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Long Term Effects Using Biological Control in Palm-Oil Ecosystem

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Abstract: **This paper is focusing on a development of simulation model that portrays the relationship of prey-predator in biological control technique in palm-oil plantation ecosystem. Palm-oil is among Malaysia's largest agricultural export. The presence of pest especially rat however causes a great damage and negative impact to the production of national palm-oil resource. This research concentrates to the usage of biological control method specifically owl to ascertain that the rat population in palm-oil plantation is under control and in minimal rate. A simulation method is applied in this research. A model prototype is developed using Stella 8 simulation software. The simulation in this research is specifically designed to observe the relationships of palm-oil resource and rat as well as the relationships of rat and owl. The objective of this simulation is to identify equilibrium of the relationships of these three entities in order to assist the decision maker in determining the usage of biological control method within certain period. The model prototype developed succeeds to describe the equilibrium among the three entities involved in this research.**

Keywords: **Owl, Palm-Oil, Equilibrium, Simulation, Rat.**

1. Introduction

In this century, the usage of computer in teaching and learning is rapidly happening. One of the popular applications is simulation. Time constraint and specialty are prime problems especially to academicians in delivering the teaching in order to reach its objectives. To overcome this, a radical change from a passive teaching and learning to an active approach is indeed needed. Lots of active teaching and learning methods in science field and one of them is simulation [1, 2]. Areas applying simulation are broad and unlimited inclusive of military and medical critical missions. In fact, NASA, United States military and Malaysian army harnesses this technology.

Computerized simulation method is used on most studies to eliminate several limitations. For instance, financial resource for studies, usage of area for studies, life risk in carrying out studies and many more. In this case study, the absence of palm-oil plantation is the constraint to executing system in actual ecosystem environment [9]. Therefore, Stella simulation program becomes an alternative to elaborate the relationship of prey-predator in biological control technique [3, 5, 6].

Malaysia is one the largest palm-oil exporters in the world. Under Federal Land Consolidation and Rehabilitation Authority, there are 163 palm-oil plantations in Malaysia nationwide with average area of 1152.47 ha for each plantation [7]. The average rate of palm-oil extraction in Malaysia is from 20% to 22% whereby represents the production of palm-oil from 4.8 ton to 7.0 ton for each hectare/year. This statistics indicates that the production of palm-oil is high compared with other oil-producing crops.

Palm-oil tree, *elaeisguineensis* Jacq. is a part of *cocoideae* subfamily and *palmae* family. Palm-oil tree bears fibrous root. The stem is upright and the measurement of its central line is between 35 cm and 65 cm. The height increasing rate is from 45 cm to 70 cm yearly and may achieve its maximum height from 20 m to 30 m. The stem is single with no branches and possesses fronds at the top. Annually, 20 to 30 fronds appear whereby depend on the age of that tree. The mean of matured palm-oil tree bears at least 40 fronds. The economic life period of a palm-oil tree is 25 years [4].

Rat is identified as the prime pest to palm-oil. The rat species identified in damaging palm-oil fruit is *rattustiomanicus* and *rattus diardi*. These rats live on land and nest in the pile of old fronds cut from the tree. The rat population in palm-oil plantation if neglected from control, it can reach from 200 to 600 rats per hectare [13]. The rat lifespan is between 10 months and 22 months. The sexual maturity of a rat is 4 months. Female rat is able to reproduce between 5 and 10 rat pups from every 3 months to 4 months [14].

The propagation of rats is handled by planters through many ways. The popular one is using poisonous palm-oil fruit baits to kill the rats [8, 10]. The popular type of poison used in Malaysia is *rodenticide brodifacoun*. This pesticide is also the cause of death of predator birds when they eat the rats died due to the poisoning [3]. This clarifies the reason it is less appropriate because the poison is too strong that even can kill the untargeted animals. This method also affects the infertility of soil [4]. The safer measure therefore to maintain the soil nutrient as well as secure the predator birds population is biological control.

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The owl concerned as the predator to owl in this simulation is from species of *tytoalba* that is barn owl. The selection of this type of owl as the predator is due to its ability to live with the diet of rats amounting 98% [2, 3, 7]. The estimation of rat nutrition by a couple of owls and its one owlet is 1,300 rats per year [10, 12, 13]. *Tytoalba* is a medium-sized owl with 38 cm or 16 in length of body, 106 cm opening of wing has long and strong-gripping legs [8].

The biological control cared is the usage of predator to control pest population in an area [14, 15]. The rat is the pest, the owl is the predator and the palm-oil plantation provides the food supply to the pest. These three elements are taken into considerations in this simulation research.

2. Objective of Simulation

The objective of simulation is to observe the equilibrium resulted from the relationships of palm-oil and rat and relationships of rat and owl. The objective of this simulation is also to perceive the long-term effects concerned with these three entities.

3. Simulated Model

A. Software of Simulation

This simulated model is developed by using Stella 8 software. It is a graphical simulation program developed by Isee Systems Inc. in Windows platform.

B. Sector of Palm-Oil Resource

The initial value for overall palm-oil resource is equivalent to 207,000,000 palm-oil pieces. The calculation concerned in determining the initial value of this palm-oil resource is based upon the following information:

- *1 bunch = 1500 pieces*
- *1 tree = 10 bunches*
- *1 hectare plantation =138 trees*
- *Assumption of overall plantation area in simulation = 100 ha*
- *Palm-oil resource (Sumbersawit) = 1500 pieces × 10 bunches × 138 trees × 100 ha = 207,000,000 pieces*

The size of palm-oil resource yearly relies on the balance of palm-oil resource in previous years, fruits growth, damaged fruits due to rats and the fruits cropped by planters. The correlation among these factors is explained through the following formula:

- *Palm-oil resource (Sumbersawit) (t) = palm-oil resource (t−dt) + (fruit growth − damaged fruit − the fruits cropped) × dt*

Figure 1 illustrates the sector of palm-oil in the simulation performed and it is followed by the constant and variable values concerned.

- *Palm-oil density (Kepadatansumbersawit) =palm-oil resource (Sumbersawit) / plantation area (Luas ladang)(ha)*
- *Fruit maturity rate (Kadar kematanganbuah) = twice per year = 2/12 = 0.17*
- *Crop rate assumption = 1/10 of palm-oil resource = 0.1*

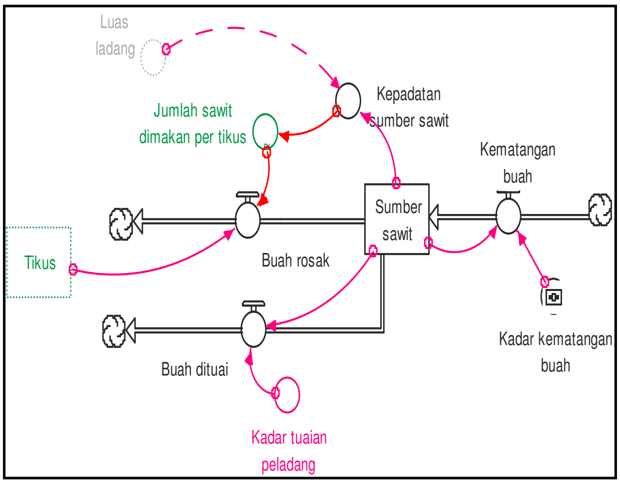

Fig.1. Sector of Palm-oil

- *Fruit maturity (Kematanganbuah) = palm-oil resource (Sumbersawit) × fruit maturity rate (Kadar kematanganbuah)*
- *Damaged fruit (Buahrosak) = rat (Tikus) × total of palm-oil eaten per rat (Jumlahsawitdimakan per tikus)*
- *The fruit cropped (Buahdituai) = (palm-oil resource (Sumbersawit) × crop rate by planter (Kadar tuaianpeladang)) − damaged fruit (Buahrosak)*

The total of palm-oil eaten per rat hangs on the palm-oil density. This simulation describes the total of palm-oil eaten per rat increases by linear based upon the values of palm-oil density.

Total_of_palm-oil_eaten_per_rat (Jumlahsawitdimakan per tikus)= GRAPH(Palm-oil_resource_density)(0.00, 0.00), (1000, 1.00), (2000, 2.00), (3000, 3.00), (4000, 4.00), (5000, 5.00), (6000, 6.00), (7000, 7.00), (8000, 8.00), (9000, 9.00), (10000, 10.00)

A. Sector of Rat

The initial value set for rat is 20,000. Without control, the rat population in palm-oil plantation can reach from 200 to 600 per hectare (Wood, 2001). This simulation applies the average value based on the range given:

- *Rat (Tikus) = 200 × 100 ha = 20000*

The size of rat population every year depends on the total of rat population in previous years and rats' birth and death. The correlation among these factors is explained through the following formula:

- *Rat (t) = Rat (t−dt) + (rat's birth (Kelahirantikus) − rat's death (Kematiantikus)) × dt*

Figure 2 illustrates the sector of rat in the simulation performed and it is followed by the constant and variable values concerned.

- *Rat birth rate (Kadar kelahirantikus) = 3 times yearly = 3 / 12 = 0.25*
- *Rat birth (Kelahirantikus) = Rat × Rat birth rate (Kadar kelahirantikus)*
- *Rat density (Kepadatantikus) = Rat / Farm area (Luas ladang)*
- *Rat death (Kematiantikus) = Owl (BH) × Rats killed per owl (Tikus yang dibunuh per BH)*

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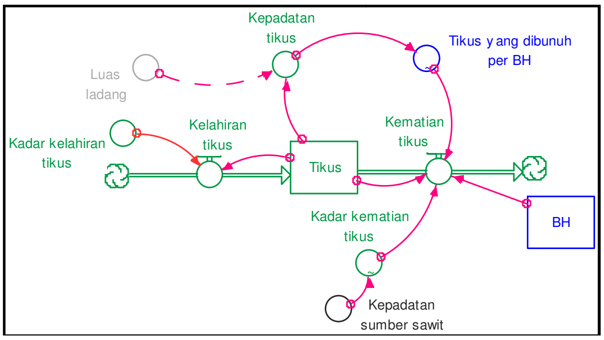

Fig.2. Sector of Rat

There are two reasons regarding the rat's death in this simulation. The former is due to the lack of food supply that is palm-oil and it depends upon the palm-oil resource density. The latter is because of being eaten by owl. This simulation indicates that the rat's death decreases by exponent based upon the values of palm-oil density.

Rat_death_rate(Kadar kematiantikus) = GRAPH(Palm-oil_resource_density(Kepadatansumbersawit))(0.00,50.0), (10.0, 49.0), (20.0, 47.0), (30.0, 44.0), (40.0, 40.0), (50.0, 35.0), (60.0, 29.0), (70.0, 22.0), (80.0, 14.0), (90.0, 3.00), (100, 0.00)

The owl's nutrition relies on the rat's density. This simulation displays that the rats killed per owl increase exponentially based upon the rat's density value.

Rats_killed_per_owl (Tikus yang dibunuh per BH)= GRAPH(Rat_density (Kepadatantikus))(0.00, 0.00), (50.0, 250), (100, 720), (150, 1080), (200, 1640), (250, 2160), (300, 2800), (350, 3700), (400, 4700), (450, 6080), (500, 8000)

B. Sector of Owl

The initial value stipulated for owl is 12. In Indonesia, 1 cage of owl is placed to monitor a plantation of 25 acre (Sudharto, 2000). 1 cage of owl consists of 1 male owl, 1 female owl and 1 owlet (Duckett and Karuppiah, 1989). The early size of owl population therefore can be explained via the following formula:

- *Owl (BH) = (100 ha / 25 ha) × 3 owls = 12*

The size of owl population each year hangs on the total of owl population in years before and owl's birth and death. The correlation among these factors is explained through the following formula:

- *Owl (t) = owl (t−dt) + (owl's birth (Kelahiran BH) − owl's death (Kematian BH)) × dt*

Figure 3 illustrates the sector of owl in the simulation performed and it is followed by the constant and variable values concerned.

- *Owl birth rate (Kadar kelahiran BH)= 0.17*
- *Owl birth (Kelahiran BH) = Owl (BH) × Owl birth rate (Kadar kelahiran BH)*
- Owl death (Kematian BH) = Owl (BH) × Owl death rate (Kadar kematian BH)

The owl's death rate is in accordance to the rat's density. This simulation shows the owl's death rate drops exponentially to the rat's density value.

Owl_death_rate (Kadar kematian BH) = GRAPH (Rat_density (Kepadatantikus))(0.00, 50.0), (10.0, 49.0), (20.0, 47.0), (30.0, 44.0), (40.0, 40.0), (50.0, 35.0), (60.0, 29.0), (70.0, 22.0), (80.0, 14.0), (90.0, 3.00), (100, 0.00)

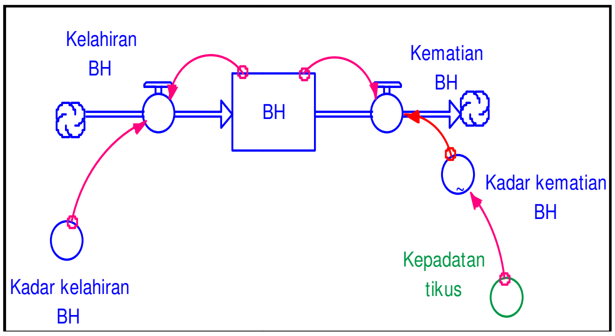

Fig.3. Sector of Owl

4. Discussion

The discussion of this study will divide into three sections. Each section will discuss on the equilibrium of relationships of the entities involved, the impact produced by the rat population to palm-oil resource and explaining the equilibrium of rat and owl relationships.

A.Equilibrium Among Entities

The relationships of palm-oil resource, rat and owl achieve equilibrium on constant and variable values are included in Section 3 in this paper. Figure 4 shows a graph population for these three entities involved. Owl represent by 'BH', Palm-oil resource represent by 'Sumbersawit', and rat represent by 'Tikus'.

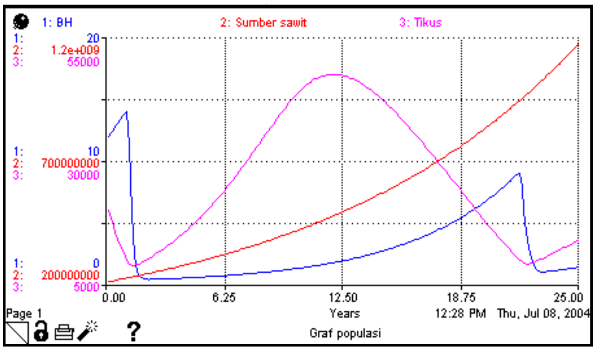

Fig.4. Population Graph for Palm-oil Resource, Rat and Owl

The relationship of rat and owl produced is positive. Observing the graph, when the rat population deteriorates, the owl population follows the same pattern as rat due to the lack of food supply. In timeframe of 1.25 years, the rat population increases back whereby in line with the increment of palm-oil resource. In year 12, the rat population is found falling down because of nutrition rate by owl is higher than the rat's birth rate. In timeframe of 21.75 years, the owl population declines as the rat population reduces.

The palm-oil resource enhances exponentially due to the presence of rat population that can be controlled by the owl. Nevertheless, the rat's presence still impacts the palm-oil resource. In time of rat population is highest that

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is 1.25 to 12 years, the palm-oil increment rate is lower than the state when the rat population experiences decrement as a result being killed by the owl.

B. Relationships of Crop and Damaged Fruit

Apart from the equilibrium issue, the relationships of crop and damaged fruit are also studied. Figure 5 illustrates the correlation of crops by planters and the fruits damaged by rats. Crops represent by 'Buahdituai', and damaged fruits represent by 'Buahrosak'.

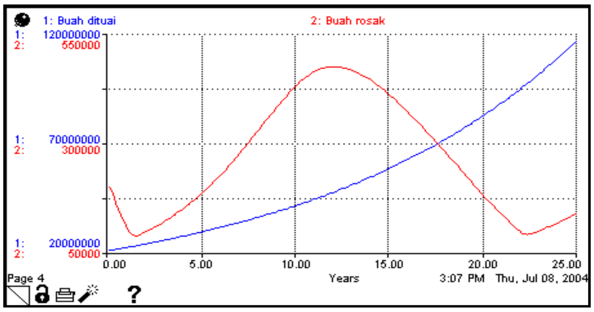


Fig.5(a). Graphs of Crop and Damaged Fruit per Year

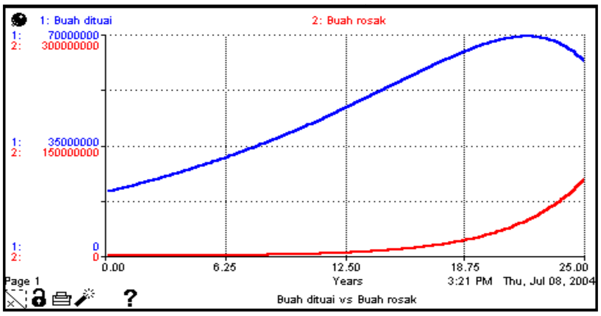


Fig.5(b). Graphs of Crop and Damaged Fruit per Year

Based upon Figure 5(a), the fruits cropped by planters are in accordance with the increment of palm-oil resource. Meanwhile, the increment and decrement of damaged fruits are influenced by ups and downs of rat population. This graph is a result of the rat control available by the owl. Should the rats are let without control, the rat population sooner or later reduces the palm-oil resource and affects negatively to the planters. Within longer timeframe, the rat is capable to finish up all palm-oil resources. Figure 5(b) predicts that circumstance.

C. Relationships of Rat and Owl

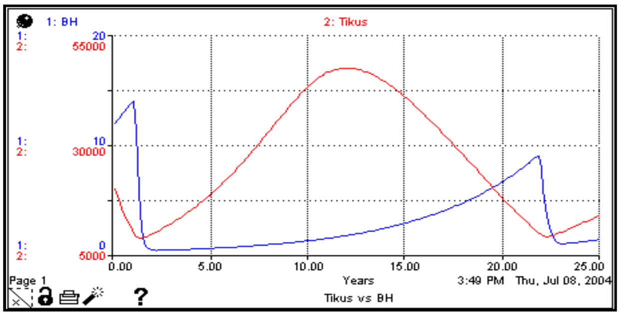


Fig.6(a). The Relationships of Rat and Predator in 25 years.

The owl in this simulation is able to control the rat population. Within 25 years of palm-oil economic duration, the graph roughly is unable to indicate the equilibrium pattern of rat and owl relationships. Therefore, 100 years are chosen to observe the equilibrium of this prey-predator relationship. Figure 6(a) and Figure 6(b) respectively display the relationships of rat and predator in 25 years and 100 years. Owl represent by 'BH', and rat represent by 'Tikus'.

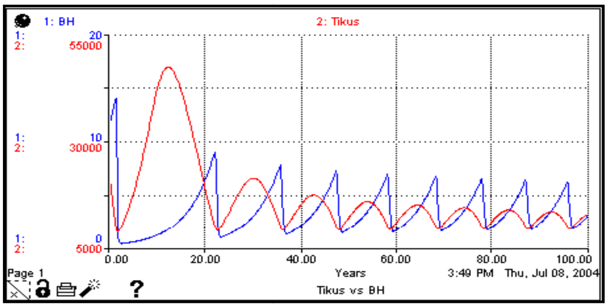


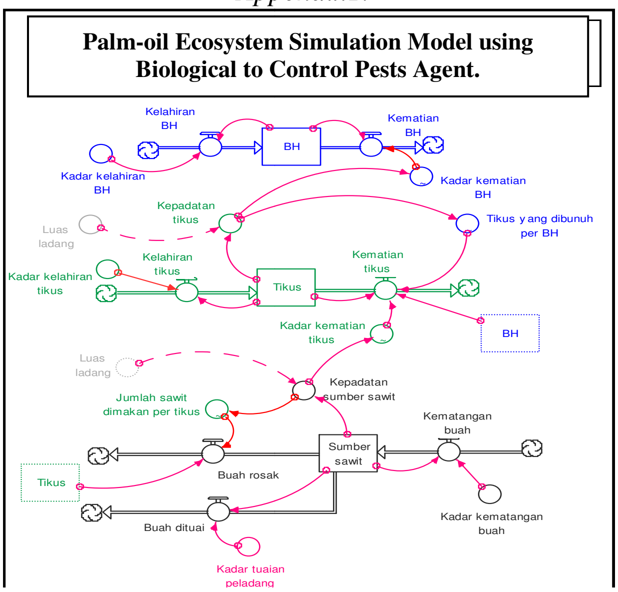
Fig.6(b). The Relationships of Rat and Predator in 100years.

As perceived in Figure 6(a), it only depicts the relationships of owl and rat is at rate of 1 cycle only in 25-year palm-oil economic period. Within 100-year timeframe, the pattern of owl population is clearly identified in Figure 6(b) to decrease the rat population in palm-oil plantation.

5. Conclusion

The result of the simulation performed proves the equilibrium of relationship among palm-oil, rat and owl. Through this simulation developed as well, the method of biological control can be planned to control the rat's propagation along 25-year palm-oil economic period. This outcome assists the plantation management to make decision earlier pertaining to rat issues as the pest in palm-oil plantation ecosystem. In future, the study will do a further action to take into account another possibility to reduce the pests agent from rat and increase the biological of palm-oil.

Appendix1.



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Appendix2.

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BH(t) = BH(t - dt) + (Kelahiran_BH - Kematian_BH) * dt
INIT BH = 12
INFLOWS:
Kelahiran_BH = BH*Kadar_kelahiran_BH
OUTFLOWS:
Kematian_BH = BH*Kadar_kematian_BH

Sumber_sawit(t) = Sumber_sawit(t - dt) + (Kematangan_buah - Buah_rosak - Buah_dituai) *
dt
INIT Sumber_sawit = 207000000
INFLOWS:
Kematangan_buah = Sumber_sawit*Kadar_kematangan_buah
OUTFLOWS:
Buah_rosak = Tikus*Jumlah_sawit_dimakan_per_tikus
Buah_dituai = Sumber_sawit*Kadar_tuaian_peladang

Tikus(t) = Tikus(t - dt) + (Kelahiran_tikus - Kematian_tikus) * dt
INIT Tikus = 20000
INFLOWS:
Kelahiran_tikus = Tikus*Kadar_kelahiran_tikus
OUTFLOWS:
Kematian_tikus = (Tikus*Kadar_kematian_tikus)+(BH*Tikus_yang_dibunuh_per_BH)

Kadar_kelahiran_BH = 0.17
Kadar_kelahiran_tikus = 0.25
Kadar_kematangan_buah = 0.17
Kadar_tuaian_peladang = 0.1
Kepadatan_sumber_sawit = Sumber_sawit/Luas_ladang
Kepadatan_tikus = Tikus/Luas_ladang
Luas_ladang = 100

Jumlah_sawit_dimakan_per_tikus = GRAPH(Kepadatan_sumber_sawit)
(0.00, 0.00), (1000, 1.00), (2000, 2.00), (3000, 3.00), (4000, 4.00), (5000, 5.00), (6000, 6.00),
(7000, 7.00), (8000, 8.00), (9000, 9.00), (10000, 10.0)

Kadar_kematian_BH = GRAPH(Kepadatan_tikus)
(0.00, 50.0), (10.0, 49.0), (20.0, 47.0), (30.0, 44.0), (40.0, 40.0), (50.0, 35.0), (60.0, 29.0),
(70.0, 22.0), (80.0, 14.0), (90.0, 3.00), (100, 0.00)

Kadar_kematian_tikus = GRAPH(Kepadatan_sumber_sawit)
(0.00, 50.0), (10.0, 49.0), (20.0, 47.0), (30.0, 44.0), (40.0, 40.0), (50.0, 35.0), (60.0, 29.0),
(70.0, 22.0), (80.0, 14.0), (90.0, 3.00), (100, 0.00)

Tikus_yang_dibunuh_per_BH = GRAPH(Kepadatan_tikus)
(0.00, 0.00), (50.0, 250), (100, 720), (150, 1080), (200, 1640), (250, 2160), (300, 2800), (350,
3700), (400, 4700), (450, 6080), (500, 8000)
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