average of 83%–86% in a previous study on Taiwanese hotel energy use [41]. The amounts of LPG and fuel use comprised less than 10% of the total energy use for the other types of farms.

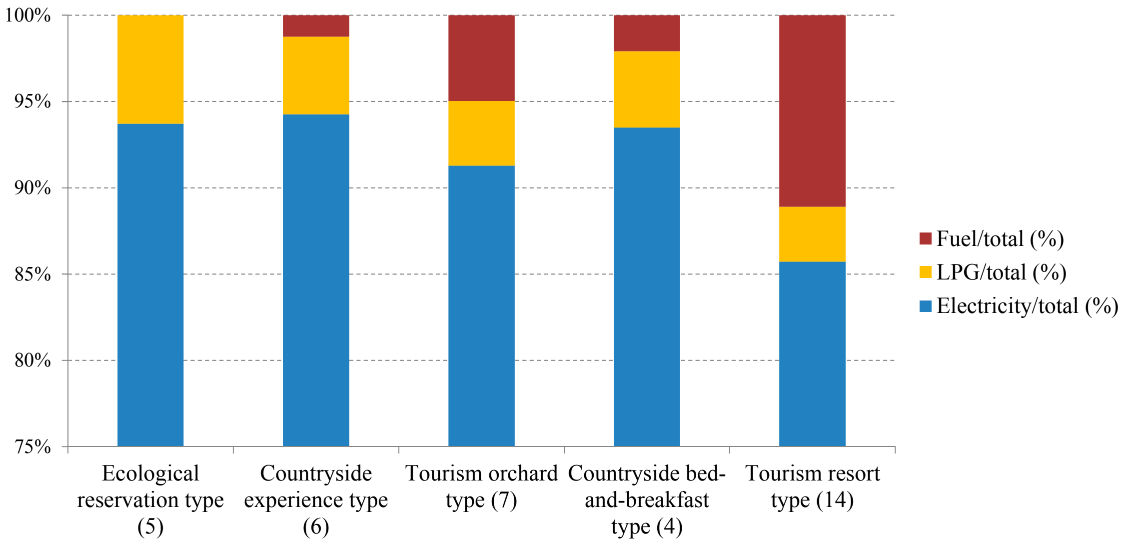


**Figure 4.** Breakdown of energy use sources of various types of farms.

*3.4. GHG Emission Analysis of Leisure Farms without Lodging*

As lodging activity has a large influence on the amount of GHG emissions, to further discuss and compare the GHGs among different types of farms, we standardized the GHG emissions of each case by subtracting the energy used for lodging from the total energy consumption. However, since most of the farms with accommodation units did not have independent electricity meters, it was not feasible to analyze the annual electricity use of each individual accommodation unit. The average number of rooms for farms provided with accommodations was 52 units with a 46.3% annual occupancy rate, which corresponds remarkably well with the 52 units and 46.3% occupancy rate observed in the previous general hotels studies conducted by Wang and Huang [40,41]. Therefore, the method we adopted in the standardization process was to deduct the total energy use with the averaged lodging energy use, which was 15.3 MWh/room·year, or 86.2 kWh/occupied room/night, taken from the above literature.

The GHG emissions per person after deducting the lodging electricity uses are tabulated in Table 4. The monthly average GHG emission per person on EC type farms was 3.36 $kgCO_2eq$/person per visit, which was the lowest. The values of GHG emissions per person on CE, TO, and BnB ranged between 4 to 6 $kgCO_2eq$/person. The GHG emission per person on TR type farms was 7.8 $kgCO_2eq$/person, which was the highest among all the types. The sizes of TR farms are usually larger. As these farms usually have multi-functional business models, there are more service facilities and production equipment. For instance, because of the widespread area, electric powered four-wheel vehicles are used on the E02 farm. The extra electricity demand of those electric-powered vehicles resulted in the highest energy use per person among all cases. For the case of E04, although it is not such a vast farm area as E02, and even though the visitors have been fewer in number, the GHG emissions of E04 still ranked second because of the high-end services of the body spa it provides.

As the electricity use of farms located at altitudes higher than 600 m are lower due to less cooling energy demand, we categorized these eight cases as mountainous farms independently. The results (not shown in the Table 4) showed that the average electricity use per person was similar to that of EC type farms, further suggesting that the electricity uses of farms located in mountain areas tend to be lower and should be discussed separately in predicting their energy use.

**Table 4.** Monthly GHG emission per person without lodging of different types of farms (unit in $kgCO_2eq$/person).

| Sample | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ecological reservation type (EC) | | | | | | | | | | | | |
| Average | 3.36 | 1.90 | 3.00 | 2.30 | 3.19 | 4.06 | 3.49 | 3.96 | 4.55 | 3.94 | 3.12 | 3.46 |
| Countryside experience type (CE) | | | | | | | | | | | | |
| Average | 5.36 | 3.87 | 4.27 | 4.51 | 5.47 | 7.15 | 6.47 | 6.87 | 7.70 | 7.02 | 6.34 | 5.15 |
| Tourism orchard type (TO) | | | | | | | | | | | | |
| Average | 5.08 | 3.04 | 4.17 | 3.64 | 4.59 | 5.68 | 4.04 | 4.58 | 6.62 | 4.26 | 4.36 | 4.20 |
| Countryside bed-and-breakfast type (BnB) | | | | | | | | | | | | |
| Average | 5.86 | 2.33 | 4.10 | 3.94 | 4.51 | 5.48 | 3.86 | 5.07 | 4.95 | 5.56 | 4.80 | 4.83 |
| Tourism resort type (TR) | | | | | | | | | | | | |
| Average | 7.58 | 5.66 | 7.58 | 7.03 | 9.01 | 9.42 | 6.47 | 7.97 | 10.29 | 8.11 | 7.80 | 6.70 |

## 4. Discussion

### *4.1. Analysis of the Influential Factors on GHG Emission*

In order to formulate strategies on reducing GHG emissions to alleviate the environmental impact, the influential factors on GHG emissions should be identified in advance. This section focuses on the correlation analysis of various factors against emission values of total GHGs, GHGs per person, GHGs per unit land area, and GHGs per unit floor area. The results provided in Table 5 show that the factor of total GHG emissions was positively correlated with farm size, building floor area, the number of accommodating rooms, and the number of visiting tourists. The p-value of these factors against total GHG emissions were all less than 0.01 with the coefficients of Pearson correlation being 0.468–0.650, showing a significant relationship in between. Only the entrance admission fee whose p-value is larger than 0.05 is insignificant against the GHG emissions. It reveals that the demand from tourists and the related tourist activities are the main cause of the GHG emissions of leisure farms. Moreover, as accommodation services are provided in BnB and TR type farms, their GHG emissions were generally higher than the other types of farms.

The climate at around 1000 m is considered the mildest and the most comfortable weather in Taiwan. Buildings located at altitudes higher than 1000 m usually have a heating demand in winter while those located lower than this altitude may have cooling demands in summer. All these cooling or heating demands lead to additional GHG emissions. Therefore, to reflect this demand, a factor of altitude counts was adopted. Altitude counts are defined as a positive integer of +1 was assigned to farms for every 100 m in altitude they resided above or below 1000 m, with farms at 1000 m given a base value of 0.

**Table 5.** Correlation analysis of various factors to GHG emission.

| | | Types [1] | Site Area | Building Area | Entrance Admission Fee | Altitude Counts [2] | Number of Rooms | Number of Tourists |
|---|---|---|---|---|---|---|---|---|
| Total GHG | Pearson correlation | **0.423 *** | **0.468 **** | **0.650 **** | 0.286 | **0.344 *** | **0.569 **** | **0.639 **** |
| | *p-value* | 0.010 | 0.004 | 0.000 | 0.091 | 0.040 | 0.000 | 0.000 |
| GHG per person | Pearson correlation | **0.377 *** | 0.142 | 0.067 | −0.084 | 0.050 | 0.206 | **−0.376 *** |
| | *p-value* | 0.023 | 0.410 | 0.697 | 0.627 | 0.773 | 0.229 | 0.024 |
| GHG per square meter of land area | Pearson correlation | **−0.356 *** | **−0.349 *** | −0.298 | 0.090 | 0.025 | **−0.334 *** | −0.209 |
| | *p-value* | 0.033 | 0.037 | 0.078 | 0.603 | 0.883 | 0.047 | 0.221 |
| GHG per square meter of floor area | Pearson correlation | −0.083 | −0.152 | **−0.336 *** | 0.002 | −0.082 | **−0.347 *** | 0.199 |
| | *p-value* | 0.628 | 0.376 | 0.045 | 0.989 | 0.634 | 0.038 | 0.244 |

* denotes to statistically significant when *p-value* < 0.05 (two tails). ** denotes to statistically significant when *p-value* < 0.01 (two tails). [1] 1 for EC type farms; 2 for CE type farms; 3 for TO type farms; 4 for BnB type farms; 5 for TR type farms. [2] 0 for altitude = 1000 m with a count of +1 for every 100 m increment or decrement, e.g., 500 m altitude is count as +5 and 1800 m altitude is count as +8.

In regard to GHG emissions per person, the values were higher for farms with accommodation services and those oriented toward vacation needs. In contrast, the GHG emissions per person seem to drop when the visiting tourists are many in number when it reached the economies of scale. With respect to the factor of GHGs per land area, our results show that the GHG level is lower for bigger and more luxurious farms. These types of farms usually have larger land spaces and more accommodation rooms to provide versatile leisure facilities and landscapes that would attract more tourists. Moreover, these farms are usually located in remote areas with relatively low land cost, which further contributes to the farm scale and building floor area being bigger. This tendency toward having very large land areas explains the lower GHG emission values when calculated as GHGs per land area. The same situation also occurs in the factor of GHGs per floor area. In general, GHG per person, GHG per square meter of land area, and GHG per square meter of floor area were all less correlated to the factors than the total GHG emission.

### *4.2. GHG Prediction and Analysis*

In order to further understand and estimate the GHG emissions of leisure-based farms for formulating carbon reduction actions, two predictive models of GHGs were established by means of stepwise multiple regression analysis. In the process of step-wise regression analysis, factors with their significant values (*p-value*) against annual values of total GHGs of farms as well as GHGs per person higher than 0.05 were excluded. The results are tabulated in Table 6. Only the factors of building floor area and annual number of tourists were significant against total GHGs and were included in the model. The adjusted coefficient of determination $R^2$ was 0.543 with a *p-value* of 0.002, showing that it was statistically significant. These two factors were able to explain 56.9% of the total variability of the independent variable. However, although factors such as type of farm, land area, altitude, and number of rooms were excluded during analysis, they were all positively correlated with the total GHGs. In regards to GHGs per person, the dependent variables of farm type and number of tourists were included, and the adjusted $R^2$ was 0.292 with a *p-value* of 0.004, but there was only 33.2% that could be explained by the variability of GHGs per person. After ruling out 7 unique cases (20%) with large bias, we back tested the models with the 36 cases, and the average absolute errors were 29% and 31% respectively, showing that the models established were statistically significant.

**Table 6.** Step-wise multiple regression analysis on total GHGs and GHGs per person.

| **Dependent Variable: Total Annaul GHGs** | | | | | | |
|---|---|---|---|---|---|---|
| **Priority of Independent** | **Coefficient of *R*** | **Coefficient of Determination ($R^2$)** | **$R^2$ Change ($\Delta R$)** | ***F* Value** | ***F* Change** | **Standardized Coefficients** |
| Building floor | 0.650 | 0.423 | 0.423 | 24.879 | 24.879 | 0.451 |
| Number of tourist | 0.754 | 0.569 | 0.146 | 21.776 | 11.194 | 0.431 |
| Total annual GHGs(t) = 305.7 + 98.5 × Building floor area in 1000 m² + 2.26 × Number of tourist in thousands<br>$R^2$ = 0.543 (*p-value* = 0.002) | | | | | | |

**Table 6.** *Cont.*

| Dependent Variable: GHGs per Person | | | | | | |
|---|---|---|---|---|---|---|
| **Priority of Independent** | **Coefficient of $R$** | **Coefficient of Determination ($R^2$)** | **$R^2$ Change ($\Delta R$)** | **$F$ Value** | **$F$ Change** | **Standardized Coefficients** |
| Type of farms | 0.377 | 0.142 | 0.142 | 5.630 | 5.630 | 0.442 |
| Number of tourist | 0.577 | 0.332 | 0.190 | 8.218 | 9.413 | −0.441 |
| GHGs per person (kg-$CO_2$eq/person) = 61.156 + 23.529 × Type of farms − 0.132 × Number of tourist in thousands | | | | | | |
| $R^2$ = 0.292 (*p-value* = 0.004) | | | | | | |

## 5. Conclusions

The cultivable land is limited in Taiwan. The cultivated land is vanishing at an average rate of 0.6% every year, which is equivalent to 6048 hectares. Many of the land areas have been transformed into high-end leisure farms. The energy use of these luxurious leisure farms is much higher than that of natural or eco-conservation oriented leisure farms, causing larger GHG emissions. A certain amount of crop production might decrease if cultivated lands are converted to tourism usage. However, a majority leisure farms would preserve part of cultivated lands for crop growing, as these crop growing activities might also be an attraction for the tourists. Currently, there were no quantified official reports on how many areas of these kinds of land are being transformed. Therefore, it is hard to estimate how much $CO_2$ is increased due to the vanished cultivated lands and how much $CO_2$ will be escalated owing to the increase from importing food based on a bottom-up auditing approach. Moreover, the scarcity of food due to the decrease of cultivated lands from leisure farms does not necessarily result in the quantity increase of foreign imported food. It is a complex dynamic equilibrium and involves external factors, such as domestic crop demand dynamics, agricultural crop growing directives/incentives from administrative authorities, prices of crop, origin of importing countries, *etc.*, that is beyond the scope of this study, further in-depth investigation is required to discuss with this cause-effect problem.

This research is a pioneer study on the leisure farms, and the results show that despite a revenue of 5.875 million U.S. dollars on average for each farm, they also consume an average of 2557 MWh of energy and each farm generates an average of 1287 tons of GHG emissions. The energy cost comprises 3.3% of their total revenue. For each accommodated tourist, a revenue of 28.6 USD is earned and generates 10.9 kg GHG emissions. The annual GHG emissions generated by the leisure farm industry in Taiwan is estimated at 321,751 tons [42], which is very close to the hospitality industry of 382,200 tons [40]. As the annual growth rates of leisure farms and the hotel industry are 11.7% and 8.9%, respectively, it is estimated that the total GHG emissions of leisure farms will surpass the hotel industry by 2020.

It is equally important to reduce total energy use and the energy use per person by shutting down unnecessary facilities during low seasons. While in high seasons, total energy use should be carefully controlled to increasingly lower it, especially in summer. Since the cost of electricity has risen twice during 2011–2014, an excessive amount of electricity use would lower their revenue. As air conditioning comprises most of the total energy use, energy saving strategies with the heating, ventilating, and air-conditioning (HVAC) system are crucial. The most widely used energy strategies for central HVAC systems include variable air volume system, variable water volume, heat pump system, *etc*. For cases with standalone villa type accommodation rooms, unitary air-conditioners are suggested. The second largest source of energy consumption on farms is lighting electricity. We found that many farms still use light bulbs, haloid lights, or fluorescent lights. The first two types of lighting are especially energy inefficient. As the price of LED lighting tubes has dropped significantly, they have become more cost effective than that of traditional lights. The use of an LED lighting system is encouraged due to its lighting efficiency, especially for cases of vacation oriented farms which have a large demand for night illumination. Additionally, some lighting control strategies may help save energy, such as lighting switch zonal control for vast spaces, which enable the dimming out of lighting parallel to fenestration during the daytime.

This study proposed two GHG emission estimation approaches either by the scale of farms in terms of building floor area or by the type of farms. Both models use the number of tourists as predictor variables. The potential application of the models could be used by farm owners or operators to evaluate the energy use of their leisure farms to take measures in improving energy efficiency. Moreover, the leisure farm administrative authorities could make use of the models to estimate the overall GHG emissions in this industry to understand the environmental impact of leisure farms in terms of carbon dioxide emission, and to formulate strategies or criteria to reduce the environmental impact in advance.

## Acknowledgments

The authors would like to thank the Ministry of Science and Technology of Taiwan for financially supporting this research under Contract No. NSC 102-2221-E-041-009 and NSC 100-2221-E-041-017.

## Author Contributions

Both authors contributed equally to this work. In particular, Jen Chun Wang had the original idea for the study, and both co-authors conceived of and designed the methodology. Jen Chun Wang drafted the manuscript, which was revised by Kuo-Tsang Huang. All authors read and approved the final manuscript.

## Conflicts of Interest

The authors declare no conflict of interest.

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