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RESEARCH ARTICLE

A Mathematical Model to Assess the Impact of Tourism Activities on the Economy of Vendors at Bukit Maras, Terengganu, Malaysia

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Abstract Bukit Maras is one of the recreational spots that has been identified as having great potential to be promoted as a tourist destination in Terengganu. In this study, it is intriguing to see the whether the tourism activities that occurred at Bukit Maras have a positive impact on the economic activity of the local vendors from the point of view of mathematical modelling. The objective of this paper is to formulate a mathematical model in the form of ordinary differential equations (ODEs), inspired by the concept of symbiosis interaction in ecology. Further, some mathematical analyses of this model such as finding the steady states and their stability, were also proved. In addition, some numerical simulations are performed using Maple software to produce the plots of time series as well as phase portraits. To prove the positive impact of the presence of tourists on the economics of vendors, a parameter called the spending rate by the tourists was varied. The results showed that as the spending rate increased, it was expected that the number of vendors would increase too. This indicated that the economics of the vendors have improved. Moreover, it is also predicted that the number of tourists will continuously increase in the future, provided that the attractiveness factors of the Bukit Maras are well preserved. These results are significant for the local government to provide more funding for the development of Bukit Maras so that both tourists and vendors can be sustained in the future.

Keywords: Mathematical model, ordinary differential equation, tourism, economy.

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Introduction

Bukit Maras is one of the hills in Terengganu, recently becoming famous for recreational activities especially among hikers since the year 2018 due to its beautiful scenery at the top of the hill. More interestingly, this site has become popular among paragliders from both local and international regions since 2019. Approximately, 12,000 visitors have visited the hill and the numbers keep increasing with the year. With this increment, more and more locals have taken the opportunity to serve as vendors in the vicinity of Bukit Maras. This means that the tourism activities happen at Bukit Maras have encouraged the locals to involve in trading, which mainly selling food. Thus, it is very interesting to assess the impact of tourists on the economic improvement among local vendors. A pilot study has been initiated by Mohd Roslan *et al*. [1] where questionnaires have been distributed to the visitors and vendors to obtain their

feedback on Bukit Maras's reputability. There were five factors investigated:
i) facilities conditions provided near Bukit Maras Hill (such as information board, security, restroom),
ii) quality of the environment of Bukit Maras (such as flora and fauna, scenery, cleanliness),
iii) opinion on vendors (such as services, pricing, cleanliness of stalls),
iv) opinion on Bukit Maras (such as their recommendations to others about the site), and
v) spending rate by the tourist on the products sold by the vendors (such as food).

Empirical results in Mohd Roslan *et al*. [1] reported that tourists or visitors give a positive response to Bukit Maras. On the other hand, the vendors strongly agreed with the presence of the tourists since the tourism industry at Bukit Maras can help them increase their income level. However, the economic sustainability of Bukit Maras ecotourism activity remains unanswered, although it is critical to provide insight for future development. Are tourism activities at Bukit Maras having a positive impact on the economics of the locals? Therefore, in this study, it is intended to extend the work of Mohd Roslan *et al*. [1], in which a mathematical model is formulated to express the effect of the presence of tourists on the economic improvement of the local vendors. Our main idea is to derive the mathematical model from tourism sustainability models and the symbiosis model in ecological modelling.

Tourism Sustainability Dynamics Model

Studies about tourism models have evolved through the years. For instance, Casagrandi and Rinaldi [2] have proposed the first theoretical model for tourism sustainability, in which relationships between three variables were investigated: the tourists, the environment's quality, and the flow of capital. The rates of change for each of these variables were identified. First, the rate of change among tourists can be influenced by the attractiveness factors of a given site. Secondly, the rate of change in the environment's quality is increased by the natural growth rate but can be decreased by the damages induced by tourists. Finally, the rate of change of capital is the difference between the investment flow and the depreciation flow. Both tourists and the capital were observed to negatively impact the environment, while both the environment and the capital were said to positively impact the tourists.

Moreover, Johnston and Tyrrell [3] proposed another theoretical model on tourism sustainability where the relationship between tourism-related economic and environmental conditions over time was assessed. Then, more analysis on this model has been discussed in Johnston and Tyrrell [4]. Besides, Sinay and Sinay [5] also introduced another model that focused on the effect of the growth of tourism on the environment's quality. Recently, Kaslik and Neamtu [6] generalized the model by Casagrandi and Rinaldi [2] by developing a mathematical model of a given generic touristic site to reflect the number of tourists and their influence on the environment and capital flow. In accordance with the profitability and sustainability of the tourism policy, Kaslik and Neamtu [6] concluded that asymptotic stability of the positive equilibrium is desired, reflecting that a lower attractivity of the touristic site and a higher investment rate should be strongly correlated with the number of tourists from a recent past. Since Kaslik and Neamtu [6] considered the time delay in the original model, it can be concluded that most previous research studies the relationship between tourists and the environment. Their purpose was to maintain the environment's quality as well as sustain tourism activities for the benefit of tourists. However, in this paper, instead of studying the effect of tourism on the environment, the direction is changed to the local vendors.

In terms of sustainable coastal tourism, Liu *et al*. [7] propose a theoretical framework for civilized tourism behavioural intentions, which indicates that attitudes, subjective norms, and personal norms play a significant role in driving civilized behavioural intentions. This is in line with Dimitrovski *et al*. [8] and Nguyen *et al*. [9] which show tourists' attitudes, norms, and behaviour are important in understanding coastal and marine sustainability, a part of multi-stakeholder engagement in the management of coastal and marine areas.

Later, Nestico and Maselli [10] built a dataset of sustainability indicators based on a multi-criteria evaluation model. Indicators like coastal erosion and marine habitats and species have been identified as priorities for conservation and evaluated based on an analysis of the reference benchmark. In addition, Zha *et al*. [11] have identified the determinants for tourist attractions, for which they indicate the scale effect, structure effect, technology effect, capital effect, resource endowment, and environmental regulation as the indicators for tourism efficiency.

Finally, Pulido-Fernández *et al.* [12] single out sustainability as a key element for touristic competitiveness since the improvement in sustainability contributes partially to the growth of tourism. Based on the sample taken from 139 countries, Pulido-Fernández *et al*. [12] highlighted that those stakeholders should work towards environmental sustainability since effective policies and regulations could increase tourism growth in the long term.

Application of Symbiosis Model for Tourist-Vendors Case

In biology, the interaction between two or more species of organisms can be studied. Generally, there are three types of interactions: competition between species to compete for a natural resource, prey-predator interaction and symbiosis interaction, which are mutually beneficial for both species [13,14]. For example, Kooi *et al*. [15] have studied a symbiosis model between two species, as given by the following:

$$\begin{aligned} \frac{dN_1}{dt} = \dot{N}_1 &= N_1 r_1 \left(1 - \frac{N_1}{K_1} + \frac{\alpha_1 N_2}{K_1}\right), \\ \frac{dN_2}{dt} = \dot{N}_2 &= N_2 r_2 \left(1 - \frac{N_2}{K_2} + \frac{\alpha_2 N_1}{K_2}\right), \end{aligned} \tag{1}$$

where the description for each symbol in the system (1) is given in Table 1.

Table 1. The description for all the symbols for model (1)

Symbol	Description
N_1	The number of populations for species 1.
N_2	The number of populations for species 2.
r_1	The natural growth rate of species 1.
r_2	The natural growth rate of species 2.
K_1	The carrying capacity for species 1.
K_2	The carrying capacity for species 2.
α_1	The mutual benefit for species 1.
α_2	The mutual benefit for species 2.
t	Time in year.
$\frac{dN_1}{dt}$	The rate of change of population for species 1 over time.
$\frac{dN_2}{dt}$	The rate of change of population for species 2 over time.

In this paper, the concepts of attractiveness as discussed in Casagrandi and Rinaldi [2] and the symbiosis model as mentioned in Kooi *et al*. [15] are combined to formulate a mathematical model for the case of the tourist-vendor relationship. The symbiosis model (1) is applied since both tourists and vendors are assumed to benefit each other. As far as we are concerned, no models yet apply the symbiosis model to tourism cases. Thus, this paper aimed to fill the gap where a mathematical model is formulated for the tourist-vendor's interaction by adapting the concept from the symbiosis model. To formulate the model, the work in Mohd Roslan *et al*. [1] will be extended. The objectives are to analyse the formulated model by finding the steady solutions, determine the stability of the steady states using the method of stability analysis, and run numerical simulations such as time series and phase portrait plots.

Methodology

In this section, two steps of the methodology are discussed. First, the construction for a tourist-vendor model is derived. The paper by Kooi *et al*. [15] is the main reference for the construction of the model. Then, to investigate the sustainability of vendors for tourists, further analysis will be done, using the stability analysis. Several steps have been taken before the construction of the model can proceed. All the details about the research step are explained in Figure 1. Steps 1-4 have been done in Mohd Roslan *et al*. [1], and meanwhile, in this paper, Steps 5-7 are performed.

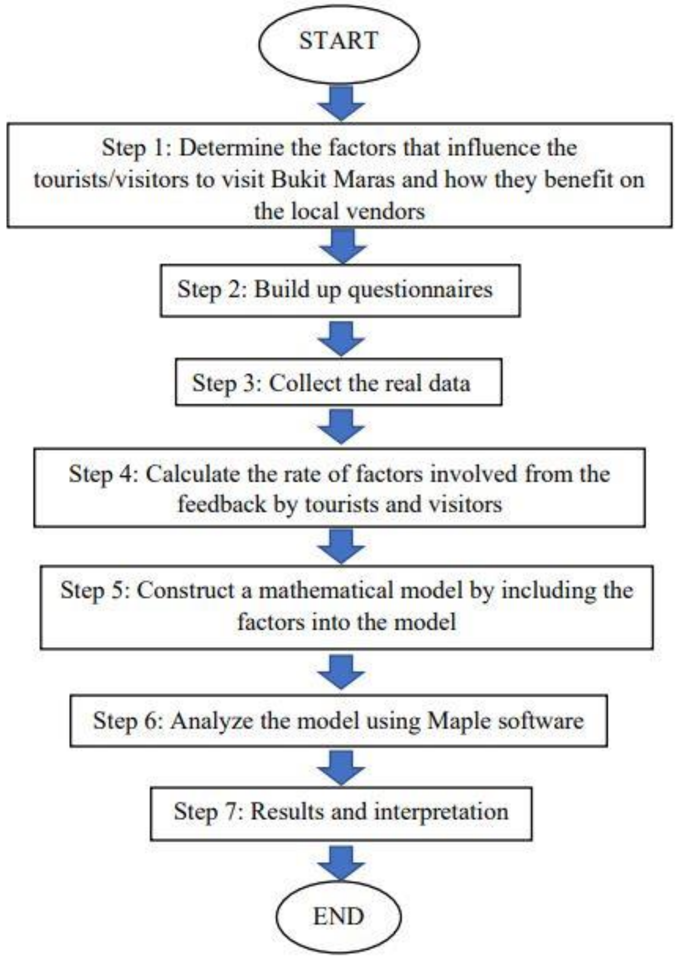


Figure 1. Flowchart of research step

Formulation of the Mathematical Model

To formulate the mathematical model for the tourist-vendor relationship, the relationship between tourists and vendors can be illustrated via a flow diagram as sketched in Figure 2. From the flow diagram, there are three arrows that represent the flows of parameters A and α to the variables of tourist, T and the vendor, V. A represents the attractiveness of Bukit Maras, while α denotes the mutual benefit for both parties, the tourists and the vendors.

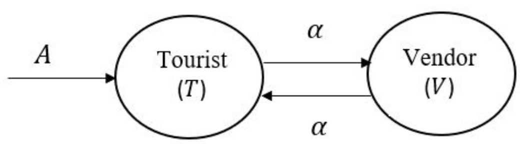


Figure 2. The flow diagram showing the relationship between tourists and vendors at Bukit Maras

Thus, from Figure 2, we propose a mathematical model in the form of ordinary differential equations (ODEs) such as follows:

$$\begin{aligned} \frac{dT}{dt} = \dot{T} &= rT\left(1 - \frac{T}{K} + \frac{\alpha V}{K} + A\right), \\ \frac{dV}{dt} = \dot{V} &= sV\left(1 - \frac{V}{K} + \frac{\alpha T}{K}\right), \end{aligned} \quad (2)$$

where $\frac{dT}{dt}$ and $\frac{dV}{dt}$ represent the rate of change of tourists and the rate of change of vendors, respectively.

The attractiveness parameter A is generated by the feedback of the tourists on Bukit Maras. The total attractiveness is the sum of rates of facility condition (f), environmental quality (e), opinion on local vendors (c) and opinion on Bukit Maras (w). Thus, $A = f + e + c + w$. Meanwhile, the notation K in the above equation represents the maximum capacity that can be occupied at Bukit Maras at one time. We summarize all the descriptions of notations in model (2) in Table 2.

Table 2. The description for all the symbols for model (2)

Symbol	Description
$\frac{dT}{dt}$	The rate of change tourists with time t
$\frac{dV}{dt}$	The rate of change vendors with time t
T	Number of tourists
V	Number of vendors
r	The growth rate for tourists
s	The growth rate for vendors
K	Carrying capacity of Bukit Maras
A	The attractiveness of Bukit Maras
α	The mutual benefit between tourists and vendors

Results and Discussion

Steady States and Stability Analysis

In this section, the steady states for system (2) are investigated. Then the stability of these states is determined using stability analysis approach. We follow this method from the book by Lynch [16]. To find the steady states or critical points, system (2) is assumed to be equal to zero. Then, the following four possible steady states are obtained:

i) both tourists and vendors are not sustained: $E_1 = (0,0)$,
ii) only vendors will be sustained: $E_2 = (0, K)$,
iii) only tourists will be sustained: $E_3 = (K(A+1), 0)$,
iv) both tourist and vendors are sustained: $E_4 = \left(-\frac{K(\alpha+A+1)}{\alpha^2-1}, -\frac{K(\alpha A+\alpha+1)}{\alpha^2-1}\right)$.

To find the stability for the above steady states, the partial derivatives for system (2) must be found. Thus, the Jacobian matrix for this system is given by:

$$J(\dot{T},\dot{V}) = \begin{bmatrix} r\left(1-\frac{T}{K}+\frac{\alpha V}{K}+A\right)-\frac{rT}{K} & \frac{r\alpha T}{K} \\ \frac{s\alpha V}{K} & s\left(1-\frac{V}{K}+\frac{\alpha T}{K}\right)-\frac{sV}{K} \end{bmatrix}. \tag{3}$$

Then, the steady states obtained are substituted in the Jacobian matrix above. By solving the determinant of $|\lambda I - J| = 0$, where λ, I and J represent the eigenvalues, identity matrix and Jacobian matrix respectively. The stability of steady states can be determined from the signs of eigenvalues. In particular:

i) if all eigenvalues are negative, then the steady state is said to be stable, and
ii) if one of or all eigenvalues are positive, then the steady state is said to be unstable.

Now, let us investigate the stability of each steady states for model (2). First, the Jacobian matrix for E_1 is given by:

$$J(E_1) = \begin{bmatrix} r(A+1) & 0 \\ 0 & s \end{bmatrix}.$$

The eigenvalues for these steady states obtained are: $\lambda_1 = r(1+A) > 0$ and $\lambda_2 = s > 0$. Since both eigenvalues are positive, therefore E_1 is said to be unstable.

Secondly, the Jacobian matrix for E_2 is given by:

$$J(E_2) = \begin{bmatrix} r(\alpha+A+1) & 0 \\ s\alpha & -s \end{bmatrix}.$$

The eigenvalues for these steady states obtained are: $\lambda_1 = r(\alpha + A) > 0$ and $\lambda_2 = -s < 0$. Since one of the eigenvalues is positive, therefore E_2 is said to be unstable as well.

For the third Jacobian matrix E_3:

$$J(E_3) = \begin{bmatrix} -r(A+1) & \alpha r(A+1) \\ 0 & s(1+\alpha(A+1)) \end{bmatrix}.$$

The eigenvalues for these steady states obtained are: $\lambda_1 = -(A+1)r < 0$ and $\lambda_2 = (A\alpha + \alpha + 1)s > 0$. Since one of the eigenvalues is positive, therefore E_3 is also said to be unstable as well.

Finally, the Jacobian matrix for E_4:

$$J(E_4) = \begin{bmatrix} \frac{r(A+\alpha+1)}{\alpha^2-1} & \frac{\alpha r(A+\alpha+1)}{\alpha^2-1} \\ \frac{-\alpha s(A\alpha+\alpha+1)}{\alpha^2-1} & \frac{s(A\alpha+\alpha+1)}{\alpha^2-1} \end{bmatrix}.$$

Thus, the eigenvalues obtained are:

$$\lambda_1 = \frac{1}{2(\alpha^2-1)}\left(B_1 + \sqrt{B_2}\right), \qquad \lambda_2 = \frac{1}{2(\alpha^2-1)}\left(B_1 - \sqrt{B_2}\right), \tag{4}$$

where $\alpha^2 \neq 1$, $B_1 = A\alpha s + Ar + \alpha r + \alpha s + r + s$ and

$$B_2 = (4A^2\alpha^3 + 4A\alpha^4 + 8A\alpha^3 + 4\alpha^4 - 2A^2\alpha + 2A\alpha^2 + 8\alpha^3 - 4A\alpha + 2\alpha^2 - 2A - 4\alpha - 2)rs + (A^2 + 2A\alpha + \alpha^2 + 2A + 2\alpha + 1)r^2 + (A^2\alpha^2 + 2A\alpha^2 + 2A\alpha + \alpha^2 + 2\alpha + 1)s^2.$$

Based on the eigenvalues obtained in (4), we have the following result:

Theorem 1. Let the parameter in (4) is $\alpha > 0$. Then the stability for the last equilibrium point can be classified as follows:

i) if $\alpha^2 < 1$, then E_4 is locally asymptotically stable, and
ii) if $\alpha^2 > 1$, then E_4 is unstable.

Thus, from the calculation above, it is observed that E_1, E_2 and E_3 are always unstable while E_4 can be both stable and unstable, depending on the value of parameter α. This means that it is predicted that the steady states E_1, E_2 and E_3 will not happen in the future. Meanwhile, from Theorem 1, since the steady state E_4 has range of stability for $\alpha \in [0,1)$, therefore this means that only E_4 will occur. This means that, in the future, both tourists and vendors can be sustained within this range of spending rate.

Numerical Simulations

In this section, numerical simulation for system (2) is performed using Maple software. The results are then presented as time series and phase portraits. The graph of the time series describes the evolution of both variables over time. In particular, the variables are referred to as both the tourist and the vendor. Meanwhile, the phase portrait is important to observe the relationship between the tourists (T) and the vendors (V). The following set of parameters in system (2) are used: $r = 1, s = 1, f = 0.83, e = 0.92, c = 0.95, w = 1, K = 100$ and α is varied for different values between 0 and 1. Note that the values of f, e, c and w are calculated from the feedback of tourists at Bukit Maras, and these values have been reported in Mohd Roslan *et al*. [1].

Meanwhile, the mutual benefit α can be determined by the spending rate of tourists on the products sold by the vendors. In Mohd Roslan *et al*. [1], they mentioned that the majority of the tourists spend less than RM50 at the site. Therefore, it can be concluded that the spending rate is still low as compared to those who spend more than RM200. The RM200 value was chosen since this amount could represent a typical daily expenditure encompassing various expenses such as food and beverages, shopping, and souvenirs [17]. To determine the value of the spending rate α, we use the probability concept where in our case, the formula is given as follows:

$$\text{Probability} = \frac{\text{Lowest amount spent}}{\text{Highest amount spent}} = \frac{\text{RM50}}{\text{RM200}} = 0.25.$$

From the above calculation, this means that the spending rate currently occurs at $\alpha = 0.25$.

Moreover, it is also intriguing to predict the behaviour of tourists and vendors as the spending rate α increases. The model shows that the economic activity near Bukit Maras is dependent on the number of tourists, this can be observed with a gradient incremental of the α. Thus, the results for both time series as well as for the phase portrait are presented in Table 3 for three different values of $\alpha = 0.25, 0.5, 0.9$. When $\alpha = 0.25$, the number of tourists reaches a plateau of 500, resulting in the number of vendors being restricted to 200. To increase the economic activity (presence of vendors and spending rate), the model suggests that the number of tourists must be increased, and this can be observed when the α is increased to 0.5 and 0.9 (Table 2). The model further demonstrates that the determining factor for the tourist to visit Bukit Maras is the rate of A – a combination of facilities condition (f), environmental quality (e), opinion (sentiment) on local vendors (c) and opinion (sentiment) on Bukit Maras (w). Thus, conforming to the Fernández *et al*. [12] finding in which environmental sustainability is the key to the tourist influx.

The spending rate (α) is a determining factor for the presence of tourists and vendors near Bukit Maras as observed in the phase portrait of the model (see Table 3). With a low spending rate, less than RM50, the tourist-vendor interaction reaches equilibrium (stable steady-state) at 500 and 200 entities, respectively. The influx of tourists or vendors may increase, but it will be temporary due to the unstable interaction. The only approach to increasing the presence of tourists and vendors is to devise a mechanism to increase tourist expenditure (α = 0.5 and 0.9), as proposed by the model. An increase in the spending rate would significantly increase the equilibrium of tourist-vendor interaction, as shown in the phase portrait of α=0.5 and α=0.9, aligned with the profitability of the vendors and the sustainability of economic activity at the touristic site [6].

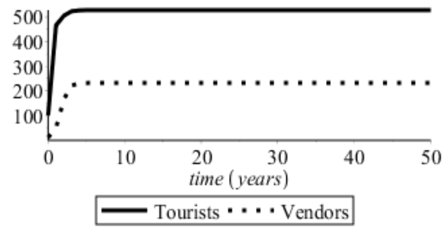
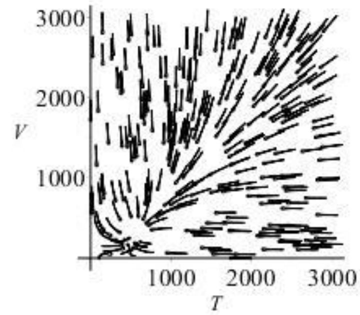
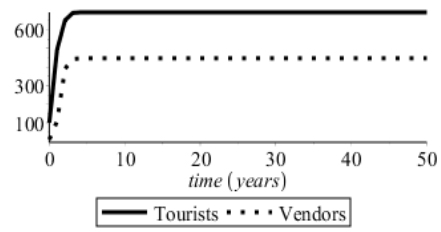
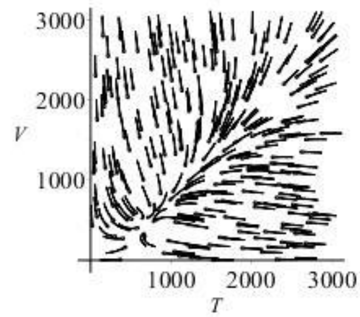
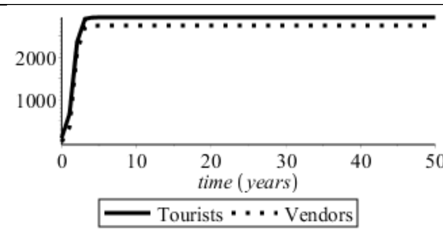
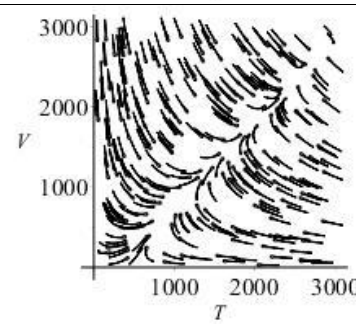
In summary, the model predicted that when the value of α is low, the number of vendors is low, and when α is high, the number of vendors is also increased. This means that the number of vendors is proportionally increased by the number of tourists as the spending rate increases. In other words, with the increase in the spending rate of tourists at Bukit Maras, this will increase the income for the vendors, and therefore, more and more vendors will be interested in running small businesses in the village.

Conclusions

In this paper, a mathematical model to assess the impact of tourism activities on the economic improvement of the local community at Bukit Maras has been successfully introduced. This model has been derived from the concept of symbiosis interaction as mentioned by Kooi *et al*. [15], and the parameters used in the model were obtained from the pilot study on Bukit Maras, that is, by Mohd Roslan *et al*. [1]. Furthermore, by using the stability analysis's method, it can be proven that the numbers of tourists and vendors can be sustained in the future provided that the tourism activities and the environment's quality at Bukit Maras are always maintained and preserved. Moreover, the numerical simulation performed for the model formulated suggested that the number of tourists and vendors will increase in the future as the mutual benefit between the two groups increases. This result can be observed from the time series plots. Thus, this means that there is a strong relationship between the tourists and vendors, and this behaviour can be seen from the phase portrait plots.

Therefore, from the findings in this paper, it is suggested that more financial support could be funded by the local government to increase promotion of Bukit Maras so that this will attract more visitors to enjoy the beautiful panorama at Bukit Maras. It is hoped that by maintaining the number of tourists, more and more locals will benefit from the tourism activities, as currently, most of the Bukit Maras' community is in B40 income level group. It is also possible to apply the model presented in this paper to a different scenario. For instance, we can investigate how tourists spend their money in the sea turtle tourism sector. For future work, it would be of interest to do more consequent surveys for both tourists and vendors. Besides that, the impact of tourists and vendors on the quality of the environment could also be studied, and this is important to ensure that both the tourism industry and the quality of the environment are sustainable.

Table 3. The time series evolution and the phase portrait for model (1) for various values of spending rate α

Value of α	Time series	Phase portrait
0.25		
0.5		
0.9		

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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