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AGENT BASED DECISION SUPPORT MODEL FOR SYMBIOSIS INTERACTION TYPE

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Abstract:

Ecological systems based models are very important where they are used in many climate models to predict the precipitation in coming years. Agent-based model is used to support such prediction. On other hand, the agent is considered a vital element in the ecological models, where it is working autonomously that means actions and internal state of it can be controlled to achieve the predictable goals. Also, the agent can share with other agents an environment through interactions and communication interface. Moreover, it can make decisions that bind behavior to the environment. This research will focus on symbiosis interaction type where we apply three processes starting from developing a computational model, then making it agent based adaptive model to finally use for a Decision Support System (DSS) in a controlled environment.

1. Introduction:

Ecological systems are very important models where they are used for example, in many climate models that help to predicate in the precipitation in next years. Furthermore, the precipitation changing greatly affects on ecological systems. Also, the main element that be dominant factor in regulate of ecological processes is the water. [1] One of the common interaction type that happens inside ecological field is symbiosis. De Bary defined symbiosis as "the living together of dissimilarly named organisms". In addition, the symbiosis is considered a friendly association between two or more species that includes parasitic, mutualistic and commensal associations. On other hand, other symbiosis definition from De Bary view which is an association determined by intimacy of interaction instead of by the sequels of that interaction. [2] One of research explained that the symbiosis is being as maintenance and acquisition of one or more organisms by another that results in metabolism or novel structures. [3] Generally, It hints to organisms living together, whether the interaction is parasitic or commensal, mutualistic. [5] On other hand, computational model is considered a mathematical model in computational science that needs wide computational resources to search the behavior of a complex system by computer simulation. Some examples of popular computational models are neural network models, weather forecasting models, flight simulator model, and earth simulator models. [6]

Based on computational model we have also an Agent Based Model (ABM). ABM is simulation model where the decision makers are formed as goal oriented entities able to take autonomous action and response to their environment. In addition, these models are generally represented via object oriented computer programs. [3] Furthermore, Decision Support Systems (DSS) will be used during this research which simply mean interactive systems using by managers. The concept has become place of interest many of managers, practitioners and researchers during management science field. The main reason of this interesting lies in using support, rather than system. Moreover, they concentrate on enhancing and understanding the decision process. [4] Many of benefits of decision support tool where it can be designed and applied usefully in any suitable and available technology for example, by tutors to minimize the number of students who are possible to fail by providing them with extra teaching material or any other support. [7] [4]

Hengguo Yu and et al, [8] applied an apparent competition community ecological model with Beddington DeAngelis functional response for describing their relationship with adequate accuracy. Based on the previous researches, the scientists and authors were had different views regarding to the definition of symbiosis term. In 1877, Frank [3] might be first one that used the term of symbiosis as a neutral concept that did not mean parasitism where it was simply depends on the regular living of difference organisms like was shown in lichens. In 1887, de Bary [9] interpreted term of symbiosis refers to the common life of parasite. In 1879, the German mycologist, Heinrich Anton de Bary [10] defined the symbiosis as the "living together of two or more unlike organisms". In 1994, Marsh [11] is the first who introduced the computational model for confidence in the distributed artificial intelligence community.

On other hand, Nael Hirzalla and et al, [12] adopted the Timeline temporal model concept due to the simplicity, easily of understanding, graphically of this model. Likewise, other researchers have offered a high level interval based temporal model between events by determining powerful operators that contain both temporal inequalities and equalities. While, time specification is just footnote part of traditional articulatory phonetics. Nonetheless, the temporal relationships between the articulatory components of a specific part are integral to speech organization. [13]

In 1999, the intelligent agents were defined by Wooldridge [9] where the agents have more flexibility to interact with other agents, a common environment and anything outside of the agents. Saleh Alaliyat and et al, [4] developed Agent Based Model (ABM) to simulate the interactions between fish and their environment for fish disease dynamics in a fish population. Actually, several factors impact in the process of fish diseases transmission such as environmental conditions, movement behavior and individual conditions. Before 1990s, some of researchers [4] saw that decision support systems are considered as subtype of Management Information System (MIS). It aimed from using computers to help and support the managers through their decision processes in semi structured tasks. Keen and et al [14] observed DSS led to aid to human decision making.

In next sections, we will display an example of an environmental model from one of previous work studies. Then, the model implementation of symbiosis will be explained. After that, the paper will show an equilibrium state for symbiosis with certain settings of parameters. Next, the parameter estimation (adaption) and sensitivity analysis manners of some parameters will be browsed. After, the decision support system for symbiosis is shown. Last section, we will write a discussion of this research. Finally, we will put list of references that were used in this study.

1.1 An Example Environmental Model:

In **Fig.1** is a causal diagram for an environmental dynamics model as mentioned of one of previous researches [15] and the purpose of using this model lies to clarify dealing with two species S_1 and S_2. Actually, this model consists of physical (abiotic) elements include moisture of the soil and also there is biological (biotic) elements. On other hand, water level plays an important role through this model where there are interactions between varaints species and abiotic factors with taking them into account by the agent. So, execution process during this model is working when manager park give specific value of water (w) at the beginning. After that, this water vale will affect on moisture (m) and this moisture will affect on carrying capacity (c). In addition this carrying capacity will affect on both of species1 (S_1) and species2 (S_2).

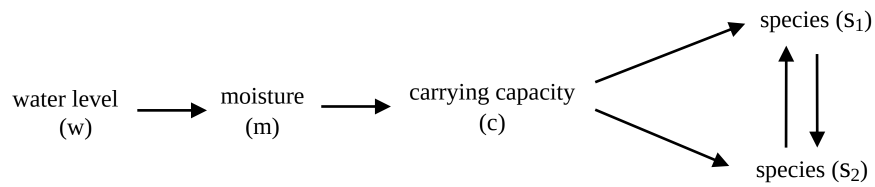


Fig 1. Causal relations for the example environmental model from previous work study.

2. Symbiosis Model Implementation:

In below equations, $S_1(t)$ and $S_2(t)$ are the densities of both species at time point t. Moreover, $c(t)$ refers into the carrying capacity for $S_1(t)$ and $S_2(t)$ at time point t. Actually, this carrying capacity depends on the moisture $m(t)$. On other hand, the moisture depends on the water level indicated by (w). In addition, the water level (w) is considered a parameter that can be controlled by stakeholders for example manager of the terrain, and is kept constant over longer time periods. Also, the parameters (beta) β and (gama) γ are growth rates for species $S_1(t)$ and $S_2(t)$. Furthermore, (pi) η and (lambda) λ are proportional contributions parameters for carrying capacity and moisture respectively. Besides, the (theta) Θ and (omega) ω are speed factors for carrying capacity and moisture respectively.

Another parameter is (alpha) α which considered the "mutual interest" of one species has over the other one in a symbiotic interaction. Moreover, (delta) Δt is the time step for every change of time point. The remaining parameters which are (a_1) and (b_2) are proportional contributions in the symbiotic environment for species $S_1(t)$ and $S_2(t)$ respectively. A differential equation form of the model for symbiosis species as mentioned of one of previous researches [15] is as follows:

$$\frac{ds_1(t)}{dt} = \beta\, s_1(t)\big(c(t) - a_1 s_1(t) + a\, s_1(t)\, s_2(t)\big)$$

$$\frac{ds_2(t)}{dt} = \gamma\, s_2(t)\big(c(t) - b_2 s_2(t) + a\, s_1(t)\, s_2(t)\big)$$

$$\frac{dc(t)}{dt} = \omega\,(\eta\, m(t) - c(t))$$

$$\frac{dm(t)}{dt} = \theta\,(\lambda\, w - m(t))$$

In **Fig 2 (a , b)** is showing the results with some of parameter settings for this particular situation. They are examples situation of variants results for proposed decision support system to help nature park manager such as to estimate or predict the densities of species (S_1) and (S_2) after a certain period of time like (20 years) with taking into account the carrying capacity (c) and moisture (m). Actually, the moisture depends on water level (w) straightforward. As shown in **Fig. 2 (a)**, we see that the vertical axis represents densities of species and horizontal axis represents number of years. Also, we see that the density for each of S_1 and S_2 increased gradually and smoothly due to low growth rate of them. On other hand, the density of species climbs and the reason of that lies is low in proportional contributions for a_1 of S_1 toward S_2. Furthermore, we see in **Fig. 2 (b)** that the vertical axis represents both of carrying capacity (c) and moisture (m) level and the horizontal axis represents number of years.

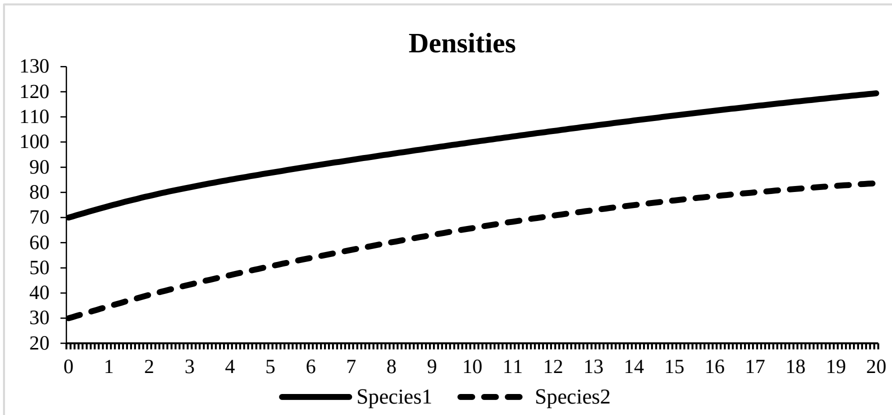
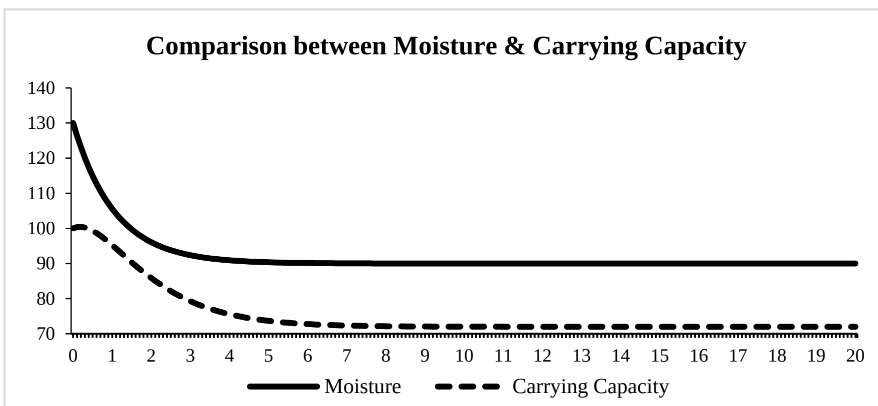


Fig. 2 (a):, Predicted densities after 20 years



(S_1 =70 , S_2 = 30 , w = 150 , m(0) = 130 , c(0) = 100 , λ = 0.6 , η = 0.8 , β = 0.001 , γ = 0.002 , a_1 = 0.5 , b_2 = 0.8)

Fig. 2 (b): Predicted moisture and carrying capacity level after 20 years
($S_1 = 70$, $S_2 = 30$, $w = 150$, $m(0) = 130$, $c(0) = 100$, $\lambda = 0.6$, $\eta = 0.8$, $\beta = 0.001$, $\gamma = 0.002$, $a_1 = 0.5$, $b_2 = 0.8$)

3. Symbiosis Equilibrium State:

An Equilibrium state has strong relation with steady-state concept where when a variable is in the case of steady-state that means the variable has been reached to an equilibrium state. (Sommer et al., 1993) researched in equilibrium state and they described that one, two or three species at maximum degree that together contribute more than 80% of the standing biomass. Actually, these species continue their coexistence for long period approximately more than two weeks without changes in their standing biomass. [16]

For this example set of equations, equilibrium can be determined as follows:

$$\beta\, s_1(c - a_1 s_1 + \alpha s_1 s_2) = 0$$

$$\gamma\, s_2(c - b_2 s_2 + \alpha s_1 s_2) = 0$$

$$\lambda\, w - m = 0$$

$$\eta\, m - c = 0$$

This can be solved by taking $m = \lambda\, w$, $c = \eta\, m = \eta\, \lambda\, w$. Moreover,

$s_1 = 0$ or $c - a_1 s_1 + \alpha s_1 s_2 = 0$

and

$s_2 = 0$ or $c - b_2 s_2 + \alpha s_1 s_2 = 0$

The four cases may be rewritten as follows

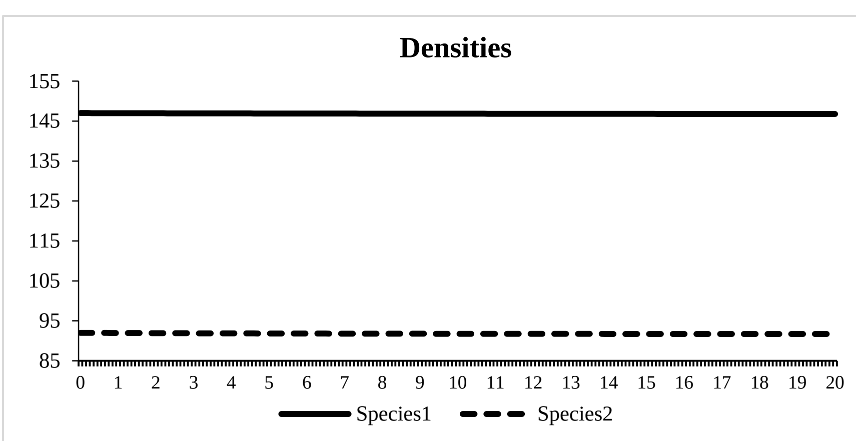
either $s_1 = s_2 = 0$

or $s_1 = 0$ and $s_2 = c/\, b_2$

or $s_2 = 0$ and $s_1 = c/a_1$

or $s_1 = \frac{b_2 \pm \sqrt{b_2{}^2 - 4\alpha(\frac{c b_2}{a_1})}}{2\alpha}$ and $s_2 = \frac{a_1 \pm \sqrt{a_1{}^2 - 4\alpha(\frac{c a_1}{b_2})}}{2\alpha}$

In **Fig.2 (a),** is an example densities of species S_1 and S_2 that we are going to apply an equilibrium state on them. In **Fig.2 (b)** also there are carrying capacity and moisture follow that scenario. Moreover, the equilibrium states for densities, moisture and the carrying capacity of **Fig.2 (a, b)** scenario may be seen in **Fig. 3 (a, b)** under the conditions as described in mathematical relation above. So, we calculated firstly the equilibrium value of moisture $m = \lambda\, w$ and we found this value 90 . Based on this moisture value then, we can



calculate the carrying capacity equilibrium value from the equation $c = \eta m$ and we found this value 72 . After that, we managed that finding the equilibrium values for both of density of S_1 = 147 and S_2 = 92 based on the previous equations. As shown in **Fig.3** both of **(a)** and **(b)** there is strong association between species and carrying capacity where the equilibrium equation of carrying capacity is applied first then, it has obtained on equilibrium value or point for carrying capacity to use this value to calculate both of S_1 and S_2 equilibrium equation. On other hand, it could not apply carrying capacity equilibrium equation until finding moisture equilibrium value because, the carrying capacity depends on moisture value.

Fig. 3 (a): Equilibrium State for Densities
(w = 150, m(0) = 90, c(0) = 72, λ = 0.6, η = 0.8)

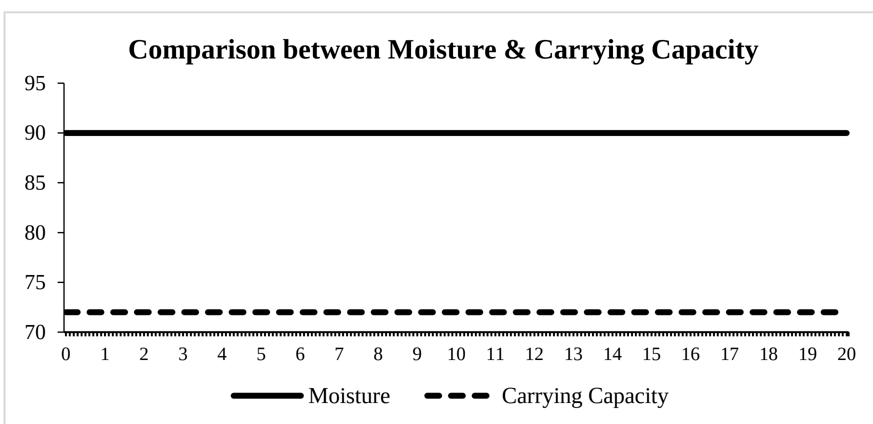


Fig. 3 (b): Equilibrium State for Moisture and Carrying Capacity
(w = 150, m(0) = 90, c(0) = 72, λ = 0.6, η = 0.8)

4. Symbiosis Sensitivity Analysis & Parameter Estimation:

In this section, agent plays an important role to test the behavior of the model on the environmental characteristics to the real characteristics. On other hand, these environmental characteristics are represented by specific set of parameters using for adaption through performing number of simulation runs. Actually, the parameters include $S_1(t)$ and $S_2(t)$ which are the densities of both species at time point t. Moreover, $c(t)$ refers into the carrying capacity for $S_1(t)$ and $S_2(t)$ at time point t. Actually, this carrying capacity depends on the moisture $m(t)$. On other hand, the moisture depends on the water level indicated by (w). In addition, the water level (w) is considered a parameter that can be controlled by stakeholders for example manager of the terrain, and is kept constant over longer time periods. Also, the parameters (beta) β and (gama) γ are growth rates for species $S_1(t)$ and $S_2(t)$. Furthermore, (pi) η and (lambda) λ are proportional contributions parameters for carrying capacity and moisture respectively. Besides, the (theta) Θ and (omega) ω are speed factors for carrying capacity and moisture respectively. Another parameter is (alpha) α which considered the "mutual interest" of one species has over the other one in a symbiotic interaction. Moreover, (delta) Δt is the time step for every change of time point. The remaining parameters which are (a_1) and (b_2) are proportional contributions in the symbiotic environment for species $S_1(t)$ and $S_2(t)$ respectively. In fact, the parameters are to estimate to the real environment characteristics and they were given initial random values in **Fig.4 (a, b)** as the following: $a_1 = 0.9$, $b_2 = 1$, $\beta = 0.001$, $\gamma = 0.002$, $S_1 = 70$, $S_2 = 100$, $m = 30$, $c = 40$, $w = 120$, $\eta = 0.2$, ʎ = 0.1 , $Q = 0.4$, $\omega = 0.4$, $\alpha = 0.0001$ and $\Delta t = 0.1$. After that, the agent can determine the change (Δa_1) in a_1 to minimize the difference in predicted and desired densities values where the target of a_1 is 1. As shown in **Fig. 4 (a)**, the density of species grows unsteady form due to that the density took same values for every iteration stage until achieved the target. Actually, it started with the value **70** until arrived the value **68.11** at the initial stage and it kept going with the same situation until the last iteration. Also, the adaption equation of a_1 could be found in the appendix

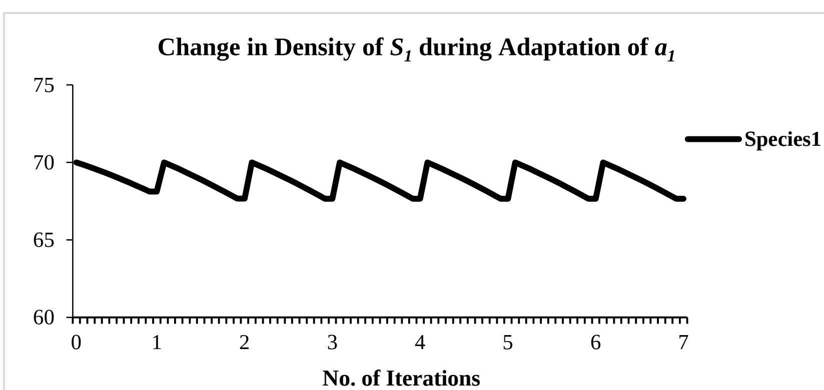


Fig. 4 (a): Change of densities of species S_1 during the adaptation process of a_1

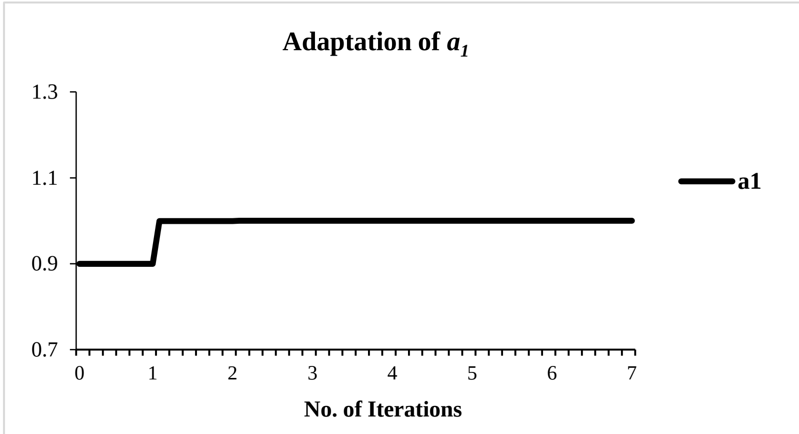


Fig. 4 (b): Adaptation process of a_1

As shown in below **Fig.4 (c)** which is for combined model for $\boldsymbol{a_1}$ between each of world and agent models. Actually, we find the line steep down sharply until density of species value **68.11** from first iteration in agent model line as compared with world model line which is dropping down gradually until the same of this value from ten iterations. On other hand, the reason of that lies into the value of $\boldsymbol{a_1}$ is **0.9** for the agent model while the normal value of $\boldsymbol{a_1}$ is **1** in world model this is the main reason of this sudden steep down. After that, we see each of these two lines for both of agent and world models met together at densities of species value **67.66** which is the target value of this scenario.

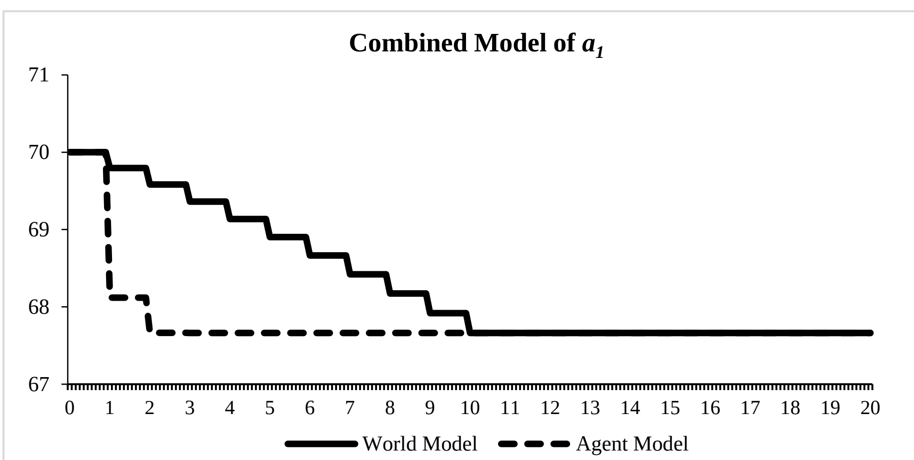


Fig. 4 (c): Combined model between World and Agent models for a_1

Same matter here in **Fig.5 (a, b)** are calculating how sensitives of b_2 on this equation through reducing the difference in predicted and desired densities value where the target of b_2 is 1. On other hand, the parameters include $S_1(t)$ and $S_2(t)$ which are the densities of both species at time point t. Moreover, $c(t)$ refers into the carrying capacity for $S_1(t)$ and $S_2(t)$ at time point t. Actually, this carrying capacity depends on the moisture $m(t)$. On other hand, the moisture depends on the water level indicated by (w). In addition, the water level (w) is considered a parameter that can be controlled by stakeholders for example manager of the terrain, and is kept constant over longer time periods. Also, the parameters (beta) β and (gama) γ are growth rates for species $S_1(t)$ and $S_2(t)$. Furthermore, (pi) η and (lambda) λ are proportional contributions parameters for carrying capacity and moisture respectively. Besides, the (theta) Θ and (omega) ω are speed factors for carrying capacity and moisture respectively. Another parameter is (alpha) α which considered the "mutual interest" of one species has over the other one in a symbiotic interaction. Moreover, (delta) Δt is the time step for every change of time point. The remaining parameters which are (a_1) and (b_2) are proportional contributions in the symbiotic environment for species $S_1(t)$ and $S_2(t)$ respectively. In fact, the parameters are to estimate to the real environment characteristics and they were given initial random values as $a_1 = 1$, $b_2 = 0.8$, $\beta = 0.001$, $\gamma = 0.002$, $S_1 = 70$, $S_2 = 100$, $m = 30$, $c = 40$, $w = 120$, $\eta = 0.2$, $\lambda = 0.1$, $Q = 0.4$, $\omega = 0.4$, $\alpha = 0.0001$ and $\Delta t = 0.1$. In **Fig. 5 (a)**, the graph represents densities of species on the vertical axis and number of iterations on horizontal axis. In addition, we see that the density of species grows unsteady form due to that the density took same values for every iteration stage until achieved the target. Actually, it started with the value **70** until arrived the value **67.66** at the initial stage and it kept going with the same situation until the last iteration. In **Fig. 5 (b)**, we find that the target was found from the second iterations at the value **67.66** . Also, the adaption equation of b_2 could be found in the appendix.

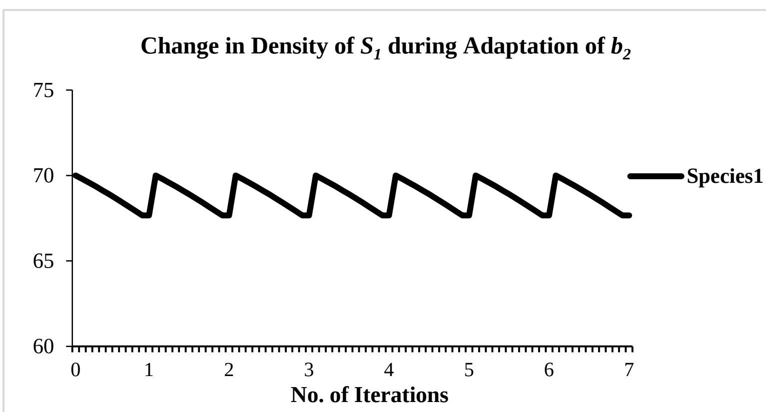


Fig. 5 (a): Change of densities of species s_1 during the adaptation process of b_2

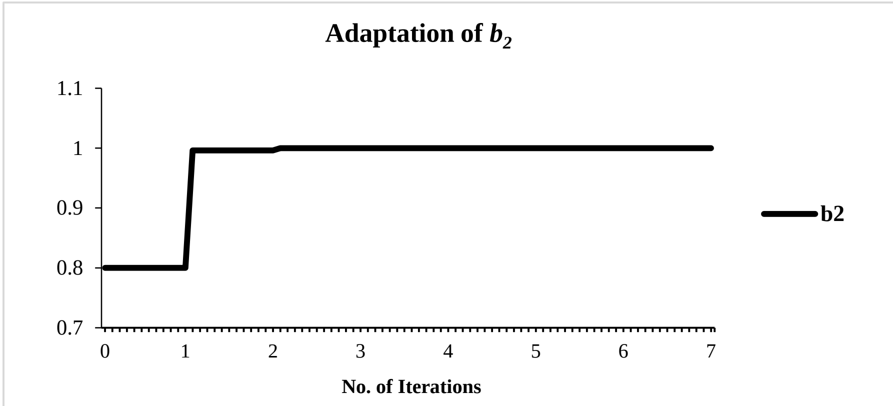


Fig. 5(b): Adaptation process of b_2

As shown in below **Fig.5 (c)** which is for combined model for $\boldsymbol{b_2}$ between each of world and agent models. Actually, we find that the line steep down sharply until density of species value **67.66** from first iteration in agent model line as compared with world model line which is dropping down gradually until the same of this value from ten iterations. On other hand, the reason of that lies into the value of $\boldsymbol{b_2}$ is **0.8** for the agent model while the normal value of $\boldsymbol{b_2}$ is **1** in world model this is the main reason of this sudden steep down. In fact, we see each of these two lines for both of agent and world models already met together at that value **67.66** which is the target value of this scenario.

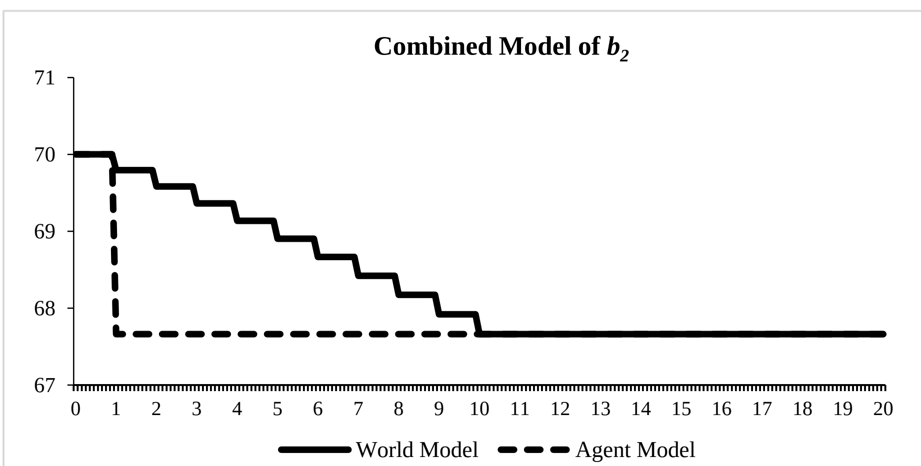


Fig. 5 (c): Combined model between World and Agent models for b_2

In **Fig.6 (a, b)** are showing the density of species1 is unstable and the target was found and achieved from second iterations with respect to alpha (α) parameter. This parameter is mutual interest between both of species. On other hand, the parameters include $S_1(t)$ and $S_2(t)$ which are the densities of both species at time point t. Moreover, *c(t)* refers into the carrying capacity for $S_1(t)$ and $S_2(t)$ at time point t. Actually, this carrying capacity depends on the moisture *m(t)*. On other hand, the moisture depends on the water level indicated by (w). In addition, the water level (*w*) is considered a parameter that can be controlled by stakeholders for example manager of the terrain, and is kept constant over longer time periods. Also, the parameters (beta) β and (gama) γ are growth rates for species $S_1(t)$ and $S_2(t)$. Furthermore, (pi) η and (lambda) λ are proportional contributions parameters for carrying capacity and moisture respectively. Besides, the (theta) Θ and (omega) ω are speed factors for carrying capacity and moisture respectively. Another parameter is (alpha) α which considered the "mutual interest" of one species has over the other one in a symbiotic interaction. Moreover, (delta) Δt is the time step for every change of time point. The remaining parameters which are (a_1) and (b_2) are proportional contributions in the symbiotic environment for species $S_1(t)$ and $S_2(t)$ respectively. In fact, the parameters are to estimate to the real environment characteristics and they were given initial random values as $a_1 = 1$, $b_2 = 1$, $\beta = 0.001$, $\gamma = 0.002$, $S_1 = 70$, $S_2 = 100$, $m = 30$, $c = 40$, $w = 120$, $\eta = 0.2$, ʎ = 0.1 , $Q = 0.4$, $\omega = 0.4$, $\alpha = 0.0003$ and $\Delta t = 0.1$. Therefore, the agent can determine the change ($\Delta\boldsymbol{\alpha}$) in α to minimize the difference in predicted and desired densities values where the target of α is 0.0001. In **Fig. 6 (a)**, the graph represents densities of species on the vertical axis and number of iterations on horizontal axis. In addition, we see that the density of species grows unsteady form due to that the density took same values for every iteration stage until achieved the target. Actually, it started with the value **70** until arrived the value **67.75** at the initial stage and slight change at the second iteration where it started with the value **70** then, it went down until arrived at the value **67.66** . After that, it kept going with the same situation until the last iteration. In **Fig. 6 (b)**, we find that the target was found from the first iteration at the value **67.66** . Also, the adaption equation of α could be found in the appendix.

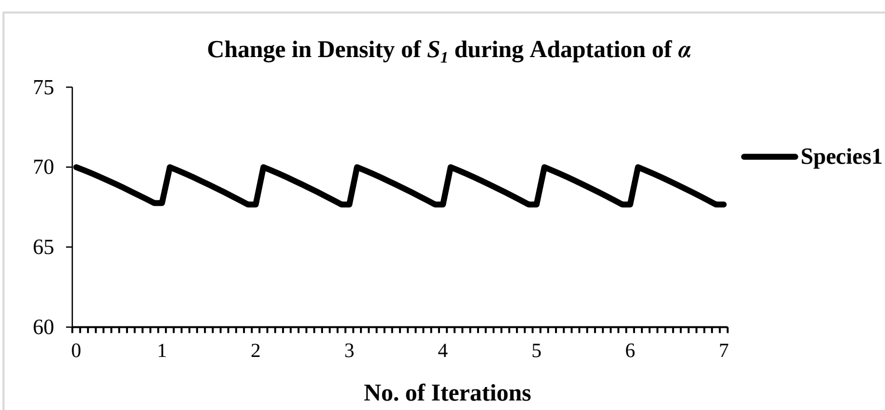


Fig. 6 (a): Change of densities of species s_1 during the adaptation process of α

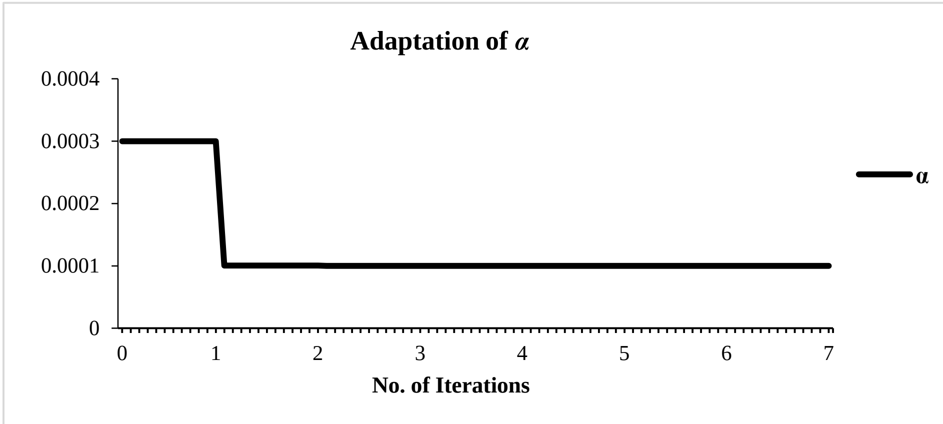


Fig. 6 (b): Adaptation process of α

As shown in below **Fig.6 (c)** which is for combined model for $\boldsymbol{\alpha}$ between each of world and agent models. Actually, we find that the line steep down sharply until densities of species value **67.75** from first iteration in agent model line as compared with world model line which is dropping down gradually until the same of this value from ten iterations. On other hand, the main reason of this sudden steep down lies into the value of $\boldsymbol{\alpha}$ is **0.0003** for the agent model while the normal value of $\boldsymbol{\alpha}$ is **0.0001** in world model and also this is the mutual interest parameter between two species. In addition, we note that the agent model is dropping slowly after the value **67.75** until the value **67.66** which is the target value and continue until adapted with the world model after ten iterations.

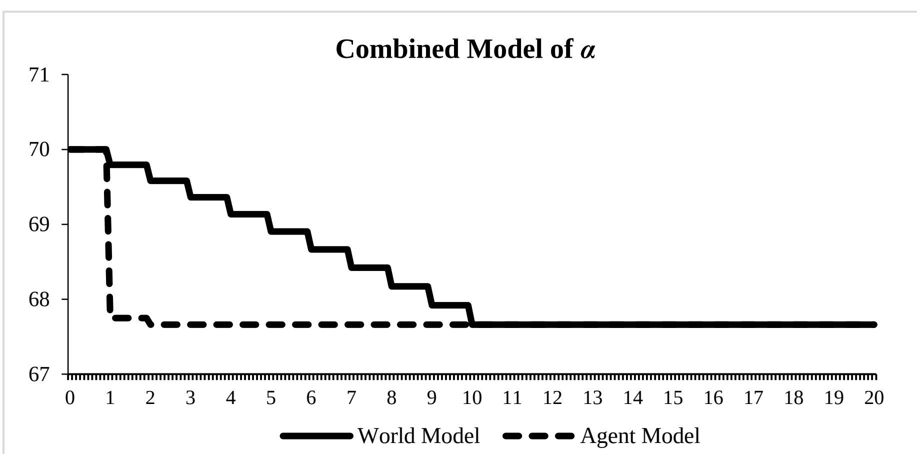


Fig. 6 (c): Combined model between World and Agent models for α

In **Fig.7 (a, b)** is displaying the density of S_1 which at the beginning is steep decline. Then, it is going to unstable until achieved and found the target that is from second iterations with respect to (beta) β parameter. This parameter is growth rate for $species_1$ towards $species_2$. Actually, the parameters include $S_1(t)$ and $S_2(t)$ which are the densities of both species at time point t. Moreover, $c(t)$ refers into the carrying capacity for $S_1(t)$ and $S_2(t)$ at time point t. Actually, this carrying capacity depends on the moisture $m(t)$. On other hand, the moisture depends on the water level indicated by (w). In addition, the water level (w) is considered a parameter that can be controlled by stakeholders for example manager of the terrain, and is kept constant over longer time periods. Also, the parameters (beta) β and (gama) γ are growth rates for species $S_1(t)$ and $S_2(t)$. Furthermore, (pi) η and (lambda) λ are proportional contributions parameters for carrying capacity and moisture respectively. Besides, the (theta) Θ and (omega) ω are speed factors for carrying capacity and moisture respectively. Another parameter is (alpha) α which considered the "mutual interest" of one species has over the other one in a symbiotic interaction. Moreover, (delta) Δt is the time step for every change of time point. The remaining parameters which are (a_1) and (b_2) are proportional contributions in the symbiotic environment for species $S_1(t)$ and $S_2(t)$ respectively. In fact, the parameters are to estimate to the real environment characteristics and they were given initial random values as $a_1 = 1$, $b_2 = 1$, $\beta = 0.004$, $\gamma = 0.002$, $S_1 = 70$, $S_2 = 100$, $m = 30$, $c = 40$, $w = 120$, $\eta = 0.2$, $\lambda = 0.1$, $Q = 0.4$, $\omega = 0.4$, $\alpha = 0.0001$ and $\Delta t = 0.1$. After that, the agent can determine the change ($\Delta\beta$) in β to minimize the difference in predicted and desired densities values where the target of β is 0.001. As shown In **Fig. 7 (a),** the density of species went down strongly at the initial iteration starting from the value 70 until the density of the species arrived the value 61.73 . Then, it went up and went down gradually and normally form. In fact, the reason of this sudden strong decreasing in the first iteration lies into that this parameter has rigid effect on $\boldsymbol{S_1}$ where is considered the growth rate of it. Actually, when the growth rate is high then, the density of species1 will increase strongly but if the growth rate is low the species1 will increase slowly. In addition, the adaption equation of α could be found in the appendix.

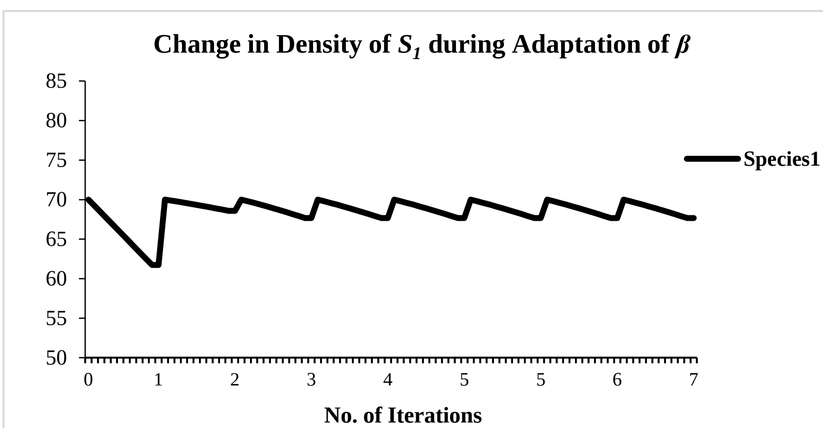


Fig. 7 (a): Change of densities of species s_1 during the adaptation process of β

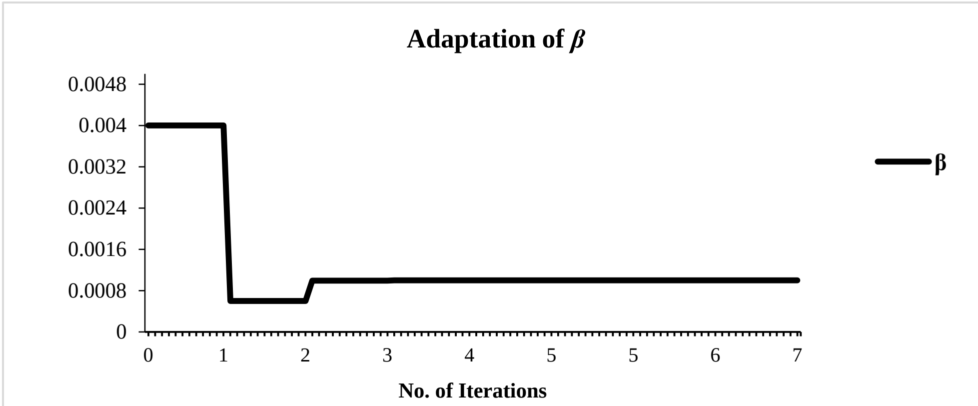


Fig. 7 (b): Adaptation process of β

As shown in below **Fig.7 (c)** which is for combined model for $\boldsymbol{\beta}$ between each of world and agent models. Actually, we find that the line steep down sharply until densities of species value **61.73** from first iteration in agent model line then it continued at the same level until the second iteration. Then, it went up strongly until the value **68.57** and the reason of that lies into (beta) $\boldsymbol{\beta}$ parameter which has rigid effect on the $\boldsymbol{S_1}$ toward $\boldsymbol{S_2}$ where it is considered the growth rate of $\boldsymbol{S_1}$. After that, it walked at the same level until third iteration. Then, it went down until **67.66** which is the target value and continued until adapted with the world model at ten iterations.

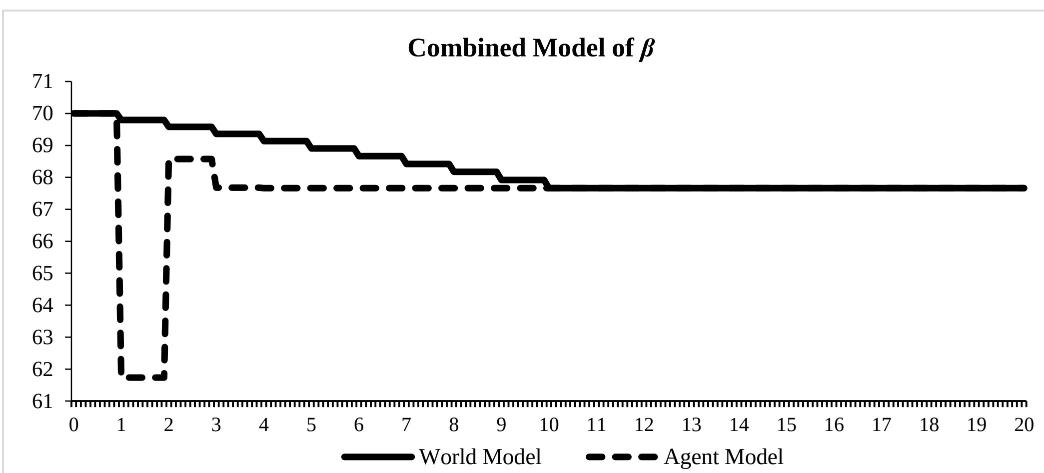


Fig. 7 (c): Combined model between World and Agent models for β

5. Symbiosis Decision Support System:

Decision Support Systems (DSS) was used during this research to support many of managers, practitioners and researchers for example to predict densities of species to achieve desired target after a specific time for example after 20 years as mentioned in **Fig.2 (a)**. On other hand, as shown on **Fig.8** below that was taken from one of previous researches [15]. Actually, it describes the way by which the agent adapts its beliefs concerning parameters representing environmental characteristics to the real characteristics. On other hand, the agent initially receives rough estimations of the values for these parameters, and maintains them as initial beliefs. With these initial beliefs the agent predicts the environmental state for after say X years. When at a certain time point the real value of some state variable is observed, as a next step the predicted value and observed value of that state variable at time X are passed to the adaptation process of the agent. The agent then tries to minimize the difference between predicted and desired value and adjust the beliefs on the environmental characteristics (i.e., the parameter values which were initially assumed). So, this process of adaptation is kept on going until the difference is negligible, i.e., until the agent has an accurate set of beliefs about the environmental characteristics. Moreover, within this adaptation process sensitivities of state variables for changes in parameter values for environmental characteristics play an important role. [15]

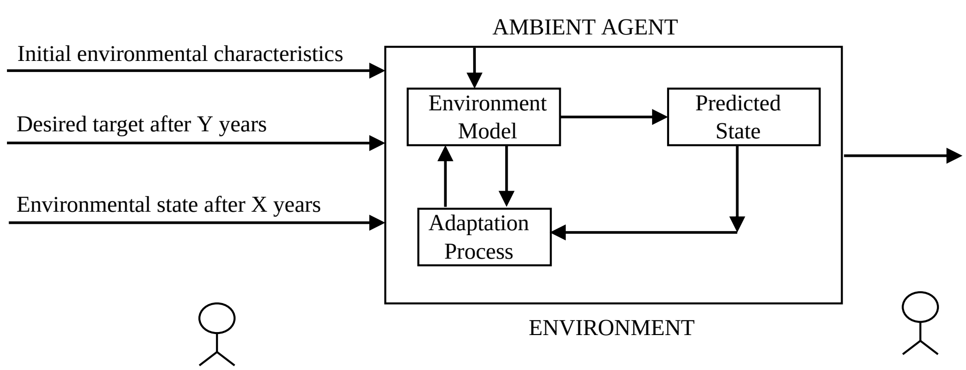


Fig. 8: The Ambient Agent's Adaptation Process of the Environment Model. [15]

In **Fig. 2 (a),** it explains the predicted densities after 20 years with these settings w = 150, m(0) = 130, c(0) = 100, $\lambda = 0.6$, $\eta = 0.8$, $\beta = 0.001$, $\gamma = 0.002$, $\Theta = 0.9$, $\omega = 0.9$**.** On other hand, the vertical axis represents the densities of species S_1 and the horizontal axis represents number of years, shows the trend in change of densities of species over 20 years given the initial values of the water level *w*. Using the following formula, the agent can determine the change (Δw) in circumstance *w* to achieve the goal at some specific time point t in future:

$$\Delta w = \left(s_1(w + \Delta w) - s_1(w)\right) / \left(\frac{\partial s_1}{\partial w}\right)$$

where $S_1(w+\Delta w)$ is the desired density at time t, $S_1(w)$ the predicted density S_1 at time t for water level *w*, and $(\partial s_1/\partial w)$ the change in density of S_1 at time t against the change in *w*.

As shown in **Fig. 9** which depicts a situation where the density of species S_1 is predicted to decrease, given *w* = 150. The initial values for species S_1 could be taken random but for this example scenario species S_1 has density 70. If the agent wants to aim it to become 120 after 20 years, then according to the model described above it has to change *w* to 226.

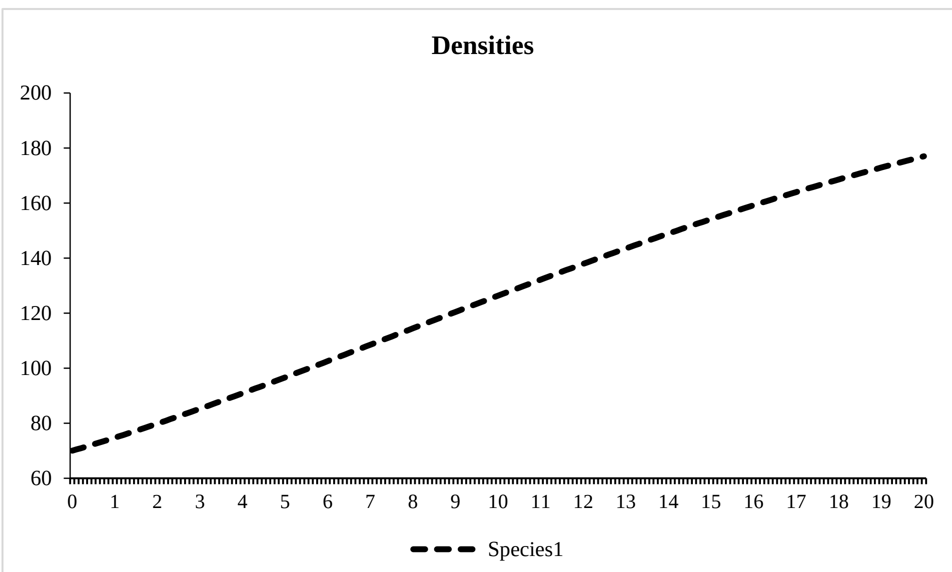


Fig. 9 : Densities, over 20 years, after incorporating
(w = 226, m(0) = 130, c(0) = 100, $\lambda = 0.6$, $\eta = 0.8$, $\beta = 0.001$, $\gamma = 0.002$, $a_1 = 0.5$, $b_2 = 0.8$, $\Theta = 0.9$, $\omega = 0.9$), $\Delta w = 76$

6. Discussion:

From this experiment results we have concluded some critical points. First point lies into that we have already existed model but there was no simulation result for that. Therefore, we have done an experiment regarding to this model and we have run different simulation. Second point, we have generated variants of results and that results were verified with our dataset through using simulation techniques such as an equilibrium state model. Third point, we have achieved equilibrium state with certain settings that helped to reach that an equilibrium level or point as shown in **Fig. 3 (a , b)** based on their initial values in **Fig. 2 (a , b).** Fourth point, we had able to adapt our model to predict densities of species to achieve desired target after a specific time and make a decision support system for example after 20 years as seen in **Fig. 2 (a , b)** with some settings where the density of species went up gradually and sometimes sharply based on growth rate and with respect to this interaction type (symbiosis). In fact, the reason of that increasing is due to definition of symbiosis interaction type concept where it is considered a friendly association between two or more species. Furthermore, alpha (α) is one of substantial parameters and it is mutual interest between both species where this is the second factor that affects on them increasingly or decreasingly. On other hand, carrying capacity factor affects on species significantly where there is strong relation between them because, it is the sink that carrying the density of species and it is based on moisture factor. Actually, the moisture affects on carrying capacity and is based on water level mainly.

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Appendices:

For *W*:

$$\frac{\partial \frac{\partial s_1}{\partial w}}{\partial t} = \beta \frac{\partial s_1(t)}{\partial w}\left(c(t) - a_1 s_1(t) + \alpha s_1(t) s_2(t)\right) + \beta s_1(t)\left(\frac{\partial c(t)}{\partial w} - a_1 \frac{\partial s_1(t)}{\partial w} + \alpha\left(s_1(t)\frac{\partial s_2(t)}{\partial w} + \frac{\partial s_1(t)}{\partial w} s_2(t)\right)\right)$$

$$\frac{\partial \frac{\partial s_2}{\partial w}}{\partial t} = \gamma \frac{\partial s_2(t)}{\partial w}\left(c(t) - b_2 s_2(t) + \alpha s_1(t) s_2(t)\right) + \gamma s_2(t)\left(\frac{\partial c(t)}{\partial w} - b_2 \frac{\partial s_2(t)}{\partial w} + \alpha\left(s_1(t)\frac{\partial s_2(t)}{\partial w} + \frac{\partial s_1(t)}{\partial w} s_2(t)\right)\right)$$

$$\frac{\partial \frac{\partial c}{\partial w}}{\partial t} = \left(\eta \frac{\partial m(t)}{\partial w} - \frac{\partial c(t)}{\partial w}\right)\omega$$

$$\frac{\partial \frac{\partial m}{\partial w}}{\partial t} = \left(\lambda - \frac{\partial m(t)}{\partial w}\right)\theta$$

For *a₁*:

$$\left(\frac{\partial s_1(t)}{\partial a1}\right)(t + \Delta t) = \left(\frac{\partial s_1(t)}{\partial a1}\right) + \left(\beta\left(\frac{\partial s_1(t)}{\partial a1}\right)\left(c(t) - a_1 s_1(t) + \alpha s_1(t) s_2(t)\right) + \beta s_1(t)\left(\left(\frac{\partial s_1(t)}{\partial a1}\right) - s_1(t) - a_1\left(\frac{\partial s_1(t)}{\partial a1}\right) + \alpha\left(s_1(t)\left(\frac{\partial s_2(t)}{\partial a1}\right) + \left(\frac{\partial s_1(t)}{\partial a1}\right) s_2(t)\right)\right)\right)\Delta t$$

$$\left(\frac{\partial s_2(t)}{\partial a1}\right)(t + \Delta t) = \left(\frac{\partial s_2(t)}{\partial a1}\right) + \left(\gamma\left(\frac{\partial s_2(t)}{\partial a1}\right)\left(c(t) - b_2 s_2(t) + \alpha s_1(t) s_2(t)\right) + \gamma s_2(t)\left(\frac{\partial c(t)}{\partial a1} - b2\frac{\partial s_2(t)}{\partial a1} + \alpha\left(s_1(t)\frac{\partial s_2(t)}{\partial a1} + \frac{\partial s_1(t)}{\partial a1} s_2(t)\right)\right)\right)$$

$$\left(\frac{\partial c(t)}{\partial a1}\right)(t + \Delta t) = \left(\frac{\partial c(t)}{\partial a1}\right)(t) + \left(\eta\left(\frac{\partial m(t)}{\partial a1}\right)(t) - \left(\frac{\partial c(t)}{\partial a1}\right)(t)\right)\omega\ \Delta t$$

$$\left(\frac{\partial m(t)}{\partial a1}\right)(t + \Delta t) = \left(\frac{\partial m(t)}{\partial a1}\right)(t)(1 - \Theta\ \Delta t)$$

For b_2:

$$\left(\frac{\partial s_1(t)}{\partial b2}\right)(t+\Delta t)=\left(\frac{\partial s_1(t)}{\partial b2}\right)+\left(\beta\left(\frac{\partial s_1(t)}{\partial b2}\right)\left(c(t)-a_1 s_1(t)+\alpha\, s_1(t)s_2(t)\right)+\beta\, s_1(t)\left(\left(\frac{\partial s_1(t)}{\partial b2}\right)-a_1\left(\frac{\partial s_1(t)}{\partial b2}\right)+\alpha\left(s_1(t)\left(\frac{\partial s_2(t)}{\partial b2}\right)+\left(\frac{\partial s_1(t)}{\partial b2}\right)s_2(t)\right)\right)\right)\Delta t$$

$$\left(\frac{\partial s_2(t)}{\partial b2}\right)(t+\Delta t)=\left(\frac{\partial s_2(t)}{\partial b2}\right)+\left(\gamma\left(\frac{\partial s_2(t)}{\partial b2}\right)\left(c(t)-b_2 s_2(t)+\alpha\, s_1(t)s_2(t)\right)+\gamma\, s_2(t)\left(\frac{\partial c(t)}{\partial b2}-s_2(t)-b2\frac{\partial s_2(t)}{\partial b2}+\alpha\left(s_1(t)\frac{\partial s_2(t)}{\partial b2}+\frac{\partial s_1(t)}{\partial b2}s_2(t)\right)\right)\right)$$

$$\left(\frac{\partial c(t)}{\partial b2}\right)(t+\Delta t)=\left(\frac{\partial c(t)}{\partial b2}\right)(t)+\left(\eta\left(\frac{\partial m(t)}{\partial b2}\right)(t)-\left(\frac{\partial c(t)}{\partial b2}\right)(t)\right)\omega\ \Delta t$$

$$\left(\frac{\partial m(t)}{\partial b2}\right)(t+\Delta t)=\left(\frac{\partial m(t)}{\partial b2}\right)(t)(1-\Theta\ \Delta t)$$

For α:

$$\left(\frac{\partial s_1(t)}{\partial \alpha}\right)(t+\Delta t)=\left(\frac{\partial s_1(t)}{\partial \alpha}\right)+\left(\beta\left(\frac{\partial s_1(t)}{\partial \alpha}\right)\left(c(t)-a_1 s_1(t)+\alpha\, s_1(t)s_2(t)\right)+\beta\, s_1(t)\left(\left(\frac{\partial s_1(t)}{\partial \alpha}\right)-a_1\left(\frac{\partial s_1(t)}{\partial \alpha}\right)+\left(s_1(t)s_2(t)+\alpha\left(s_1(t)\left(\frac{\partial s_2(t)}{\partial \alpha}\right)+\left(\frac{\partial s_1(t)}{\partial \alpha}\right)s_2(t)\right)\right)\right)\right)\Delta t$$

$$\left(\frac{\partial s_2(t)}{\partial \alpha}\right)(t+\Delta t)=\left(\frac{\partial s_2(t)}{\partial \alpha}\right)+\left(\gamma\left(\frac{\partial s_2(t)}{\partial \alpha}\right)\left(c(t)-b_2 s_2(t)+\alpha\, s_1(t)s_2(t)\right)+\gamma\, s_2(t)\left(\frac{\partial c(t)}{\partial \alpha}-b_2\frac{\partial s_2(t)}{\partial \alpha}+\left(s_1(t)s_2(t)+\alpha\left(s_1(t)\frac{\partial s_2(t)}{\partial \alpha}+\frac{\partial s_1(t)}{\partial \alpha}s_2(t)\right)\right)\right)\right)$$

$$\left(\frac{\partial c(t)}{\partial \alpha}\right)(t+\Delta t)=\left(\frac{\partial c(t)}{\partial \alpha}\right)(t)+\left(\eta\left(\frac{\partial m(t)}{\partial \alpha}\right)(t)-\left(\frac{\partial c(t)}{\partial \alpha}\right)(t)\right)\omega\ \Delta t$$

$$\left(\frac{\partial m(t)}{\partial \alpha}\right)(t+\Delta t)=\left(\frac{\partial m(t)}{\partial \alpha}\right)(t)(1-\Theta\ \Delta t)$$

For β:

$$\left(\frac{\partial s_1(t)}{\partial \beta}\right)(t+\Delta t) = \left(\frac{\partial s_1(t)}{\partial \beta}\right) + \left(\beta\left(\frac{\partial s_1(t)}{\partial \beta}\right)\left(c(t) - a_1 s_1(t) + \alpha\, s_1(t) s_2(t)\right) + s_1(t)\left(c(t) - a_1 s_1(t) + \alpha\, s_1(t) s_2(t)\right) + \beta\, s_1(t)\left(\left(\frac{\partial s_1(t)}{\partial \beta}\right) - a_1\left(\frac{\partial s_1(t)}{\partial \beta}\right) + \alpha\left(s_1(t)\left(\frac{\partial s_2(t)}{\partial \beta}\right) + \left(\frac{\partial s_1(t)}{\partial \beta}\right) s_2(t)\right)\right)\right)\Delta t$$

$$\left(\frac{\partial s_2(t)}{\partial \beta}\right)(t+\Delta t) = \left(\frac{\partial s_2(t)}{\partial \beta}\right) + \left(\gamma\left(\frac{\partial s_2(t)}{\partial \beta}\right)\left(c(t) - b_2 s_2(t) + \alpha\, s_1(t) s_2(t)\right) + \gamma\, s_2(t)\left(\frac{\partial c(t)}{\partial \beta} - b_2\frac{\partial s_2(t)}{\partial \beta} + \alpha\left(s_1(t)\frac{\partial s_2(t)}{\partial \beta} + \frac{\partial s_1(t)}{\partial \beta}\, s_2(t)\right)\right)\right)$$

$$\left(\frac{\partial c(t)}{\partial \beta}\right)(t+\Delta t) = \left(\frac{\partial c(t)}{\partial \beta}\right)(t) + \left(\eta\left(\frac{\partial m(t)}{\partial \beta}\right)(t) - \left(\frac{\partial c(t)}{\partial \beta}\right)(t)\right)\omega\ \Delta t$$

$$\left(\frac{\partial m(t)}{\partial \beta}\right)(t+\Delta t) = \left(\frac{\partial m(t)}{\partial \beta}\right)(t)(1-\Theta\ \Delta t)$$