

**EVALUATION OF RAT OCCURRENCE IN OIL
PALM PLANTATIONS USING GIS AND
REMOTE SENSING TECHNIQUES**



CHONG CHEE WEY

UMS
UNIVERSITI MALAYSIA SABAH

**SCHOOL OF INTERNATIONAL
TROPICAL FORESTRY
UNIVERSITI MALAYSIA SABAH
2012**

**EVALUATION OF RAT OCCURRENCE IN OIL
PALM PLANTATIONS USING GIS AND
REMOTE SENSING TECHNIQUES**

CHONG CHEE WEY



UMS

**THESIS SUBMITTED IN FULFILLMENT FOR THE
DEGREE OF MASTER OF SCIENCE**

**SCHOOL OF INTERNATIONAL
TROPICAL FORESTRY
UNIVERSITI MALAYSIA SABAH
2012**

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN TESIS

JUDUL : _____

IJAZAH : _____

SAYA : _____ SESI PENGAJIAN : _____

(HURUF BESAR)

Mengaku membenarkan tesis *(LPSM/Sarjana/Doktor Falsafah) ini disimpan di Perpustakaan Universiti Malaysia Sabah dengan syarat-syarat kegunaan seperti berikut:-

1. Tesis adalah hak milik Universiti Malaysia Sabah.
2. Perpustakaan Universiti Malaysia Sabah dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (/)

SULIT

(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di AKTA RAHSIA RASMI 1972)

TERHAD

(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

TIDAK TERHAD

Disahkan oleh:

(TANDATANGAN PENULIS)

Alamat Tetap: _____

TARIKH: _____

(TANDATANGAN PUSTAKAWAN)_____
(NAMA PENYELIA)

TARIKH: _____

Catatan:

*Potong yang tidak berkenaan.

*Jika tesis ini SULIT dan TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT dan TERHAD.

*Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana Secara Penyelidikan atau disertai bagi pengajian secara kerja kursus dan Laporan Projek Sarjana Muda (LPSM).

DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, excerpts, equations, summaries and references, which have been duly acknowledged.

1st June 2012

Chong Chee Wey
PF2008-8382



UMS
UNIVERSITI MALAYSIA SABAH

CERTIFICATION

NAME : **CHONG CHEE WEY**
MATRIC NO. : **PF2008-8382**
TITLE : **EVALUATION OF RAT OCCURRENCE IN OIL PALM
PLANTATIONS USING GIS AND REMOTE SENSING
TECHNIQUES**
DEGREE : **MASTER OF SCIENCE (FORESTRY)**
VIVA DATE : **25th September 2012**

DECLARED BY

1. SUPERVISOR

Assoc. Prof. Dr. Phua Mui How

Signature




2. CO-SUPERVISOR

Assoc. Prof. Dr. Abdul Hamid Ahmad



3. CO-SUPERVISOR

Assoc. Prof. Dr. Hafidzi Mohd Nor



DR. HAFIDZI BIN MOHD. NOR
Jabatan Perlindungan Tumbuhan
Universiti Putra Malaysia
43400 UPM Serdang
Selangor Darul Ehsan
Malaysia

ACKNOWLEDGEMENTS

This project was funded by MOSTI, Malaysia (ScienceFund No. 05-01-10-SF0094). I would like to express my deepest gratitude and appreciation to my supervisors Assoc. Prof. Dr. Phua Mui How, Assoc. Prof. Dr. Abdul Hamid Ahmad, and Assoc. Prof. Dr. Hafidzi Mohd Nor for all their advices, guidance and support throughout the research work that led to completion of this thesis. I would like to thank the field assistance rendered, generous cooperation of various parties involved in the course of this study, including FELDA, Sabah Forestry Department, and Tabin Wildlife Reserve.

Chong Chee Wey
1st June 2012



UMS
UNIVERSITI MALAYSIA SABAH

ABSTRAK

PENILAIAN KEHADIRAN TIKUS DI LADANG KELAPA SAWIT DENGAN MENGGUNAKAN TEKNIK GIS DAN PENDERIAAN JAUH

Kerosakan yang disebabkan oleh tikus di ladang kelapa sawit membawa kerugian ekonomi. Dalam kajian ini, faktor-faktor yang mempengaruhi kewujudan tikus telah dikaji dengan menggunakan teknik GIS. 255 ekor tikus telah ditangkap dengan menggunakan perangkap dan kebanyakannya adalah *Rattus rattus diardii*. Di ladang kelapa sawit, species tikus adalah *R. r. diardii*, *R. argentiventer*, dan *Maxomys whiteheadi*. Di hutan pula, species tikus adalah *R. r. diardii*, *M. whiteheadi*, dan *M. surifer*. Data tangkapan tikus digabungkan dengan beberapa faktor. Faktor yang mempengaruhi kehadiran tikus telah dikenalpasti melibatkan umur pokok, jarak dari jalan, jarak dari kilang pemprosesan, dan indeks vegetasi NDVI. Persamaan logistik binomial dan multinomial telah dibangunkan untuk meramal taburan tikus di ladang kelapa sawit. Kajian ini telah mengenalpasti kawasan yang tinggi, sederhana, dan rendah kehadiran tikus. Kawasan tanam semula merupakan kawasan yang paling tinggi kehadiran tikus (Kadar tangkapan 25.35%, Kehadiran tikus di 95.31% lokasi). Sarang burung hantu boleh diletakkan di kawasan tersebut, dan kehadiran tikus di ladang kelapa sawit boleh ditangani dengan lebih berkesan.

ABSTRACT

Rat damage in oil palm plantation brings significant economic losses. In this study, factors that influence rat occurrence were investigated using live trapping and GIS-based multicriteria analysis. 255 rats, mostly Rattus rattus diardii were captured using live trapping from nearly two thousands trap-night efforts. In oil palm plantation, rat species captured is R. r. diardii, R. argentiventer, Maxomys whiteheadi. In forest, rat species captured is R. r. diardii, M. whiteheadi, and M. surifer. Rat capture data was examined using several spatial factors. Factors that influence rat occurrence are found to be palm age, distance from road, distance from mill, and Normalized Difference Vegetation Index (NDVI) value. Binomial and multinomial logistic regression models were developed for prediction of rat occurrence in oil palm plantation. This study identified high, medium, and low rat occurrence area in oil palm plantation; highest rat occurrence (25.35% success rate, 95.31% points with rat) was recorded in replanting area. Identification of high rat occurrence area allow effective placement of barn owl nest box, for addressing rat problems in resource saving and environmental friendly way.



UMS
UNIVERSITI MALAYSIA SABAH

TABLE OF CONTENTS

	Page
TITLE	i
DECLARATION	ii
CERTIFICATION	iii
ACKNOWLEDGEMENTS	iv
<i>ABSTRAK</i>	v
ABSTRACT	vi
LIST OF CONTENTS	vii
LIST OF TABLES	x
LIST OF FIGURES	xii
LIST OF ABBREVIATIONS	xiv
LIST OF SYMBOLS	xv
LIST OF APPENDIX	xvi
CHAPTER 1: INTRODUCTION	1
1.1 Research objectives	2
1.2 Problem statements	2
1.3 Justification	2
CHAPTER 2: LITERATURE REVIEW	3
2.1 Rat and their habitat	3
2.1.1 Background	3
2.1.2 Rat in oil palm plantation	4
2.1.3 Rat control method	6
i. Chemical control	6
ii. Physical control	7
iii. Biological control	7
2.2 Live trapping of rats	9
2.3 Daytime resting area of rats	10
2.3.1 Locating rat daytime resting area	10
2.3.2 Calculation of the size of daytime resting area	11
2.4 Evaluation of rat species occurrence in their habitat	13
2.5 Multicriteria analysis	16

2.6	GIS-based habitat evaluation	17
CHAPTER 3: METHODOLOGY		21
3.1	Study site	21
3.1.1	FELDA plantation	21
3.1.2	Permai plantation	22
3.2	Data collection	25
3.2.1	Live trapping	25
	i. Systematic sampling	25
	ii. Factors combination map	30
3.2.2	Radiotracking	31
3.2.3	Satellite data acquisition	34
	i. GeoEye data	34
	ii. Landsat data	35
	iii. Plantation map	37
	iv. Elevation data	38
3.3	Data analysis	38
3.3.1	Satellite image processing	38
	i. Preprocessing and panchromatic sharpening	38
	ii. Normalized Difference Vegetation Index (NDVI)	39
	iii. Object-based classification	39
3.3.2	Mapping of rat occurrence	43
CHAPTER 4: RESULTS		47
4.1	Results of the overall captures in FELDA and Permai plantations	47
4.2	Daytime resting area	50
4.3	Rat occurrence	53
4.3.1	Rat occurrence in FELDA plantation	53
	i. Binomial logistic regression	53
	ii. Multinomial logistic regression	56
4.3.2	Rat occurrence in Permai plantation	60
4.4	Land cover map using the GeoEye data	64
4.4.1	Land cover types	64
4.4.2	Accuracy assessment for object-based classification	64

4.5	Association of rat occurrence and land cover type	68
CHAPTER 5: DISCUSSION		75
5.1	Trap success rate and rat population	75
5.2	Rat species composition compared to other studies	80
5.3	Factors that influence rat occurrence	81
5.3.1	Age of plantation and NDVI	81
5.3.2	Proximity to road	83
5.3.3	Proximity to oil processing mill	84
5.4	Potential use for supporting Integrated Pest Management	84
5.5	Rat control strategies	85
5.5.1	Forest remnants – to keep or not to keep?	85
5.5.2	Rodenticide – to use or not?	87
5.5.3	Barn owl introduction	88
5.5.4	Placement of barn owl nest box	89
5.6	Further research	90
5.6.1	Rat population and behavior	90
5.6.2	Rodenticide tolerance of <i>R. r. diarddi</i>	90
CHAPTER 6: CONCLUSION		92
REFERENCES		93
APPENDIX		114

LIST OF TABLES

		Page
Table 2.1	Main differences of <i>R. r. diardii</i> , <i>R. argentiventer</i> , and <i>R. tiomanicus</i>	4
Table 3.1	Trap settings in Permai and FELDA	29
Table 3.2	Transmitter used in radiotracking	32
Table 3.3	Reclassification table for road, river, plantation age, and oil processing mill	45
Table 4.1	Result of live trapping in forest near Permai, Permai and FELDA plantation	48
Table 4.2	Sex of rat captured	49
Table 4.3	Daytime resting area (m ²) of male <i>R. r. diardii</i> in FELDA plantation	50
Table 4.4	Daytime resting area (m ²) of female <i>R. r. diardii</i> in FELDA plantation	51
Table 4.5	Daytime resting area (m ²) of male <i>R. r. diardii</i> in Permai plantation	51
Table 4.6	Daytime resting area (m ²) of female <i>R. r. diardii</i> in Permai plantation	51
Table 4.7	Daytime resting area (m ²) of male <i>Maxomys whiteheadi</i> in forest adjacent to Permai plantation	52
Table 4.8	Daytime resting area (m ²) of female <i>Maxomys whiteheadi</i> in forest adjacent to Permai Plantation	52
Table 4.9	Comparison of regression analysis of FELDA plantation	53
Table 4.10	Accuracy matrix for binomial logistic regression of FELDA plantation	56
Table 4.11	Accuracy matrix for binomial logistic regression of FELDA plantation	59
Table 4.12	Comparison of regression analysis of Permai plantation	60
Table 4.13	Accuracy matrix for binomial logistic regression of PERMAI plantation	61
Table 4.14	Error matrix for object-based classification	67

Table 4.15	Users and producers accuracy for object-based classification	67
Table 4.16	Kappa statistic for object-based classification	68
Table 4.17	Area (m ²) for each class in area of high, medium and low rat occurrence probability	73
Table 5.1	Comparison with other studies	76
Table 5.2	Species composition compared to other studies	82



UMS
UNIVERSITI MALAYSIA SABAH

LIST OF FIGURES

		Page
Figure 2.1	Zink collar on young oil palm	7
Figure 2.2	Minimum convex polygon (MCP)	12
Figure 2.3	Harmonic mean (HM)	12
Figure 2.4	Kernel estimator (KE)	13
Figure 3.1	Location of the FELDA plantation	22
Figure 3.2	Main road marking the border between the Permai Plantation (left) and the Tabin Wildlife Reserve (right). The road connects Tomanggong and Lahad Datu.	23
Figure 3.3	Location of the PERMAI plantation	24
Figure 3.4	Trapping point distribution in FELDA plantation	26
Figure 3.5	The recently cleared PERMAI oil palm plantation is adjacent to forest remnants.	27
Figure 3.6	Trapping point distribution in PERMAI plantation and adjacent forest	27
Figure 3.7	The process of building factors combination map	30
Figure 3.8	<i>R. r. diardii</i> with transmitter attached	32
Figure 3.9	Estimation of the sample location by using three azimuths	33
Figure 3.10	GeoEye satellite image	34
Figure 3.11	Downloading image from USGS website	35
Figure 3.12	The two Landsat images	36
Figure 3.13	Supervised classification of Landsat image	37
Figure 3.14	Panchromatic sharpening of GeoEye image	39
Figure 3.15	NDVI image created from pan-sharped image	39
Figure 3.16	The process of object-based classification	40
Figure 3.17	Object-based classification	42
Figure 3.18	The process of rat occurrence mapping	46
Figure 4.1	Species captured in forest and oil palm plantation	49
Figure 4.2	Probability of rat occurrence in FELDA plantation by binomial logistic regression	55

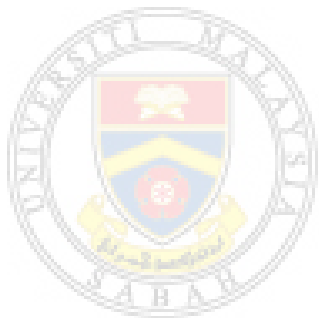
Figure 4.3	Probability of rat occurrence in FELDA plantation by multinomial logistic regression	58
Figure 4.4	Probability of rat occurrence in Permai plantation by multinomial logistic regression	63
Figure 4.5	Land cover map from object-based classification	64
Figure 4.6	Reference points were assigned for whole FELDA plantation for accuracy assessment.	66
Figure 4.7	Process of determining pattern of rat occurrence area	69
Figure 4.8	Land cover classes in area of high rat occurrence probability	70
Figure 4.9	Land cover classes in area of medium rat occurrence probability	71
Figure 4.10	Land cover classes in area of low rat occurrence probability	72
Figure 4.11	Distribution of area for each class (m ²) in area of high, medium and low rat occurrence probability	73
Figure 5.1	Young plantation is covered by mixture of newly planted oil palm, grasses, bushes, and these leftover	83
Figure 5.2	Rat damage (%) in Permai plantation from January 2009 to May 2010	86

LIST OF ABBREVIATIONS

GIS	Geographic information system
RISDA	Rubber Industry Smallholders Development Authority
NDVI	Normalized Difference Vegetation Index
FFB	Fresh fruit bunch
IPM	Integrated Pest Management
USEPA	United States Environmental Protection Agency
BOP	Barn owl programmes
DOA	Department of Agriculture
FELDA	Federal Land Development Authority
FASSB	FELDA Agricultural Services Sdn. Bhd.
THC	Tetracycline hydrochloride
MPOB	Malaysian Palm Oil Board
PHVA	Population and habitat viability assessment
MCA	Multicriteria analysis
USGS	United States Geological Survey
DEM	Digital elevation model
OBC	Object-based Classification
MCP	Minimum Convex Polygon

LIST OF SYMBOLS

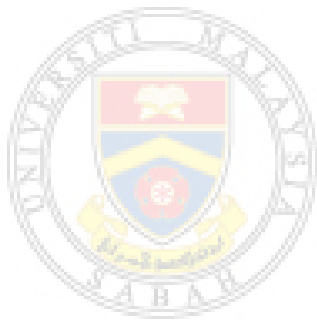
g	Gram
ha	Hectares
χ^2	Chi-square
R^2	R-square
m	Meter
m^2	meter square
P	Probability
$P(Y)$	Probability of rat occurrence
ρ	significance level
K^{\wedge}	Kappa statistic



UMS
UNIVERSITI MALAYSIA SABAH

LIST OF APPENDIX

	Page
Appendix A Details of GeoEye data	114



UMS
UNIVERSITI MALAYSIA SABAH

CHAPTER 1

INTRODUCTION

The oil palm industry is threatened by the persistence of pest problems, such as the red palm weevil, the rhinoceros beetle and rats (RISDA, 2010). Rat damage in oil palm plantation brings significant economic losses up to RM9700/ha/year, resulting from physical damage to oil palm fresh fruit bunch and the cost of rat control practices involved (Hafidzi & Saayon, 2001). Many plantations relied on rodenticide to control rat. The drawback of rodenticide use is it also consumed by non-target animals such as palm civets or cause secondary poisoning in predators that prey on rat (Naim *et al.*, 2010).

A widely employed environmentally safe approach in controlling rat is by relying on the natural predator, the barn owl (*Tyto alba*) (Hafidzi & Saayon, 2001). Natural propagation of the barn owl by way of provisioning artificial nest boxes started in the oil palm plantation in Malaysia in the 1980's (Duckett & Karuppiah, 1989; Smal, 1989). By and large the placement of the nest boxes in the oil palm plantation was largely random and not based on factors that influence rat density and distribution. As a consequence the nest boxes failed to attract barn owls and achieve optimum occupancy rates. From the point of sustainable agriculture perspective this is wastage of resource allocation and compromises on the effectiveness of the system. To successfully manage rat problem in plantation, it is important to know what are the factors that influence rat occurrence. However, the spatial aspect of rat occurrence has not been sufficiently studied.

Geographic information system (GIS) is suitable in habitat assessment of small mammals, such as foxes (Gerrard *et al.*, 2001), squirrels (Menzel *et al.*, 2006; Pereira & Itami, 1991) and urban rat (Traweger & Slotta-Bachmayr, 2005). In this study, the occurrence of rat and the spatial assessment that influence this in oil palm plantation in Sabah was investigated.

1.1 Research objectives

1. To develop a spatial model of rat occurrence in oil palm plantations using GIS and remote sensing techniques.
2. To estimate rat occurrence in monoculture plantation and plantation adjacent to forest.

1.2 Problem statements

Despite various studies done on oil palm pest, none of them focus on examining the occurrence of rat using GIS and remote sensing techniques (Darus & Wahid, 2000; Deoras *et al.*, 1972; Liau, 1990; Wood, 1976). Although the barn owl has been introduced for decades, allocation of their nest box is still based on trial and error. The success of the use of the barn owl in controlling rodent pests might rely on deeper ecological settings of the rodents, which in turn influence the function of the owl as a predator. Through this study, the spatial distribution of rats in oil palm plantations and factors that influence it were examined.

1.3 Justification

This study was conducted to support sustainable development of oil palm industry, especially on the using of biological control method. It will bring us more understanding on rat and allow us to deal with rat problem through strategic placement of barn owl nest box. This study will provide an alternative to placement of nest boxes for the barn owl allowing the possibility to further enhance the use of biological control of rat pests in the oil palm plantations.

CHAPTER 2

LITERATURE REVIEW

2.1 Rats and their habitat

2.1.1 Background

In order to effectively handle rat problems, we need more understanding in their behavior and habitat. Rat makes up about 30% of the world mammalian species (Wilson & Reeder, 2005). They are highly adaptive creature and are well distributed all over the world. *Rattus rattus* for example, has a world-wide range and includes subantarctic islands (Pye *et al.*, 1999; Schwarz, 1960). Another common species, *R.norvegicus* has a more northerly distribution (Schwarz, 1960), and dominates cities in temperate regions (Cavia *et al.*, 2009). Subspecies *R. r. diardii* is found in Sabah and the taxonomy is as follows (Payne *et al.*, 1998):

phylum	: chordata
class	: mammalia
order	: rodentia
suborder	: sciurognathi
family	: muridae
subfamily	: murinae
subspecies	: <i>Rattus rattus diardii</i>
common name	: black rat or house rat

It was reported that rat feed on nuts, plant leaves, stems, seeds, grass and insects (Horskins *et al.*, 1998). A pair of mature rat can produce up to 2000 offspring per year and their infants reach maturity in three to four months (Payne *et al.*, 1998; RISDA, 2010). Innes and Skipworth (1983) studied *R.rattus* in New Zealand and found that *R.rattus* has stable home range with irregular shape, appear in different area in different nights, but stayed within their home range.

2.1.2 Rat in oil palm plantation

Rat is a problem in oil palm plantation, either newly planted or matured (RISDA, 2010). They are prevalent in oil palm plantations due to its favorable environment for breeding and taking refuge from predators (Hafidzi, 1995). The most widespread rat species found in oil palm of Peninsular Malaysia is the Malaysian wood rat (*R. tiomanicus*), the Malayan black rat (*R. r. diardii*), and ricefield rat (*R. argentiventer*) (Hafidzi & Saayon, 2001). Their main differences are listed in Table 2.1.

Eighty percent of *R. rattus* diet consists of plant matter (McDonald *et al.*, 1997). They are considered pest in oil palm plantation where they damage the oil palm fruit's bunches and cause stunted growth in both matured and young oil palm seedlings (Hafidzi & Saayon, 2001; Heru *et al.*, 2000). Study of 5372 rat in oil palm plantation showed that 96% of the stomach content is oil palm fruit (Wood & Liau, 1984). The abundance of rat has been found to have direct relationship to crop damage (Brown *et al.*, 2006).

Table 2.1 : Main differences of *R. r. diardii*, *R. argentiventer*, and *R. tiomanicus*

	<i>R. r. diardii</i>	<i>R. argentiventer</i>	<i>R. tiomanicus</i>
Wt (g)	100-200	85-180	78-125
HB (mm)	122-219	140-210	140-188
T (mm)	121-220	130-192	120-181
T/HB	>100%	<100%	75-120%
HF (mm)	32-39	32-36	28-35
Skull: cbl	33.8-42.9	35.1-39.7	34.3-36.9
Skull: io	5.8-7.4	5.6-6.6	5.9-6.5
Skull: mt	6.2-7.0	7.0-7.1	6.0-6.8
Upperparts	Finely grizzled olive-brown	Pale brown with brown speckling	Finely grizzled olive-brown
Underparts	paler, buffy brown with grey bases	Wholly silvery-grey	Pale grey with buffy white tips/White

Tail	Brownish	Brownish	Dark brownish
Female mammas	10	12	10
Ridge on feet	No	No	Yes
Black guard hair on rump	Yes	No	Whole body
Distinct feature	Big body size	Mostly subterranean, attack young oil palm	Good climbers, dominant (in Peninsular Malaysia)



Wt: weight
 HB: length of head and body
 T: length of tail
 HF: length of hinge feet
 cbl: condylobasal length
 io: interorbital breadth
 mt: metatarsal

UMMS
 UNIVERSITI MALAYSIA SABAH

Source: A Field Guide to the Mammals of Borneo (Payne *et al.*, 1998)

Newly planted oil palm is vulnerable to rat attacks; rat eat the young tissue which leads to stunted growth and death of the young oil palm (Padilla *et al.*, 1995; RISDA, 2010). In matured oil palm plantations, rat eat fresh fruit of oil palm. Rat also eat oil palm florescence when their population exceeds carrying capacity (RISDA, 2010). Their high adaptability had caused their population to exceed the carrying capacity in oil palm plantation (Hafidzi, 1993; Hafidzi, 1995). It was reported that estimated damage from rat activities can reach 3 ton/ha/year or RM1200/ha/year (Hafidzi & Saayon, 2001). The damage is even more critical in seriously attacked oil palm plantation (RISDA, 2010).

2.1.3 Rat control methods

Rat can be controlled using chemical, physical, or biological control method (RISDA, 2010). The cost of rat control varied with method used and it falls between RM30-RM70/hectare/year (RISDA, 2010).

i. Chemical control

Chemical control by means of rodenticide can be found in various formulations with different active ingredients (RISDA, 2010). There are more than 50 registered formulations of rodenticide registered in Malaysia alone (RISDA, 2010).

Wood (1976, 1984, 1988) suggested a six months interval baiting, while Ho (1996) recommended baiting when rat damage exceeds 5% of the fresh fruit bunch (FFB) (RISDA, 2010). In practice, some plantation modified the system suggested. For example, FELDA oil palm plantation do baiting three times a year, while another oil palm plantation, PERMAI, do baiting when damage exceeds 10% of FFB.

The drawback of rodenticide is rat will develop resistance to them over time after extended usages. There are two types of rodenticide, the first generation anticoagulants and the second generation anticoagulants. The latter was introduced when rat have developed resistance to the former (RISDA, 2010). Currently, the most widely employed first generation rodenticide in Malaysia is warfarin (Naim, 2009). Study also showed that using of rodenticide can only provide short term solution. A study done in 17 farms in United Kingdom showed that rat population can return to 50% of pre-treatment population in just one year (Cowan *et al.*, 2003).

Rodenticide has other drawbacks. Rat has high annual mortality rate and short lifespan, but with an extraordinary high reproductive potential (r-selected life strategy). Thus, the reduction of population by means of rodenticide can only provide short-term effect (Witmer, 2007). In oil palm plantation where food availability is high, rodenticide can be ineffective against rat (Leung & Clark, 2005). Leung & Clark (2005) investigated the effectiveness of baiting in a pig farm in Australia by using several types of commonly applied rodenticide. They concluded