CHAPTER I
INTRODUCTION

1.1 Introduction

An increased level of atmospheric CO_2 through the combustion of fossil fuel or more precisely its likely effect on the global climate, is caused for concerned (Ayukai,1998). The storage of carbon reduces the greenhouse effect that linked to problems of global climate change (Lim,2007). Thus, many scientists have recognized the carbon sources or sink.

Soil Organic Carbon (SOC) is played a major role in virtually all edaphdogical processes (Zinn et al ., 2002) and is a key element within the global carbon cycle (Martine et al., 2010) using soil as a carbon sink to sequester carbon dioxide has been attracted much attention in recent years (Su et al., 2006). Within the pedosphere, global soil carbon stock to 1 meter depth is estimated as 1.55x 10^{12} tons, approximately 75% of the total carbon stock in the terrestrial ecosystem which is nearly three times of the aboveground biomass and approximately twice of the atmospheric Carbon pool, respectively. (Post et al., 1982; Eswaran et al.,1993) A large proportion of soil carbon is also found to exist in the form of organic carbon ($1.50x10^{12}$ tons) (Lal, 2003).At 3 meters depth, SOC is about 2,300 Pg of Carbon (Jobbagy and Jackson,2000). Thus, the soil can be the largest global terrestrial Carbon pool and source or sink of atmospheric CO_2 then SOC is played an important role in mitigating greenhouse gas emission.

In addition to, many scientific studies found that tree can help to reduce the problem of global warming, Carbon Dioxide is absorbed by tree that used for photosynthesis. Tree can absorb CO_2 from the atmosphere that transformed to biomass. This process is called “Carbon Sequestration” which is the best effective on CO_2 reduction in atmosphere (Sridang,2008). Then , forest is an important role of carbon sink and carbon cycle. Therefore forest area increasing is the more carbon sequestration sources and decreasing of CO_2 in the air (Schroeder,1992).

Especially, mangrove ecosystem plays an important role in the global carbon cycle. (Ayukai,1998). It protects a coast erosion and storms, encourages sediment deposition and provides the most productive ecosystems and their carbon stock per unit area can be enormous (Twilley et al.,1992; Ong, 1993). To better understand the dynamic of carbon cycle in the forest, the amount of leaf area index and biomass is concerned in this cycle. The canopy structure of a vegetated area is frequently described in term of leaf area index (LAI). Measurement of LAI is monitored the changing of canopy structure due to pollution and climate change (Gholz et al., 1991). It is necessary to measure a leaf area index (LAI) with stringent calculation of the amount of CO_2 sequestration by forest (Ishii and Tateda, 2004). The important of LAI stems from the relationship which established between it and a range of ecological processes (rates of photosynthesis, transpiration and evapotranspiration (McNaughton and Jarvis,1983; Pierce and Running,1988); net primary production (Monteith,1972; Norman, 1980; Gholz,1982; Meyers and Paw, 1986; Mayers and Paw, 1987); rate of energy exchange between plants and the atmosphere(Botkin, 1986; Gholz et al ., 1991). The estimate leaf area index and biomass is a valuable tool for modeling of the ecological processes occurring within a forest and in predicting ecosystem responses.

It is difficult to get data from the field entirety. Then, data from satellite has been used for the management and maintenance of geo-environment in recently years (Saito et al., 2001). Remote Sensing data is shown the potential data which estimated of LAI and created LAI surfaces for analyzed further by the remote sensing technique (Kantirach and Ditsariyakul,). By using remote sensing imaginary is applied to analyze and evaluate the data received from the survey in order to estimate Carbon Sequestration. Application of remote sensing is widely used for estimation of LAI and above ground biomass in agriculture and forestry because of it can save time and has high accuracy. Moreover, this method can be used to estimate LAI and biomass in all season and it can be applied to calculate other area where has the same type of vegetations (Domrongsutsiri,2001).The final result from the study takes to use for mangrove forest resource management to help an effective improvement of Carbon Sequestration in the near future. It was suggested (Green et al., 1998) that higher spatial resolution data can be improved the accuracy of predicting LAI of mangrove forest from remote sensing imagery. Moreover, predictive models using by these methodology are widely used to assess the impacts of management and environmental variables on carbon cycle dynamic.

Consequently, the goal of this research is to develop predictive models for estimation of carbon sequestration rates in the mangrove forest filtration system where discharges the municipal waste water. It is contained rich of nutrients. In addition to, to study the factors which affect on the increased potential of CO_2 sequestrations rates in the mangrove forests.

1.2 Objectives

The main objective of this study is to develop of predictive model which estimating the rate of carbon sequestration. In addition, this research find out the factors which affected in mangrove forests as a carbon stock. There are 3 objectives as follows :

1.2.1 To develop a new model for estimating the rate of carbon sequestration in the mangrove forest filtration system.

1.2.2 To investigate the effects of the quality of municipal wastewater parameters on the Leaf Area Index and the above-ground biomass the mangrove forest filtration system.

1.2.3 To estimate the rate of biomass and above-ground carbon sequestrations by using the high-resolution satellite images.

1.3 Hypotheses

1.3.1 The study site where directly affected from municipal waste water has more soil organic carbon than the reference site.

1.3.2 The quality of municipal waste water parameters which influenced on the rates of the Leaf Area Index and the quantity of the above-ground biomass.

1.3.3 The study site has more above-ground carbon sequestrations than the reference site.

1.3.4 High-resolution satellite imagery has a high potential for developing predictive model to estimate the rate of above-ground carbon sequestration of mangrove trees in the mangrove forest filtration system.

1.4 Scope of work

1.4.1 The study area is the mangrove forest filtration system pond within the King"s Royally Initiated Laem Phak Bia Environmental Research and Development Project , Laem Phak Bia Sub-District, Ban Laem District, Petchaburi Province, Thailand.

1.4.2 The period work is two periods: wet season (May-September) and dry season (October-April).

1.4.3 The scope of this work is divided into three compartments.

1.4.3.1 The soil compartment, soil organic carbon was performed in the sediment at 30 cm soil depth.

1.4.3.2 The water compartment, Total organic carbon (TOC) was analyzed representation for total of dissolve organic carbon.

1.4.3.3 The mangrove tree compartment, LAI and above-ground biomass are calculated for studying the ability of ecological processes occurring within a forest in term of above-ground carbon sequestration.

1.4.4 Three parameters in the soil compartment: pH values, the percentages of organic matter and the percentages of organic carbon

1.4.5 Seven parameters in the water compartment: pH unit, BOD, DO, salinity, conductivity, temperature and TOC.

1.4.6 LAI, above-ground biomass and above-ground carbon are studied in the mangrove forest compartment.

1.4.7 The rate of above-ground carbon sequestration in the dominant species of mangrove tree is calculated by the formal research biomass equations for this area in unit of ton per hectare.

1.4.8 The LAI is calculated by measuring the DBH of three samples in this study area and using by theory of allometric relationship between leaf area and D^2H equations.

1.4.9 Estimation of biomass and above-ground carbon is focused on above-ground.

1.4.10 The available remote sensing satellite images in this research are a multispectral LANDSAT 5-TM, a multispectral THEOS and a multispectral Quickbird.

1.4.11 The vegetation indices in this research are the Normalized Difference Vegetation Index (NDVI), the Ratio Vegetation Index (RVI), and the Difference Vegetation Index (DVI).

1.4.12 Validation is analyzed by the statistical parameters: ANOVA and T-Test.

CHAPTER II
BACKGROUND AND LITERATURE REVIEW

2.1 CO_2 sequestrations

2.1.1 Definitions

Carbon dioxide sequestration is the process of removing carbon from the atmosphere and depositing it in a reservoir. It describes long-term storage of carbon dioxide or other forms of carbon to either mitigate or defer global warming. It has been proposed as a way to show the atmospheric and marine accumulation of greenhouse gases, which are released by burning fossil fuels (UNFCCC, n.d.)

Sequestration is the removal of CO_2, either directly from anthropogenic sources, or from the atmosphere, and disposing of it either permanently or for geologically significant time periods.(Bachu,2000)

2.1.2 Criteria for CO_2 sequestration in geological media

There are a number of various criteria that have to be considered when selecting any of the above option for CO_2 sequestration in geological media such as Geological criteria, Geothermal criteria, Hydrodynamic criteria and Economic and societal criteria (Bachu and Gunter,1998).

2.1.3 Previous studying

Many scientists attempt to study on the potential of mangrove forest in order to increase their abilities on carbon sequestration such as Fujimoto et al.,1999 have been estimated the carbon sequestration of Mangrove forest in Pacific Island which found the amount of carbon sink reach to 208 tons per rai. For Thailand, Aksornkoae (1989) was studied the average of carbon sequestration in mangrove forest in Krabi and Sa-ton provinc, the results was showed 0.63 and 0.62 ton-carbon per rai, respectively. Moreover, Ong (1993) was studied the amount of carbon sequestration at Matang, Malasia showed that mangroves may also be a source of carbon they may out-well significant amounts of carbon to adjacent coastal ecosystems and thus play a vital role in coastal fisheries production. Thus, forest is expected to a function as the sink of carbon, By their CO_2 sequestration ability due to a high primary productivity.

2.2 CO_2 sinks

There are two types of carbon dioxide sinks: directly from the atmosphere, which can be enhanced, and by capture and either utilization or sequestration. The first category involves the removal of carbon after it has been dispersed into the atmosphere. The main options for enhancing carbon sinks directly from the atmosphere are forestry measures, which are also low risk options and have positive environmental and sometime socio economic effects. Because it would take 40-50 years for a large forestry plantation to sequester a significant amount of carbon, biomass fixation is neither a quick fix solution, nor necessarily a permanent one. In practice, all forestry measures are ultimately limited because forest area in competition with other potential land uses and because of societal and economic pressures (Jepma and Munasinghe,1998). CO_2 capture and disposal involves recovery of carbon from an energy conversion process. The captured CO_2 can be either utilized or disposed of at sites other than the atmosphere. CO_2 utilization represents only a minute fraction (<1%) of the huge CO_2 quantities that have to be eliminated (Herzog et al.,1997).

The Ocean is the most significant and largest natural sink for CO_2 International Energy agency Greenhouse Gas R&D program (1997). For depths greater than 3,000 meters, CO_2 density is greater than that of seawater, thus sinking to greater depths and forming either plumes or hydrates at the ocean bottom. Thus, the deep ocean represents a potential artificial sink for CO_2 with a huge capacity. However, the technology of disposing from either ships or deep pipelines at these depths is only in the process of development and testing. In addition, the effects of disposing of CO_2 in oceans are not well know, particularly the chemistry of the ocean in the vicinity of the disposal site, the fate of CO_2 plume and how marine life will be affected. Transportation of CO_2 from inland regions to offshore sites can be economically prohibitive and unacceptable from an environmental and societal point of view. Actually, environmental impacts, and social and political considerations may be the most significant factors determining the acceptability of ocean storage (Herzog et al.,1997).

2.3 Mangrove forests

Mangrove forests, otherwise known as "rainforests by the sea", are one of the most important coastal ecosystems in the world in terms of coastal protection and the primary production of food sources. Mangrove trees are specially adapted to live in saline habitats. The specialized seeds of mangrove trees are tough and sometimes travel great distances in salt water, and take root far from their parent trees. The seeds germinate and grow into seedlings during which time they acquire the carbohydrates that they will later need to grow into trees. Mangrove trees have a unique biological adaptation in order to survive in a marine environment, including their reproductive biology, a high level of salt tolerance, and growth rate. For example, mangrove trees are well adapted to anoxic sediments. The trees produce aerial and tap roots which filter out the salt in the brackish water they grow in, and support roots which grow downward into the mud to anchor them. Buttresses and the above ground roots enable mangrove trees to grow in unstable mud flats. Their foliage removes excess salt from the sap and conserves water to cope with periods of high salinity.

2.4 Mangrove forest filtration system

This system is implemented by creating a plot to detain the sea water and the waste water from the local community as well as by cultivating two types of plants in the mangrove forest which help in the treatment of waste water. This system relies on the dilution of the waste water by the sea water, and can be applied in the local community or in shrimp farming areas next to the mangrove forest without having to create a mangrove plot. However, it needs a pond to detain the waste water until the latter is released into the mangrove forest area during high tide.

2.5 Leaf Area Index

Leaf Area Index (LAI, m^2 leaf area/m^2 ground area) is a key variable, functionally related to plant biomass production, canopy microclimate, water interception, radiation extinction, and water and carbon exchange (Van Wijk and Williams 2005), therefore accurate estimation of LAI is of importance for monitoring and analyzing many biophysical processes in ecosystems. The traditional method of estimating LAI is to harvest vegetation in a certain area and measure all the one-sided leaf areas directly. The method is time-consuming and destructive. Modern developments in optical devices have made it possible to use optical gap fraction instruments, such as LAI 2000 and TRAC sensor to estimate LAI indirectly (Hichs and Lascano 1995; Cutini et al.1998; Lu et al. 2004), but its application is not feasible for low-stature vegetation types, such as arctic, alpine, or short grassland vegetation. Numerous studies have shown that the widely used spectral reflectance index NDVI (Normalized Difference Vegetation Index) is a good estimator of LAI and has been used to estimate LAI indirectly (Colombo et al. 2003; Lu et al. 2004; Van Wijk and Williams 2005; Steltzer and Welker 2006).

2.5.1. Definitions and units

The LAI was first defined in 1947 as the total one-sided area of photosynthetic tissue per unit ground surface area. However, after reviewing various other definitions (some measurement approach – dependent), Jonckheere *et al*. (2004) concluded that in the current literature the LAI is defined as one half of the total leaf area per unit ground surface area. They also noted that different definitions can result in significant differences between calculated LAI values. The LAI is a dimensionless unit of measurement (the area of the leaf area divided by the area of the ground surface area). Leaf Area Indexes (LAI) are important variables in many ecological systems and environments. The LAI of an individual leaf is defined as one half of the total leaf area per unit ground surface area. The LAI of a tree is estimated by measuring the canopy using a fisheye lens and the allometry equations developed to approximate the LAI.

2.5.2 . Existing *in situ* measurement methods and standards

Direct and indirect *in situ* LAI measurement methods have been developed. The various methods were described and discussed in two recent reviews (Jonckheere *et al*., 2004; Breda, 2003).

2.5.2.1 Direct methods

Direct methods are accurate but labour intensive and therefore are not used very often. They consist of two steps, leaf collection and leaf area measurement.

Leaf collection

2.5.2.1.1 Harvesting methods:

1) Destructive sampling: collection and removal of green leaves from a sampling plot.
2) Model tree method: destructive sampling of a small amount of representative trees out of the stand, from which the leaf area and vertical distribution of the leaf area is measured leaf by leaf.
3) Non-harvesting litter traps: collection during autumn leaf-fall period.

2.5.2.1.2 Non-harvest methods:

1) Leaf litter collection during the leaf-fall period employs “traps” (open boxes with predetermined size and lateral sides that prevent wind blowing leaves from falling out of the traps). There seems to be no consensus on the sampling design of the traps (Jonckheere *et al*., 2004). Litter traps assume that the leaves captured are representative of the whole stand. They provide an integrated measure for LAI, but neither an accurate measure at a specific time during the growing season, nor a vertical LAI profile; climate can also have an effect on the data collected from litter traps (Jonckheere *et al*., 2004).

2) Leaf area determination:Leaf area can be calculated by means of either planimetric or gravimetric techniques.

2.1) Planimetric approach: based on the correlation between the individual leaf area and the number of area units covered by that leaf in a horizontal plane (Jonckheere *et al*., 2004). Leaf perimeter can be measured with a planimeter, and its area then computed. Special instruments have been designed for this purpose.

2.2) Gravimetric method: based on the correlation between the dry weight of leaves and the leaf area using predetermined leaf mass per area (LMA, determined from a sub-sample). Once the LMA is known, the entire field sample is oven-dried and the leaf area is calculated from its dry-weight and the sub-sample LMA (Jonckheere *et al*., 2004). LMA variability represents a source of uncertainty.

2.5.2.2 Indirect methods

Using indirect methods, the leaf area is inferred from observations of another variable. These are generally faster, amenable to automation, and thereby allow for a larger spatial sample to be obtained, Thus they are becoming increasingly important (Jonckheere *et al*., 2004).

2.5.2.2.1 Indirect contact LAI measurements. Inclined point quadrat: this consists of penetrating a vegetation canopy with a long thin needle at specific angles and counting the number of contacts with "green" canopy element. The principal disadvantages of this method are the large number of points needed, making the technique laborious, and its unsuitability for canopies exceeding 1.5m in height (Jonckheere *et al*., 2004).

2.5.2.2.2 Allometric techniques (for forests): based on the relationships between leaf area and other dimension(s) of the woody plant element that support the green leaf biomass (e.g. stem diameter, sapwood fraction, tree height). The relationships generally are species and site-specific and may also vary with season, site fertility (nutrition and soil water availability), local climate, and canopy structure (Jonckheere *et al*., 2004).

2.5.2.2.3 Indirect non-contact measurements

These methods are mostly based on the measurement of light transmission through canopies, and employ various instruments developed mostly over the last 20 years. They can be divided into two groups, depending on whether they measure gap fraction distribution (proportion of area patches illuminated by direct sunlight) or gap size distribution (the size distribution of the patches). The instruments provide data that represent LAI distribution at a point location, along a line, or over an area (hemispherical photography).

1) Gap fraction distribution: the existing instruments employ canopy image analysis techniques or differential light measurements above and below the canopy. The maximum measurable LAI is generally lower for these devices measuring the gap fraction than the one accessed via direct methods, and reaches a saturation level at LAI=5.

2) Gap size distribution: the available instruments measure the dimensions of individual surface patches that are directly illuminated. Analytical procedures and supporting measurements are employed to convert the measurements into LAI. Hemispherical photography is one such technique.

2.5.2.2.3. Existing satellite measurement methods and standards. Satellite-based estimation of LAI is an indirect approach, relying on the relationship between LAI and the characteristics of reflected radiation from the canopy as measured by the satellite sensor. Besides the process of light interaction within the canopy, the satellite data are affected by the intervening atmosphere, the characteristics and performances of the sensor, and the processing of the received signal. Various approaches have been developed to transform satellite data into LAI estimates in the form of maps. While no standardization of procedures or products has been achieved to date, progress has been made in this direction, especially through convergence of approaches to validation and inter-comparisons of the various methods and products.

Takashi and Yutaka (2004) estimated the Leaf Area Index and biomass of a mangrove plantation in Trat province, eastern Thailand. They developed an LAI measuring method using satellite data and compared this with the direct method as described in previous paragraph.

2.6 Soil Organic Matter

Alongi *et al*. (2001) estimated organic carbon accumulation in the sediment of mangrove forests in southern Thailand. They discovered that these tropical mangrove forests are storage sites for sediment and, on average, retain approximately 60% of total input of organic carbon to the sediment.

Kennedy *et al*. (2004) studied organic carbon sources in coastal sediments in the southeast of Thailand. They discovered that at the sites dominated by mangroves the concentration of organic matter in the sediment is generally higher than at seagrass dominated sites due to the outwelling of organic matter from the mangrove stands.

2.7 Soil Organic Carbon

Many scientists have recognized the potential of soil as a carbon sink to counteract the increasing trend of atmospheric CO_2 concentration.(Marland and Schlamadinger, 1999; Li et al., 2001; Morisada et al., 2004) Understanding of implementing effective land management procedures to increase the capability of soil carbon sequestration is a big challenge facing mankind.(Liu et al 2004) The Carbon source or sink capacity of soil is determined by the dynamic equilibrium between the processes of Carbon input from primary biomass production and Carbon output by mineralization. (Kogel-Knabner et al.,2008) A holistic understanding of such mechanisms is required for predicting the effects of global climate change, and for the development of management strategies to increase Carbon sequestration in soil. (Marschner et al.,2008) Carbon storage in a native ecosystem reflects the capacity of that ecosystem to sequester Carbon, which relies on reliable quantification of current Carbon storage in the ecosystem as the baseline. Hence, the Carbon accumulated inventories have been established in many regions.(Zhang et al.,2007) such as North

America (Lacelle et al., 1997), South America (Bernoux et al.,2002) , Europe (Batjes 2002; Krogh et al., 2003) and Asia (Li and Zhong,2001; Wang et al., 2002; Li et al., 2003; Wu et al.,2003; Li et al., 2004; Zhang et al,2007) However, At country-scale in Thailand, we still lack of a more general knowledge and deeply understanding of temporal dynamics of SOC and available SOC data. Therefore, the available soil organic carbon data and accuracy of inventory data were significant for management of a small or large scale.

2.8 Electromagnetic Spectrum

The electromagnetic spectrum is the continuum of energy that ranges from meters to nanometers in wavelength, all of which travel at the speed of light, and is transmitted through a vacuum such as outer space. All matter radiates a range of electromagnetic energy, with the peak intensity shifting toward progressively shorter wavelengths with increasing temperature of the matter (Sabins and Floyd, 1986).

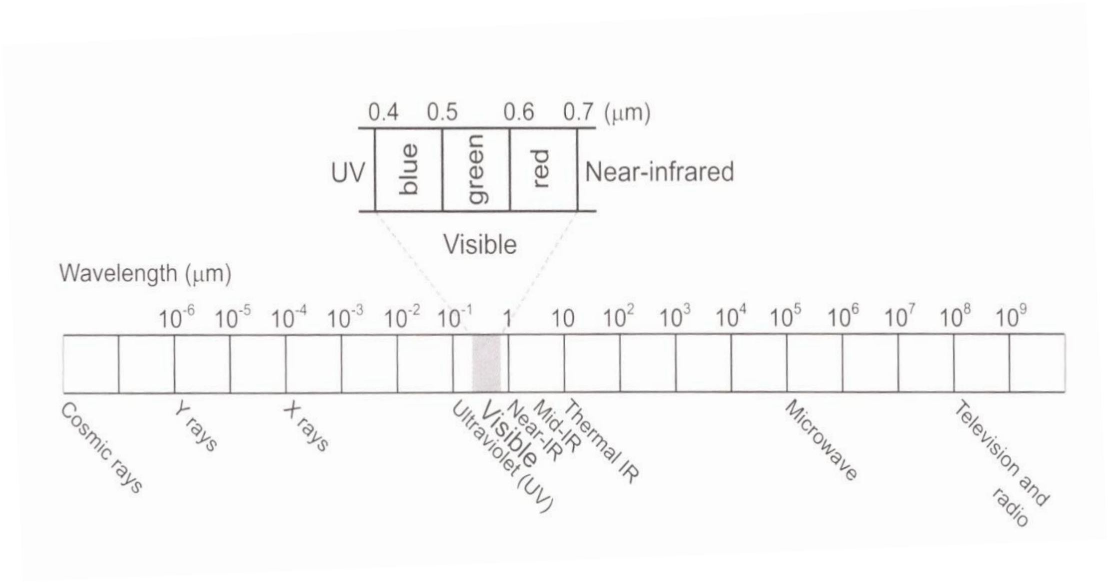

Figure 2-1 The Electromagnetic Spectrum – expanded versions of the visible regions. Source: Sabins and Floyd (1986)

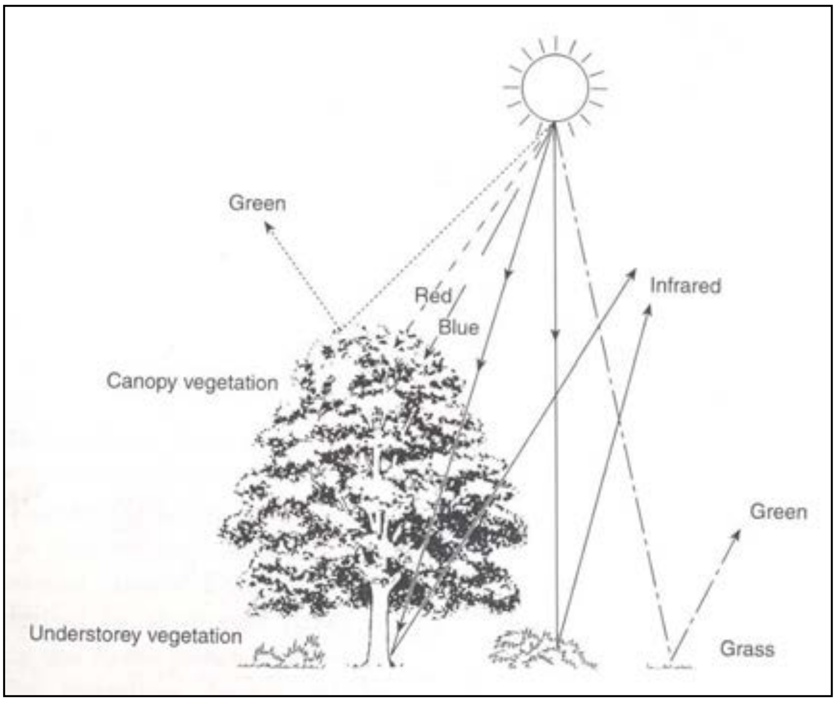

Figure 2-2 Leaves are selective filters of light

Source: Sabins and Floyd (1986)

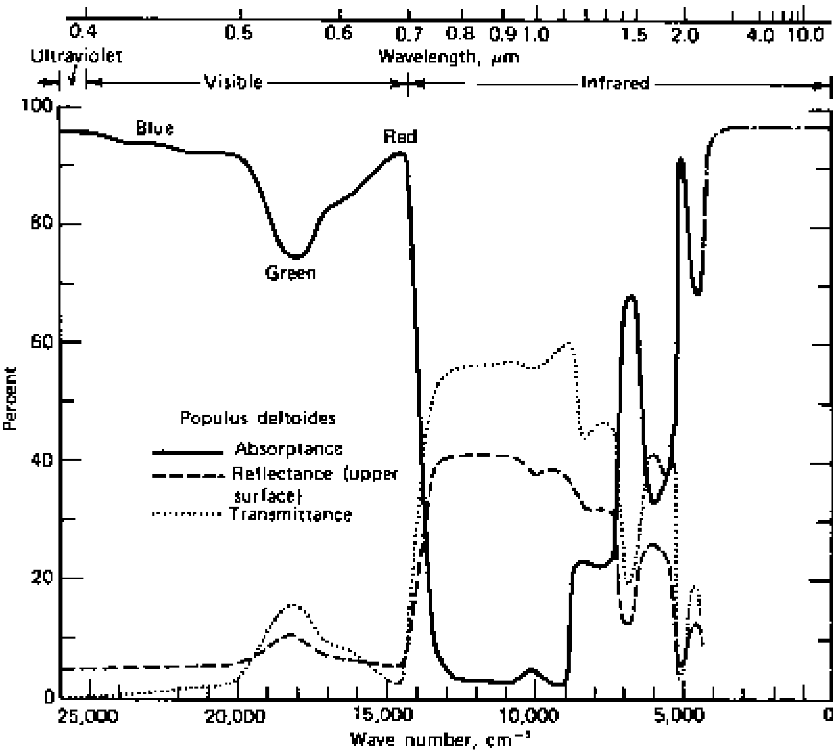

Figure 2-3 All leaves are not equal absorption spectra

Source: Sabins and Floyd (1986)

2.9 Vegetation Indexes

Vegetation Indexes can be used to measure of vegetative amounts and conditions. They can also predict canopy characteristics such as biomass, leaf area, and the percentage of vegetation cover.

Since the 1960s, scientists have extracted and modeled various vegetation biophysical variables using remotely sensed data. Much of this effort has involved the use of vegetation indices – dimensionless, radiometric measures that indicate relative abundance and activity of green vegetation, including leaf-area-index (LAI), percentage green cover, chlorophyll content, green biomass, and absorbed photosynthetically active radiation (APAR). A vegetation index should. (Running et al., 1994; Huete and Justice, 1999): maximize sensitivity to plant biophysical parameters preferably with a linear response in order that sensitivity be available for a wide range of vegetation conditions, and to facilitate validation and calibration of the index; normalize of model external effects such as Sun angle viewing angle, and the atmosphere for consistent spatial and temporal comparisons;normalize internal effects such as canopy background variations, including topography (slope and aspect), soil variations, and differences in senesced or woody vegetation (nonphotosynthetic canopy components); be coupled to some specific measurable biophysical parameter such as biomass, LAI, or APAR as part of the validation effort and quality control. The example of vegetation indexes:

2.9.1 Normalized Difference Vegetation Index – NDVI

Rouse et al. (1974) developed the generic Normalized difference vegetation index (NDVI):

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}}$$

The NDVI is functionally equivalent to the simple ration; that is there is no scatter in an SR vs. NDVI plot, and each SR value has a fixed NDVI value. When we plot the mean NDVI and SR values for various biomes, we find that the NDVI approximates a nonlinear transform of the simple ratio (Huete et al., 2002b). The

NDVI is an important vegetation index because: Seasonal and inter-annual changes in vegetation growth and activity can be monitored. The rationing reduces many forms of multiplicative noise (sum illumination differences, cloud shadows, some atmospheric attenuation, some topographic variations) present in multiple bands of multiple-date imagery.

Table 2-1 The example of Vegetation Indexes

Vegetation Indexes	**Equations**	**References**
The Simple Ratio Index (SR)	SR=RED/NIR	Birth and McVey (1968)
The Normalized Difference Vegetation Index (NDVI)	NDVI=(NIR-RED)/(NIR+RED)	Rouse et al. (1974)
The Triangular Vegetation Index (TVI)	TVI=0.5(NIR-GREEN)-200(RED-GREEN)	Broge and Leblanc (2001)
The Green Vegetation Index (GVI)	GVI=-0.29(Green)-0.56(RED)+0.60(NIR)+0.49(NIR)	Kauth et al. (1978)
The Ratio Vegetation Index (RVI)	RVI=NIR/RED	Jordan (1969)
The Difference Vegetation Index (DVI)	DVI = NIR-RED	Tucker (1979)

Remarks: RED = BAND 3, GREEN = BAND 2, NIR = BAND 4

Table 2-2 Specifications of LANDSAT-5 TM bands

Sensor	Band	Wave Length (µm)
LANDSAT-5TM	Band 1 (Blue)	0.45-0.52
	Band 2 (Green)	0.52-0.60
	Band 3 (Red)	0.63-0.69
	Band 4 (NIR)	0.76-0.90

Reference: Apinan et al., (n.d.)

Table 2-3 Specifications of THEOSE bands

Sensor	Band	Wave Length (µm)
THEOSE	Band 1 (Blue)	0.45-0.52
	Band 2 (Green)	0.53-0.60
	Band 3 (Red)	0.62-0.69
	Band 4 (NIR)	0.77-0.90

Reference: Kaewmanee et al.,(n.d.)

Table 2-4 Specifications of Quickbird multispectral bands

Sensor	Band	Wave Length (µm)	Spatial resolution
Quickbird	Band 1 (Blue)	0.45-0.52	2.8 meters (multi.)
	Band 2 (Green)	0.52-0.60	
	Band 3 (Red)	0.63-0.69	
	Band 4 (NIR)	0.78-0.90	

Reference: Wang et al., 2004

2.10 Predictive statistical models

Several different statistical models have been used under both the content-based and the collaborative approach. The main models are: linear models, TFIDF-based models, Markov models, neural networks, classification and rule-induction methods, and Bayesian net-works.

2.10.1 Linear models

Linear models have a simple structure, which makes them easily learnable, and also enables them to be easily extended and generalized. Linear models take weighted sums of known values to produce a value for an unknown quantity. For example, consider using the collaborative approach to build a linear model that predicts a user"s rating for news articles. In this model, for each candidate article, the known values may be the ratings assigned to this article by other users, and the weights may be a measure of the similarity between the user in question and the other users. The resulting linear model is the weighted sum of the ratings (such a model is described in Resnick et al., 1994). Linear models have also been used under the content-based approach, e.g., to predict the time intervals between a user"s successive logins (Orwant, 1995), and to predict a user"s ratings of films (Raskutti et al., 1997)

2.10.2 TFIDF-based models

The TFIDF (Term Frequency Inverse Document Frequency) method is a weighting scheme commonly used in the field of Information Retrieval to find documents that match a user"s query (Salton and McGill, 1983). This method represents a document by a vector of weights, where each weight corresponds to a term in the document. The similarity between two documents (or between a document and a query) is then measured by the cosine of the angle at the origin which subtends the vectors corresponding to these documents. Balabanovic (1998), Moukas and Maes (1998) and Basu et al. (1999) applied TFIDF-based models in content-based systems that recommend documents to a user based on other (similar) documents of interest to this user. Moukas and Maes extended this approach in that they used genetic algorithms to automatically adapt their recommender system to a user‟s (possibly changing) requirements.

2.10.3 Markov models

Like linear models, Markov models have a simple structure. This is due to their reliance on the Markov assumption to represent sequences of events (according to this assumption, the occurrence of the next event depends only on a fixed number of previous events). Given a number of observed events, the next event is predicted from the probability distribution of the events which have followed these observed events in the past. For example, when the task at hand consists of predicting WWW pages to be requested by a user, the last observed event could be simply the last visited WWW page or it could contain additional information, such as the link which was followed to visit this page or the size of the document. Bestavros (1996) and Zukerman et al. (1999) used Markov models under the collaborative approach in order to predict users‟ requests on the WWW. Bestavros‟ model calculated the probability that a user will ask for a particular document in the future, while Zukerman et al. (1999) compared the predictive performance of different Markov models which calculate the probability that a user will ask for a particular document in the following request. The predictions generated by these models were then used by systems which pre-send to a user documents s/he is likely to request (Bestavros, 1996: Albrecht et al., 1999)

2.10.4 Neural networks

Neural networks are capable of expressing a rich variety of non-linear decision surfaces. This is done through the structure of the networks, non-linear thresholds and the weights of the edges between the nodes. Jennings and Higuchi (1993) used neural networks under the content-based approach to represent a user‟s preferences for news articles. For each user, they learned a neural network where the nodes represent words that appear in several articles liked by the user and the edges represent the strength of association between words that appear in the same article.

2.10.5 Classification

Classification methods partition a set of objects into classes according to the attribute values of these objects. Given an n-dimensional space that corresponds to the attributes under consideration, the generated clusters or classes contain items that are close to each other in this space and are far from other clusters. Classification methods are unsupervised in the sense that there is no a priori information regarding the class to which each item belongs.

Under the collaborative approach, Perkowitz and Etzioni (2000) used a variation of traditional clustering in order to automatically create index pages which contain links to WWW pages that are related to each other (these are pages that users tend to visit during the same session). Their classification technique, which they called cluster mining, finds a small number of high-quality clusters (rather than partitioning the entire space of documents), and can place a document in several overlapping clusters.

2.10.6 Rule induction

Rule induction consists of learning sets of rules that predict the class of an observation from its attributes. The techniques used for rule induction differ from those used for classification in that during training, rule induction techniques require the class of each observation as well as its attributes. The models derived by these techniques can represent rules directly, or represent rules as decision trees or in terms of conditional probabilities.

Rule-induction techniques have been used under both the content-base and the collaborative approach. Under the content-based approach, Morales and Pain (1999) used Ripper, a system that learns rules from set-valued features (Cohen, 1996), to learn rules that predict a user‟s next action in an experiment where the user has to balance a pole on a cart. Chiu and Webb (1998) combined C4.5, a rule-induction technique which builds decision trees (Quinlan, 1993), with feature based modeling, an attribute-value modeling method designed for tutoring applications (Webb and Kuzmycz, 1996), to predict features of subtraction errors performed by students. Joerding (1999) used CDL4, a semi-incremental algorithm that learns rules (Shen, 1997), to learn users‟ media preferences for product presentations in a WWW shopping environment. Billsus and Pazzani (1999) applied a mixture of rule-induction methods and TFIDF-based and linear models to recommend news articles to a user. Their system used two models to anticipate whether a user would be interested in a candidate article. One model maintained a TFIDF vector representation of the articles in the system‟s knowledge base, and used only those articles that were similar to the candidate article in order to build a linear model that predicts whether the user will be interested in this article. This technique is particularly useful when building an initial model on the basis of limited data, since only a few news articles are required to identify possible topics of interest. The other model applied a naïve Bayesian classifier (Duda and Hart, 1973) to a Boolean feature vector representation of the candidate article, where each feature indicates the presence or absence of a word in the article. This classifier calculates the probability that an item belongs to a particular class (e.g., the class of articles a user finds interesting) under the assumption that the attributes of the items in a given class are independent.

Under the collaborative approach, Basu et al. (1998) used Ripper to learn a set of rules which predict whether a user will like or dislike a film, and Litman and Pan (2000) used Ripper to learn a set of rules that adapt the dialogue strategy used by a spoken dialogue system. Gervasio et al. (1998) used ID3 (Quinlan, 1986) to learn a decision tree that predicts which action will be performed next by a user working on a scheduling problem.

2.10.7 Bayesian networks

Bayesian networks (BNs) (Pearl, 1988) and various extensions of BNs have steadily been gaining popularity in the Artificial Intelligence community, and have been used for a variety of user modeling tasks (Jameson, 1996). BNs are directed acyclic graphs where nodes correspond to random variables. The nodes are connected by directed arcs, which may be thought of as causal links from parent nodes to their children. Each node is associated with a conditional probability distribution which assigns a probability to each possible value of this node for each combination of the values of its parent nodes. BNs are more flexible than the models discussed above in the sense that they provide a compact representation of any probability distribution, they explicitly represent causal relations, and they allow predictions to be made about a number of variables (rather than a single variable, which is the normal usage of the above models). In addition, BNs can be extended to include temporal information (dynamic Bayesian networks, Dean and Wellman, 1991) and utilities (influence diagrams, Haward and Matheson, 1984).

An important property of BNs is that they support the combination of the collaborative and the content-based approach. The collaborative approach may be used to obtain the conditional probability tables and the initial beliefs of a BN. These beliefs can then be updated in a content-based manner when the network is accessed by a user. This mode of operation enables a predictive model to overcome the data collection problem of the content-based approach (which requires large amounts of data to be gathered from a single user), while at the same time enabling the tailoring of aspects of a collaboratively-learned model to a single user.

BNs have been used to perform a variety of predictive tasks. Horvitz et al. (1998) used a BN to predict the type of assistance required by users performing spreadsheet tasks. Albrecht et al. (1998) compared the performance of several dynamic Bayesian networks which predict a user‟s next action, next location and current quest in a Multi-user Adventure Game. Lau and Horvitz (1999) built a BN which models search queries on the WWW and predicts the type of query-related action a user will perform next, e.g., generalize or further specify a query. Finally, Gmytrasiewicz et al. (1998) and Jameson et al. (2000) used influence diagrams to predict agents‟ behaviour. Gmytrasiewicz et al. considered various models that predict an agent‟s actions in an air-defense scenario, and incrementally updated the probability assigned to each model according to its predictive accuracy. Jameson et al. predicted the error rates of users when following instructions given in a certain style (e.g., “several together” versus “one at a time”), and selected an instruction style that minimizes this error rate.

2.10.8 Comparative studies of predictive models

Ideally, one would like to determine the most suitable representation method for a particular application based on the features of the problem at hand. However, in the absence of such information, an empirical comparison of the performance of different techniques is warranted. Such empirical studies have been performed in the framework of both the content-based and the collaborative approach.

Chiu et al.,1997, Davison and Hirsh,1998 and Macskassy et al.,1999 performed comparative studies of predictive models under the content-based approach. Chiu et al. compared the predictive performance of the models learned by two rule induction techniques, C4.5 (Quinlan, 1993) and FFOIL (Quinlan, 1996), in a system that anticipates the features of the result obtained by a student when performing subtraction. Davison and Hirsh compared the performance of the decision tree learned by C4.5 with that of a Markov model in a system that predicts a user‟s next UNIX command. An interesting feature of Davison and Hirsh‟s Markov model is that it was built incrementally, giving greater weight to more recent events in order to increase the system‟s sensitivity to changes in a user‟s behaviour. According to Chiu et al.‟s study, the decision tree learned by C4.5 made more predictions and more accurate predictions than the rules learned by FFOIL, while Davison and Hirsh reported that their incrementally learned Markov model performed at least as well as the decision tree learned by C4.5. Macskassy et al. performed a preliminary comparison of the recommendations generated by a naïve Bayes classifier, two TFIDF-based models, a rule-based model inferred using Ripper (Cohen, 1996), and a voting scheme in a system that determines which email messages should be forwarded to a user‟s personal pager. However, owing to the use of the pager (which is a prototype), only a few users could be involved in this study. Hence, its results are as yet inconclusive.

A collaborative recommender system for three different domains, WWW pages, television programs and films, is described in (Breese et al., 1998). This system was used as a platform for comparing the predictive performance of several linear models (with different weighting schemes), a BN and a naïve Bayes classifier. Breese et al.‟s results indicate that BNs outperform the other methods for a wide range of conditions.

A different type of comparative study was performed by Alspector et al. (1997) for the domain of film recommendations. They compared the performance of a recommender system built under the collaborative approach against that of a system built under the content-based approach. In addition, they considered two linear models under the collaborative approach, and linear networks (which are mixture of linear models) and decision trees under the content-based approach. Their results showed that the models obtained using the collaborative approach preformed significantly better than those obtained using the content-based approach, and that among the content-based models the linear networks performed better than the decision trees. Alspector et al. also identified the following limitations of each approach: collaborative methods cannot be appli8ed to new items (which no one has rated) nor to users which haven‟t been assigned to a group, while content-based methods require careful feature selection. These results led them to conclude that a (film) recommendation system should combine the content-based and the collaborative approach.

2.10.9 Evaluation methods

To date, predictive statistical models used for user modeling have been evaluated using mainly the following technique: recall and precision, which are borrowed from the field of Information Retrieval; and predicted probability, accuracy and utility, which are sourced from machine learning.

The recall and precision measures are particularly suitable for recommender systems (e.g., Raskutti et al. 1997; Basu et al. 1998; Billsus and Pazzani 1999). Recall measures the proportion of items of interest recommended by a system among the items of interest in the system‟s knowledge base, and precision measures the proportion of items of interest among the items recommended by the system. Thus, most of the predictive models that use these evaluation measures require users to provide ratings for all the items in the system‟s knowledge base. Ideally, a predictive model should have both high recall and high precision. However, current systems typically trade off these measures against each other.

Accuracy and predicted probability are measures used to evaluate models that predict a user‟s actions, locations of goals. Accuracy calculates the percentage of times the event that actually occurred was predicted with the highest probability (over several trials), while predicted probability returns the average of the probabilities with which this event was predicted (over several trials). Accuracy and variants thereof have been widely used (e.g., Breese et al. 1998; Chiu and Webb 1998; Gervasio et al. 1998; Davison and Hirsh 1998; Morales and Pain 1999), while both predicted probability and accuracy were used in (Albrecht et al., 1998) to compare the performance of different predictive models. The results obtained by Albrecht et al. show that predicted probability provides finer-grained information about the performance of a predictive model than accuracy. This is because for each trial, accuracy returns mainly a binary value (0 when the probability of the actual event is lower than that of any other event, and 1 when the probability of the actual event exceeds that of all the other events), while predicted probability returns the probability with which the actual event was predicted.

Finally, utility is a measure of the benefit derived from using a particular system – in our context, a system that uses a predictive model. This measure requires a function that represents the advantage resulting from a correct action performed by the system and the disadvantage resulting from a wrong action (Breese et al., 1998; Albrecht et al., 1999). Utility-based evaluations constitute an indirect evaluation of a predictive model, since they evaluate an action performed on the basis of the predictions made by such a model (and different protocols may be used to determine this action). In addition, utility-based evaluations are closer to user-based evaluations than the techniques described above, since they take into account at least some of the user‛‛s requirements.

As stated above, the only measures used to evaluate predictive statistical models for user modeling have been those inherited from machine learning. This is a first step in the evaluation of these models, since the validity of a model must be determined by means of intrinsic evaluations before usability studies can be conducted. However, even before such studies are considered, the different evaluation measures must be revisited in order to determine which features of a predictive model are evaluated by means of each measure. This will support the selection of a coherent suite of evaluation measures to assess different aspects of system performance.

2.11 The methods for estimation the biomass of forests

The field survey of mangrove biomass and productivity is rather difficult due to muddy soil conditions and the heavy weight of the wood. The peculiar tree form of mangroves such as their unusual roots especially theirs surrounding factors then the forest ecologists have developed various methods to estimate the biomass of forests. Three main methods have been developed for estimating forest biomass. There are the harvest method, the mean-tree method, and the allometric method.

2.11.1 The harvest method cannot be easily used in mature forests and in itself is not reproducible because all trees must be destructively harvested.

2.11.2 The mean-tree method is utilizes only in forests with a homogeneous tree size distribution, such as plantations.

2.11.3 The allometric method estimates the whole or partial weight of a tree from measurable tree dimensions, including trunk diameter and height, using allometric equations. This is a nondestructive method and is thus useful for estimating temporal changes in forest biomass by means of subsequent measurement.(Komiyama, Ong and Poungparn,2008)

Table 2-5 Allometric equations for various mangroves in Thailand based on DBH

Species of Mangrove	Equations	study site	Reference
Rhizophora apiculata	$Ws=0.015(D_{20}H)^{1.0554}$ $W_B=0.005(D_{20}H)^{1.0860}$ $W_L=0.0799(D_{20}H)^{0.5470}$ $W_R=0.0098(D_{20}H)^{2.0085}$	Ranong	Chaisit (1993)
Rhizophora mucronata	$Ws=0.0787(D^2H)^{0.7553}$ $W_B=0.0214(D^2H)^{0.8345}$ $W_L=0.0571(D^2H)^{0.6536}$	Ranong	Chaisit (1993)
Xylocarpus granatum	$Ws=0.0430(D^2H)^{0.9490}$ $W_B=0.0018(D^2H)^{1.0718}$ $W_L=0.0027(D^2H)^{1.0357}$	Phangnga	Patimaporn (2002)
Avicennia alba	$Ws=0.079211DBH^{2.470895}$ $W_B=0.481575(1.246280)^{DBH}$ $W_L=0.171711(1.196367)^{DBH}$	Samutsakhon	Jirasak and Apiruk (1997)
Avicennia officinalis	$Ws=0.079211DBH^{2.470895}$ $W_B=0.481575(1.246280)^{DBH}$ $W_L=0.171711(1.196367)^{DBH}$	Samutsakhon	Jirasak and Apiruk (1997)

Remarks: D_{20} = diameters at 20 cm height (cm) D = diameters at breast height (cm)
H = height (m) Ws = biomass of the stem (kg)
W_B= biomass of the branches (kg) W_L = biomass of leaves (kg)
W_R= biomass of the roots (kg)

2.12 Developments of Modeling

Jorgensen, 1988 explained about the process of model development follow as figure 2.4 .

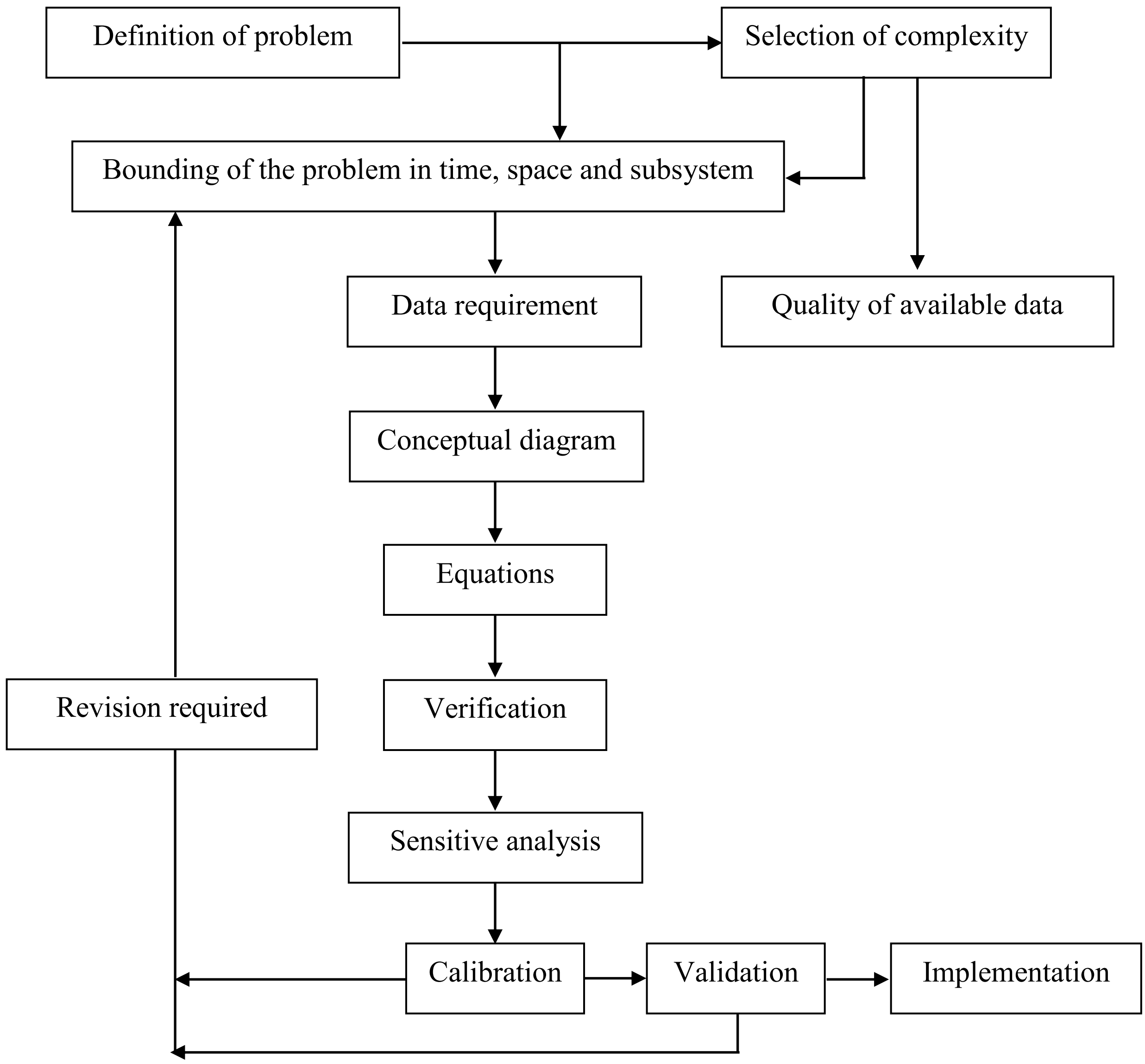

Figure 2-4 The process of model development in the system. (Jorgensen, 1988)

CHAPTER III
METHODOLOGY

3.1 Description of study area

The study site is The King"s Royally Initiated Laem Phak Bia Environmental Research and Development Project locates in Laem Phak Bia Sub-distric, Ban Laem District, Petchaburi Province, Thailand (13°03' N 100°06' E) (figure 3.1) where rests on an alluvial plain that extends the west to the east along the Gulf of Thailand. The total area is about 10.33 Km^2. The study area is the mangrove forests filtration system area where is supported the treated municipal waste water from stabilization treatment pond. The treated municipal waste water throughout 4,500-10,000 cubic meters per day. The qualities parameters of treated municipal waste water from the lagoon treatment system: DO was 6.5 -9.5 mg/l, conductivity was 1116.10-1462.95 mS, the colors less was 5-7 unit, temperature was 25.7-30.3 degree Celsius and pH was 8.1-8.4 unit which the waste water parameters of study are complied with these standards values of Pollution Control Department(In-on,2003)

Mangrove forests have strong relationships with the surrounding environment such as tidal inundation, directions and current flow. Directions and current flow speed mainly depends on the tide. The current flow are two directions in this area. There are the high tides which flow through in the north the low tides which flow along the south of costal. Although, the current flow speed rely on the monsoon influencing in each season follow as the North East monsoon during November to January and The North East monsoon during February to April. The highest of high tides speed was 0.61 meter per a second and the highest of low tides speed is 0.64 meter per a second on December whereas the highest of high tides speed is 0.85 meter per a second and the highest of low tides speed is 0.78 meter per a second on May. The average of high-low tide rates are 2.78-7.36 kilometers per hour. Surface water is the average of wind speed rating 5.9 and 6.9 kilometers per hour during February and April and November and January, respectively. The highest wind speed is 40 kilometers per hour which to create the average of wave heights are 0.14 and 0.18 meters, respectively. The undercurrent is 0.3-1.8 meters. (Sawangchat,2001)

The study area is divided into two sites.(Figure 3.2) There is the study site and the reference site.

3.1.1 The study site is the mangrove filtration system area where is directly affected from the municipal waste water. The area is about 7.46 km^2.

3.1.2 The reference site is the mangrove forest area where is indirectly affected from the municipal waste water at Ban Pranaen is located in the north of the cape.The area is about 2.87 km^2.

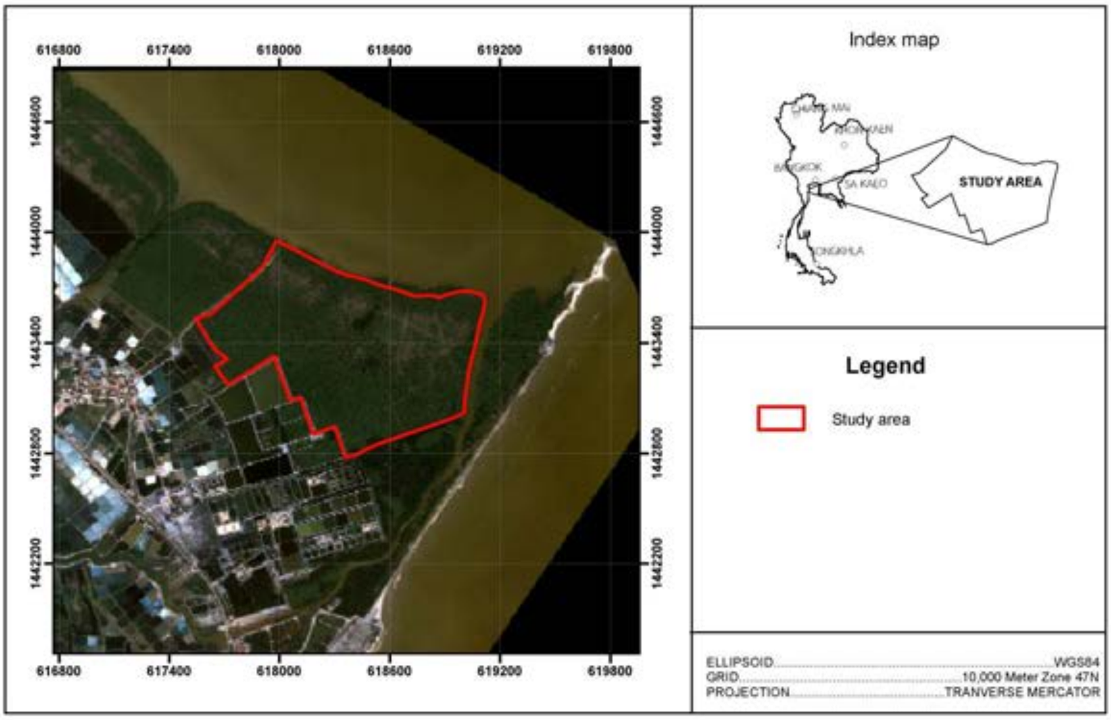

Figure 3-1 The location of the study area, Located within Laem Phak Bia Sub-district, Ban Laem District, Petchaburi Province,Thailand (13°03' N 100°06' E).(created from THEOS satellite image)

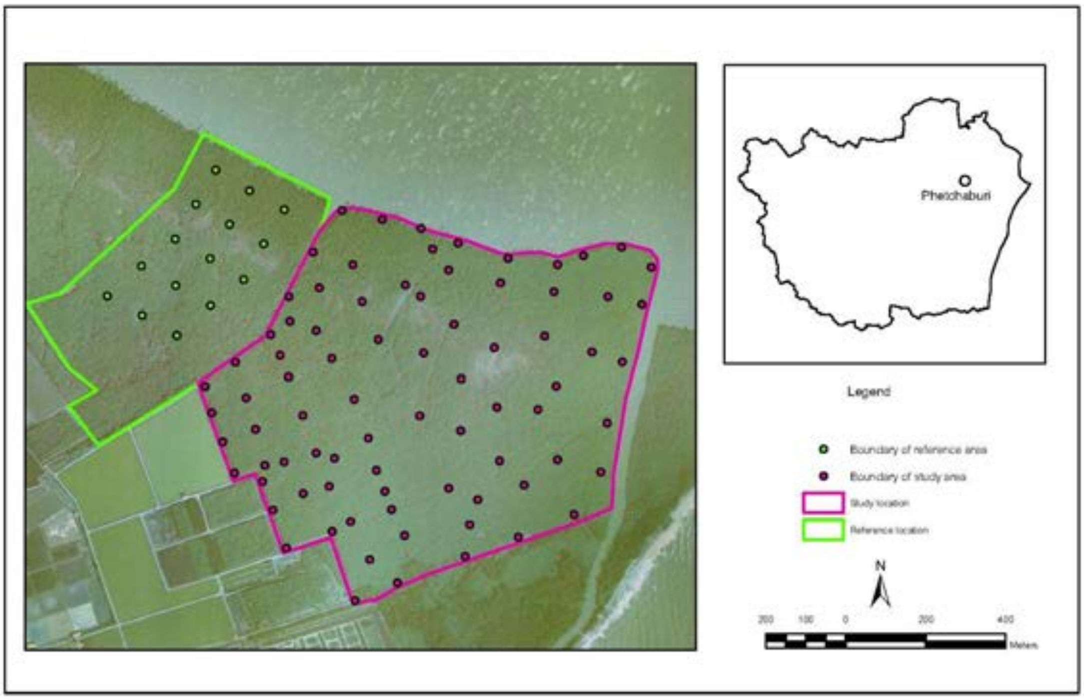

Figure 3-2 Sampling plots in the study site and reference site (created from Landsate TM 5 satellite image)

3.2 The dominant species of mangrove trees

This site is particular the mangroves that the dominant species of mangrove trees including *Rhizophora mucronata Poir* and *Avicennia marina*

3.2.1 *Rhizophora mucronata*

Rhizophora mucronata mangroves are characterized by prop roots. This specie may reach 25 m in height. Its propogules are 50-70 m in length and posses a small reserve of leaf buds.They are generally found along the canal or coastal flooding with salt water through a long period of time(Aksornkoae and Panichsuko,1987). (figure 3-3 a)

3.2.2 Avicennia marina

Avicennia marina mangroves are trees to 15 m, their seed are small diamond shaped. They are always found in the regenerated soil. (Aksornkoae and Panichsuko,1987). They grow well in very soft mud on tide flats that are frequently flooded.(Department of forestry,2000)(figure 3.3 b)

(a) *Rhizophora mucronata*

(b) *Avicennia marina*

Figure 3-3 The two dominant mangrove spices: A: *Rhizophora mucronata* and B: *Avicennia marina*

3.3 Experimental Framework

The experiments were divided into five parts as shown in Figure 3-4

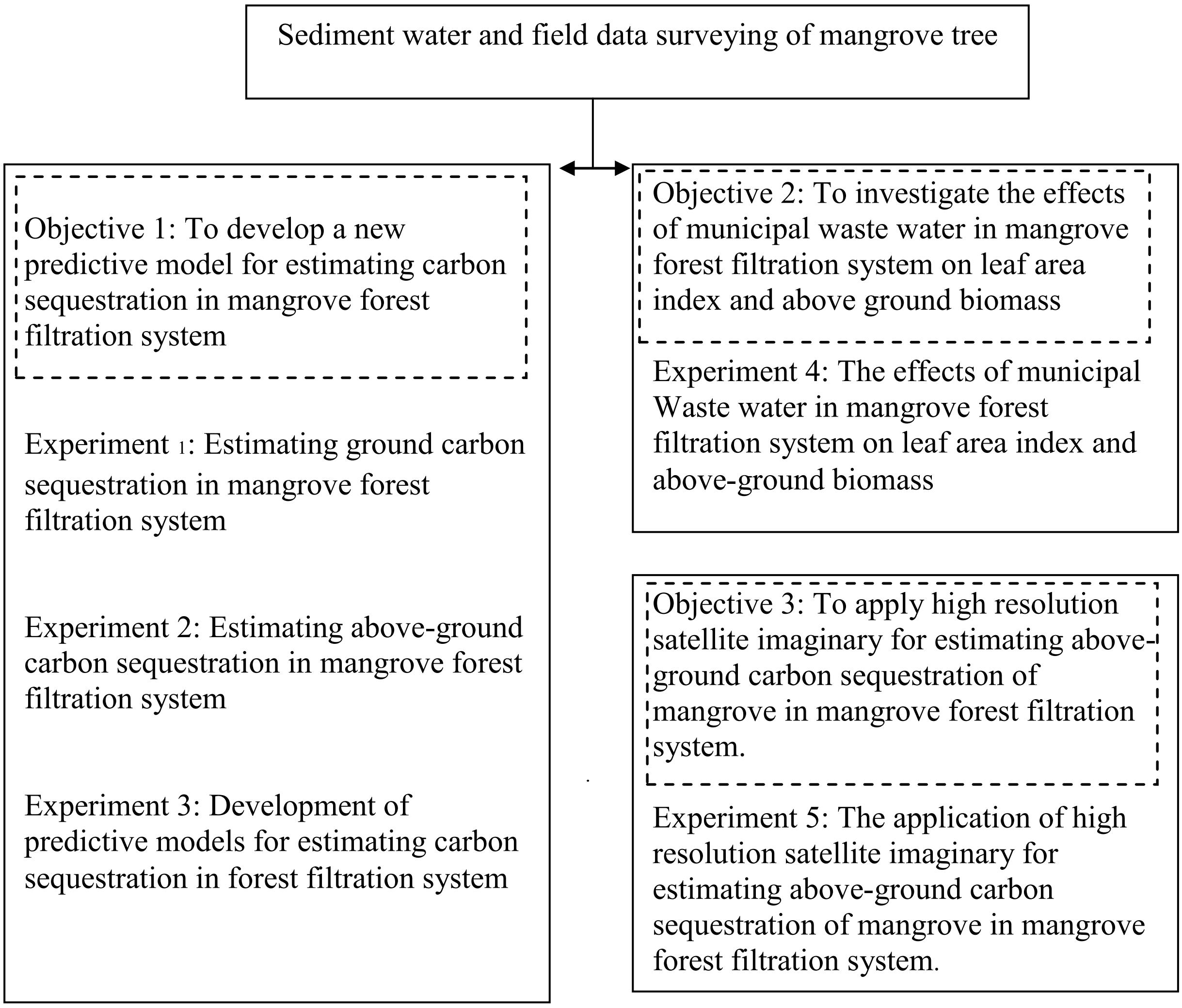

Figure 3-4 Experimental framework of study

3.3.1 Field work

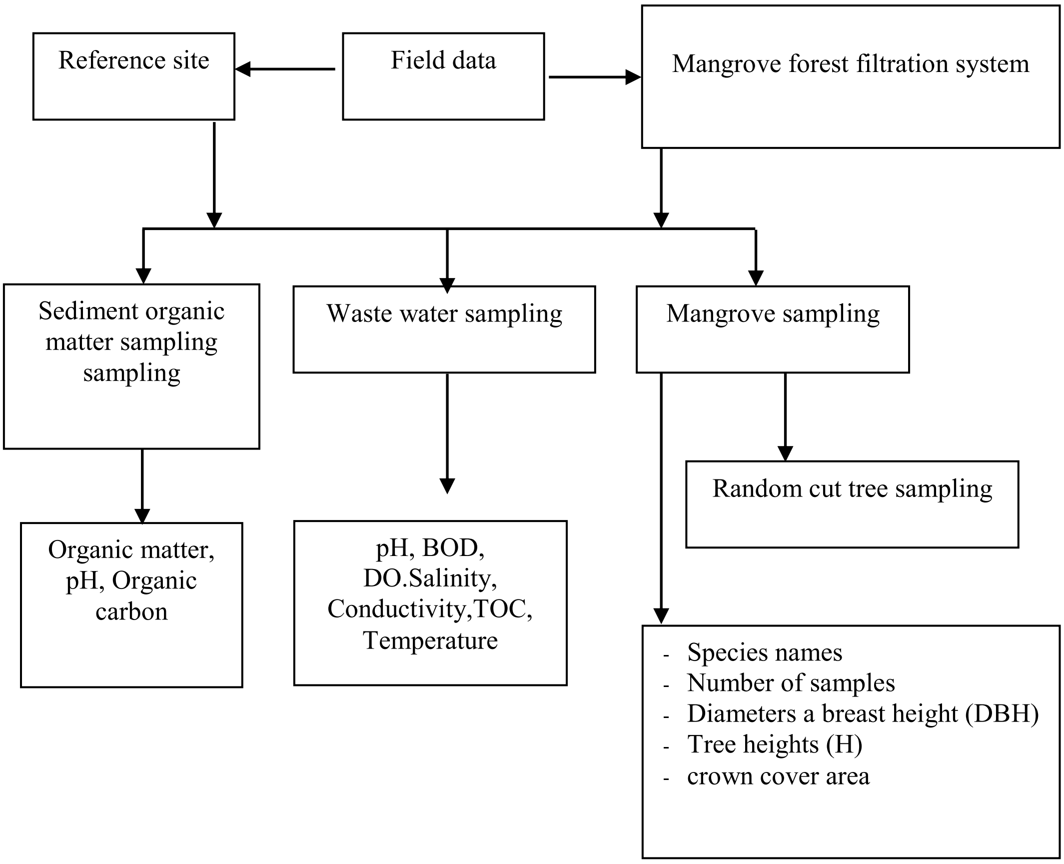

Figure 3-5 Filed work framework of study

3.4 Sediment Analysis

3.4.1 Sediment sampling location: The King‟s Royally Initiated Laem Phak Bia Environmental Research and Development Project. Located within Laem Phak Bia Sub-distric, Ban Laem Distric, Petchaburi Province**,** Thailand (13°03' N 100°06' E) was selected as study area with a total area of approximately 10.33 Km^2. The study area was divided into two sites: 1) the study site; the mangrove forest filtration system was directly by municipal waste water is about 7.46 km^2: 2) the reference site; the natural mangrove forests were indirectly by municipal waste water is about 2.87 km^2 at Ban Pranaen was located in the north of the cape (Figure 3-1).

3.4.2 Sediment sampling design : sediment samples were collected cover all season representation for wet season and dry season in July 2009, December 2009 and April 2010, respectively. Field sampling was carried out bases on a 30 m x 30 m grid system. A portable Garmin Summit GPS receiver was used to locate the sampling sites. The samplings were taken 285 sediment samples from 80 locations in study site and at 15 locations in reference site and a triplication of experiments (Figure 3.2). Xinyu Z et al., 2006 examined that soil primarily occurred within the top soil (0-25 cm) then soil sampling was performed in the 0-30 cm soil depth. The three soil replications were taken from each study areas and soil samples were taken to laboratory for determination.

3.4.3 Sediment preparation and samples analysis: sediment sampling was performed in the 0-30 cm soil depth (Su et al., 2006; Zhang et al., 2006). Soil samples were dried in the open air, and sieved at 2 mm. mixed, and analyzed. Soil pH were determined by Soil: Water (1:1) method (Matheron,1963: 58). The percentage of organic matter; O.M. (%) in soils were analyses by the wet oxidation method (Krige,1951 : 52; Mclean,1982: 9) and the percentage of soil organic carbon were analyses by the wet oxidation method of Walkey and Black (Nelson and Sommers,1982).

3.4.4 Statistical analysis: The main of statistical parameters were analyzed: average, standard error mean, pH, OM, coefficients of variation, extreme maximum and minimum values. ANOVA statistical analysis was used to test the significances between three parameters: pH, OM and SOC content practices at the 95% confidence level. Regression analyses were also used to develop modeling for carbon sequestration. The data variance was compared with those of means using Duncan's New Multiple Range Test (DMRT) and afterwards use utilized SPSS Statistical Package for the Social Science to analyze data into operational solutions.

3.4.5 SOC sequestration calculation: SOC density was expressed as the soil carbon mass of an area to the soil sampling depth, which were calculated as follow: SOC = C x Db x D where SOC (kg per sq.m.) is soil organic carbon density, C (gkg^{-1})

is soil organic content, Db(gcm^{-3}) is soil bulk density, D (m) is soil sampling depth (Zhang et al., 2006). This research on SOC was used as a carbon sink.

3.4.6 Spatial distribution mapping: The three parameters of the exponential model were used for the Kring method to produce the spatial distribution map of SOC content in soils of study area. For the spatial interpolation, a cell size of 100 m x 100 m was chosen to divide the study area into a grid system. The final result of this spatial interpolation process was shown as Figure 20-23. However, geostatistics (Matheron,1963: 58) uses the semi radiogram to quantify the spatial variation of a regionalized variable, and provides the input parameters for the spatial interpolation method of Kriging (Krige,1951). The Geostatistical analyses and the interpolated map were produced with the Geographic Information System (GIS) software.

3.5 Water Analysis

3.5.1 Water sampling location: location and plots sampling the same sediment sampling see in section 3.4.1

3.5.2 Waste water sampling : Waste water sampling carried out 6 times per day in each sample station and put in closed two-liter bottle and then store in 4 ^{0}C. A composite sample method used for collecting mean waste water samples. The recorded quality water parameters are pH, BOD, DO, Salinity, Conductivity, TOC, and Temperature. All the water samples send to the laboratory for analyses of quality of water. (APHA, AWWA and WPCF, 1995)

3.5.3 Water sampling collection: sampling design comprised ninety-eight of 30x30 m^2 field plots in the study area and three plots in the input of municipal waste water area. (figure 3.2). The locations of these plots were chosen by a systematic random sampling method. A portable Garmin Summit GPS receiver was used to locate the sampling sites. Our study divided into four area: 1) the study site: the mangrove forest were affected by municipal waste water 2) the reference site: mangrove forests were not disturbed by municipal waste water at Ban Pranaen is located in the north of the cape. 3) the shore site where was an influence of sea tide and far from the coast were100 and 200 meters. The three replicate samples were taken at 88 locations in each season. 4) the output site where was flow of waste water from the lagoon treatment. Determination of field plots follow as the directions and distribution of waste water plume. (Sawangchat, 2001) Water samples were collected for seasonal representation for wet and dry season in July, December 2009 and April 2010 , respectively. The waste water were determined pH, temperature, DO, BOD, salinity, conductivity and total organic carbon parameters.

3.5.4 Water data analysis

1) Data analysis in situ

1.1) The pH of water was directly measured by pH meter with an accuracy of $\pm$ 0.01 pH unit.

1.2) The temperature (Degree Celsius) of water was directly measured by pH meter .

1.3) The analysis of salinity was directly measured by Salinometer.

1.4) The analysis of conductivity was directly measured by multimeter.

1.5) The analysis of DO value was directly measured by Oxygen Meter.

2) Data analysis on Laboratory

All of the water samples were conducted in the Laboratory of Environmental Research Institute, Chulalongkorn University, Bangkok ,Thailand for analysis of BOD by Azide Modification Method (APHA-AWWA-WFPC, 1989)**.**The analysis of TOC using Total Organic carbon Analyzer

3) Data Analysis

A quantitative estimate of the physical and biological processes of field data were compared between the study site and other sites in addition to these results were compared with Sawangchat" studying (2001) who studied on the qualities of waste water in the same area.

3.6 Mangrove forest analysis

3.6.1 Mangrove sampling: The size of each sampling station is 30x30 m^2. Similar to sediment sampling, a simple random sampling method used for selecting the locations of the sampling stations. Mangrove tree sampling carried out in July, December 2009 and April 2010 for seasonal repersetation. The floristic parameters recorded are species names, tree heights, diameters a breast height, crown cover area, and Differential Global Positioning System (DGPS) coordinates in the UTM system (Chaichoke, 2006)

3.6.2 Tree sampling location: location and plots sampling the same sediment sampling see in section 3.4.1

3.6.3 Data field measurement

Data were collected in the field from July 2009 to April 2010. *Rhizophora mucronata* and *Avicennia marina* were the two dominant species in this area. Measurement of tree diameter at breast height (DBH) performed by measurement tape, crown diameter. and tree height measured by measuring pole and haga hypometer were sampled within 900 m^2 quadrate in the rectangular permanent sample plot by systematic system and thoroughly distribution mangrove forest area. At each plot, LAI was measured by a total leaf count technique (Ishii and Tateda, 2004).

3.6.4 Tree sampling cutting

Rhizophora mucronata and *Avicennia marina* are selected to cut for 6 set each then separation cutting to small part with length 1 meter by stratified clip technique. All cut samples were weighted and record their weighting prior to analyze the percentage of carbon content for each parts of tree samples.

3.6.5 Estimation of LAI value

Two LAI equations are developed by field data collection which a method of on the basic of Japanese national forest surveys and satellite data analysis (Ishii et al ., 2001). The LAI measurements were calculated by measuring the DBH and the total of leaf area of each tree in the field plots and analyzed the strongly relationship between leaf area and diameter at breast high and tree high. The results of two algometry equations are used in this studying.

3.6.6 Tree volume estimation

Tree volume of the two dominance species was calculated using the independent variables of algometry equation in D^2H by following equations:

$BA = ¶D^2/4$ when BA Tree surface area, D stand for tree diameter at 1.3 cm

The calculation of tree sample volume using Smalian formula (Phongsuksawat,2002)

$Vs = ½(BA_1 + BA_2) \times L$

Vs stand for the volume of tree log (cubic meter)

BA_1,BA_2 stand for both two ends diameter(square meter)

L stand for log length (meter)

For the last end log calculate the volume as following equation:

$Vtop = 1/3 \times BA_{top} \times L_{top}$

Vtop stand for the end of tree trunk (cubic meter)

BA_{top} stand for the end side diameter (square meter)

L_{top} stand for the length of the top end (meter)

3.6.7 Calculation of Biomass

For each tree sampled, was registered. To calculate the crown area, crown diameters were used and the crown area was considered an ellipse. The harvested trees were subdivided into following compartment: leaves, branches, stems and roots. To determine the total and by compartment dry weight for each sampled individual, simple linear regression of dry weight on fresh weight were run, beginning with the sub-sample dry weights. These statistical procedures may be found in (Zar,1996). The obtained regressions were grouped by compartments: leaves; branches, stems and roots. We pooled the data of two mangrove species from the various regressions to compute common regressions based on the comparison results (Soares and Schaeffer-Novelli,2005) then determining the best regression model to estimate the total above-ground biomass and compartment biomass follow by law of allometric method. (Kittredge,1944;Ogawa, H. and Kira ,T.1977) . Our measurements of nett productivity are bases on allometric techniques (Ong et al., 1984). The sample plot 12 trees of 2 dominance spices were harvested so allometric regression equations could be developed.The results of two allometric equations are used for biomass calculation.

3.6.8 Calculation carbon content (%)

The harvested trees samples were sent to laboratory at Department of Silviculture, faculty of foresty, Kasetsart University for analyze the percentage of carbon content by Dry Combustion method and using CN Corder model MT-700 (Nualngam,2002)

3.6.9 Calculation of above ground carbon sequestrations

The percentage of carbon content analyzed by laboratory from each part were taken into the calculation of carbon sequestration from above ground biomass in term of each plot (Sridang,2008) from equation “Total carbon= %carbon x biomass”.

3.7 Remote Sensing Analysis

3.7.1 Satellite imagery: The satellite data using (Landsate TM5, THEOS and Quickbird) Natural color ,covered Ban Laem District,Petchaburi Province**,**Thailand . They are acquired on July 2009, March 2010 and April 2010, respectively for dry season representative. Radiometric and geometric corrected the satellite data is registered used Ground Control Points (GCPs). The GCPs were collected using GPS in the field. Georeferenced images were applied to the UTM. Pre-classification was performed by supervised classifier using a set of training areas namely; forest, shrimp farm, open land and water body. There after post-classification was performed and the result had been verified in the field. Accuracy assessment of using error matrix (confusion table) by comparing known reference data (ground truth) and the corresponding results of the automated classification.

Remote sensing work divided into 3 main stages.

1) Preparing satellite images: Landsat TM5, THEOS and Quickbird then when through Geometric Correction the Digital Number to images reflectance were used to calculate the vegetation indices.(table 3.1).

2) Remote sensing analysis: Stepwise Multiple Regression Analysis was used relationship between the leaf area index and the vegetation indices. After that the equations of Carbon Sequestration by high resolution satellite images are tested the analysis and the accuracy by t-test statistic.

3.7.2 Data analysis: Remote sensing data were analyzed using three vegetation indices: the Normalized Difference Vegetation Index (NDVI), The Ratio Vegetation Index (RVI) and The difference Vegetation Index (DVI) (Zar,1996) Band Ratio transformations of the satellite data from three satellite images. The following mathematical expression were computed using these formulas(table :

1) The Normalized Difference Vegetation Index (NDVI)= (B4-B3)/(B4+B3) (Rouse et al.,1974;Deering et al ., 1975)

2) The Ratio Vegetation Index(RVI)=B4/B3 (Jordan,1969)

3) The Difference Vegetation Index (DVI)= B4-B3 (Tucker, 1979)

Where B4 = the near-infrared digit number

B3 = the red visible digital number

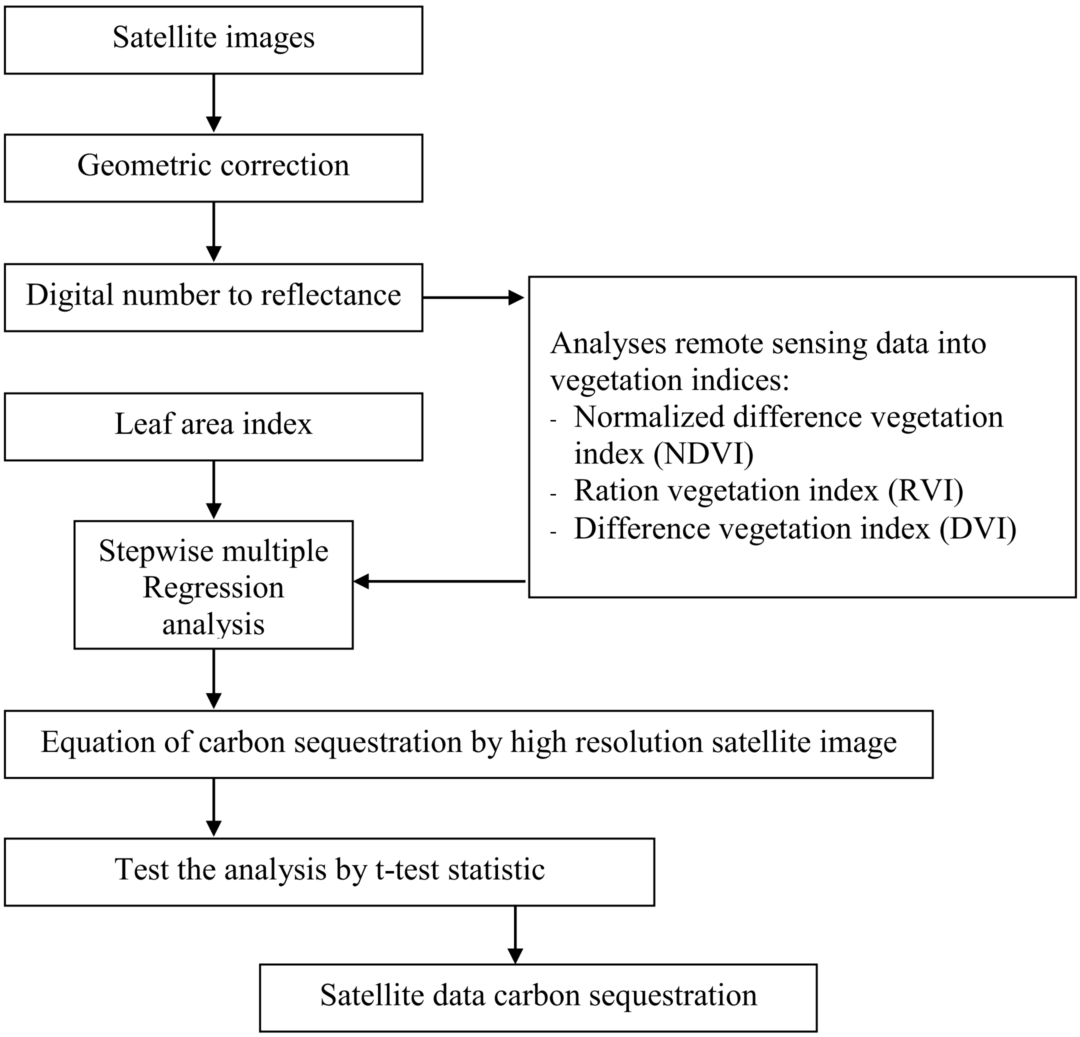

Figure 3-6 Remote Sensing analysis

Table 3-1 Equations for data remote sensing analysis

Vegetation indexes	Equations	Reference
Normalized difference vegetation index (NDVI)	NDVI = (NIR-RED)/(NIR+RED)	Rouse et al., 1974
Ration vegetation index (RVI)	RVI = NIR/RED	Jordan, 1969
Difference vegetation index (DVI)	DVI = NIR–RED	Tucker, 1979

Remarks: RED = Band 3, GREEN = Band 2, Blue = Band 4

3.8 Statistical analysis:

Some main statistical parameters were analyzed: mean, standard deviation variance, coefficients of variation, and extreme maximum and minimum values. ANOVA statistical analysis was used to test the significances almost of the parameters at $p< 0.05$. Regression analyses were also used to develop modeling for carbon sequestration. These statistical parameters were performed by using EXCEL 2003 and statistical package for the Social Science (SPSS) program. The statistical relationships between the annual field measurements and laboratory results were correlated to various regression models. The best equation model was selected by its highest coefficient of determination to calculate leaf area index in the study area. Correlation and regression analysis area useful in evaluating the association between two or more variables and expressing the nature of relationship and determination the degree of association between variables with coefficient of determination (R^2) (Lim,2007).

3.9 Spatial distribution Mapping

All of the results from the exponential model were used for the Kring method to produce the spatial distribution map of study and reference areas. For the spatial interpolation, a cell size of 100 meter x 100 meter was chosen to divide the study area into a grid system. The final result of this spatial interpolation process was shown as values spatial distribution maps. Geostatistics (Matheron, 1963) uses the semi-variogram to quantify the spatial variation of a regionalized variable, and provides the input parameters for the spatial interpolation method of Kriging (Krige,1951).The Geostatistical analyses and the interpolated map were produced with the Geographic information system (GIS) software.

3.10 Integrating ecological data into the mapping model

Spatial relationships between mangroves and the environment are well known (Macnae, 1968; Clough,1982; Semeniuk,1983; Tomlinson,1994 and Hogarth,1999). These relationships result in the mangrove zonations that are usually found in tropical mangrove forest (Tomlinson,1994; Hogarth,1999;Valarrubia,2000 and Satyanarayana et al ., 2002). Moreover, Chaichoke (2006) tested whether mangrove-environment relationships can be exploited in order to improve mapping accuracy. The study confirmed that the mangrove-environment relationships into the mapping process that can be used for mapping mangrove at the species level. The parameters of the exponential model were used for the Kring method to produce the spatial distribution map of LAI, Above ground biomass and above ground carbon of study and reference areas.

3.11 Development of modeling

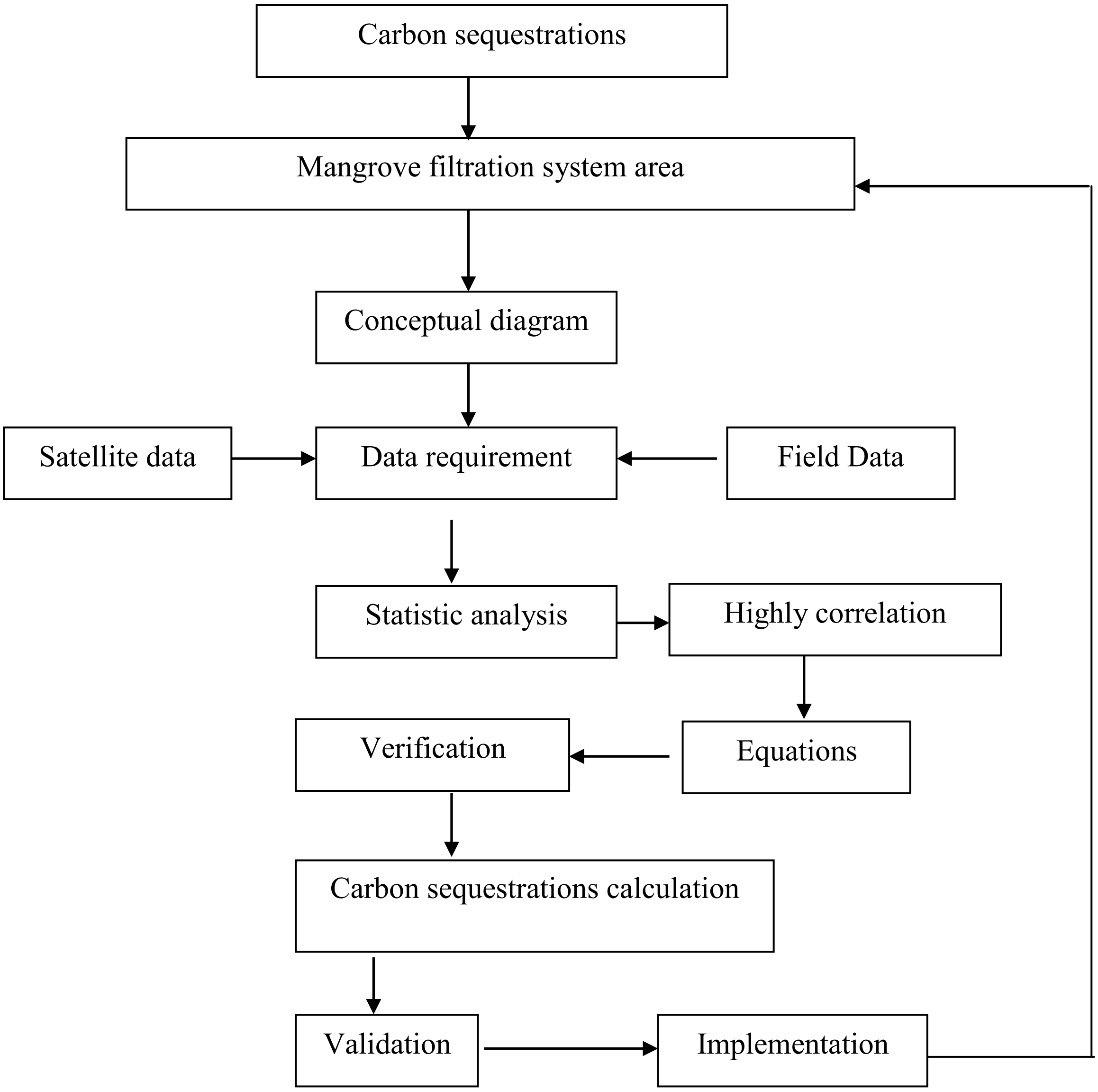

Figure 3-7 The process of model development in this systems.

CHAPTER IV
RESULTS AND DISCUSSIONS

Similar to many other plants, mangrove has strong relationships with the surrounding environment. The occurrence of mangrove species at a certain location is related to surrounding ecological gradients such as elevation, tidal inundation, water salinity and soil pH (Macnae, 1968; Clough,1982; Semeniuk,1983;Tomlinson,1994 and Hogarth,1999) then in this research focuses on carbon sequestrations into three phases: carbon in the sediment in term of sediment organic carbon, carbon in the water in term of total organic carbon and carbon in the mangrove trees in term above-ground biomass and develop the carbon sequestration modeling from these data by highly correlation.

4.1 Estimation of Soil Organic Carbon Concentration Accumulated in Mangrove Forest Filtration System

4.1.1 Soil properties

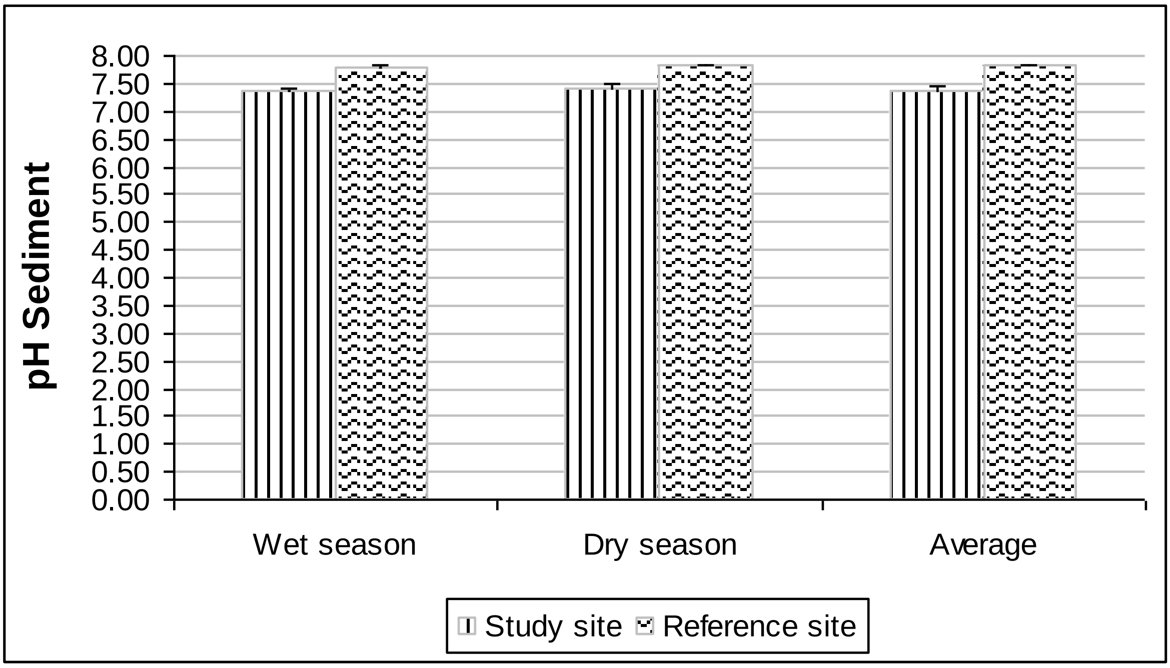

Figure 4-1 Histogram of pH sediment

1) pH sediment: The pH is one of characteristics of soil relative to other chemical characteristics of soil such as type and concentration of minerals in soil, organic matter, and level of carbon dioxide in soil(Mclean,1982). Data in Table A-1 and Table A-2 showed the result of pH values were no significant difference between the season and the area, which only found slightly difference in pH values among seasons (see in figure 4-1). pH sediment in study site showed that the annual average minimum of pH found at 4.91 meanwhile in the reference site found 7.61 and sediment pH in study site showed that the average maximum of pH found at 8.21 meanwhile in the reference site found 8.01. The area found low pH values because the sampling plots were located nearly waste water discharge point and soak area wherever far away from the discharge point found the periodically increasing of pH values, because of the influence of organic carbon accumulation and decomposition rate. The comparison of average pH values between study site and reference site found that in study site has slightly lower pH values (figure ……..) than reference site because of the study site were received source of municipal wastewater flow into the sea. While, the comparison between the annual average pH values study site and reference site were shown the soil pH range slightly alkali rating of the USDA(Thomas,1996)(see in Table F-1).

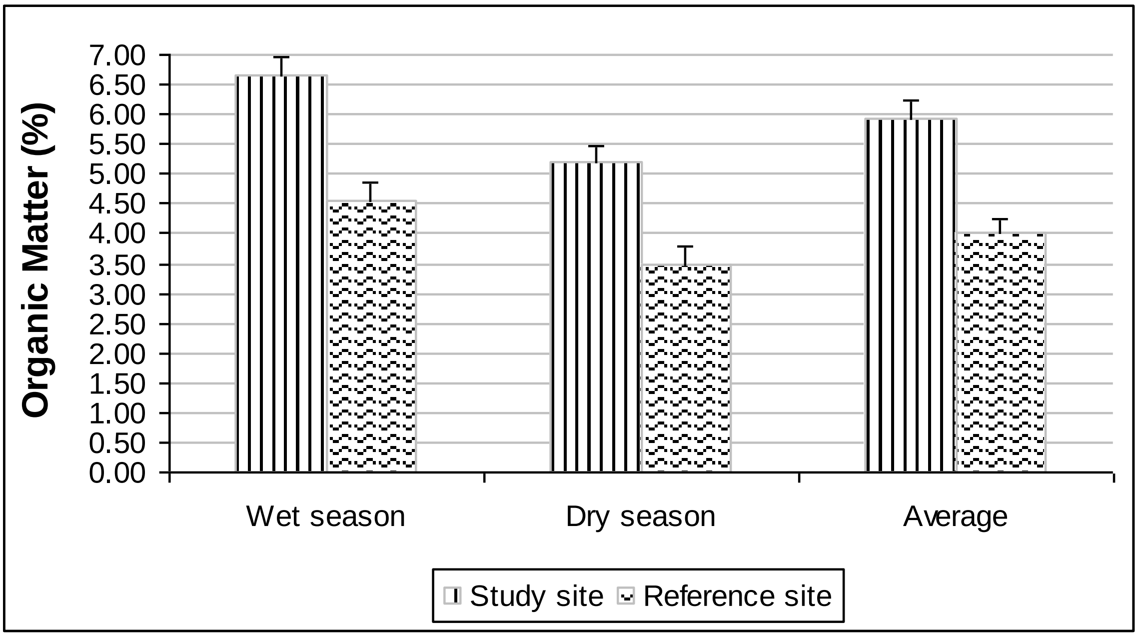

Figure 4-2 Histogram of the percentage of organic matter

2) Organic Matter (%) of sediment: Organic matter is a source of energy, carbon and mineral nutrients for soil fauna and micro biota may contain a major part of the plant available nutrient reserved of the soil. It is the largest pool in the terrestrial C cycle and is thus a crucial factor for emission or sequestration of CO_2 (Schiesinger, 1977). It may also be relevant for the control of the CO_2 content of the atmosphere (Miltner et al., 2009). From this research showed that in the study site where receiving source of municipal wastewater had the minimum percentage of organic matter was 0.69 and maximum percentage concentration of 12.36. From the reference site had minimum percentage of organic matter was 1.76 and maximum percentage concentration of 5.54 (Table A-3 and Table A-4). This compared the maximum of OM (%) values between study site and reference site found that in study site has higher than reference site almost twice times meanwhile the minimum of O.M. (%) values found at reference site has higher than study site almost twice times. However, the compared between the annual average percentage of OM (%) from the study site and reference site were showed very high and high, respectively, at soil O.M. (%) range of the USDA (Thomas,1996). (see in figure 4-2), Moreover, an analysis by Alongi et al .,(2004) confirmed that sediment organic matter was rapidly and efficiently decomposed in all forest with carbon burial rates ranging from 16 % to 27 % of total C input to the sediments.

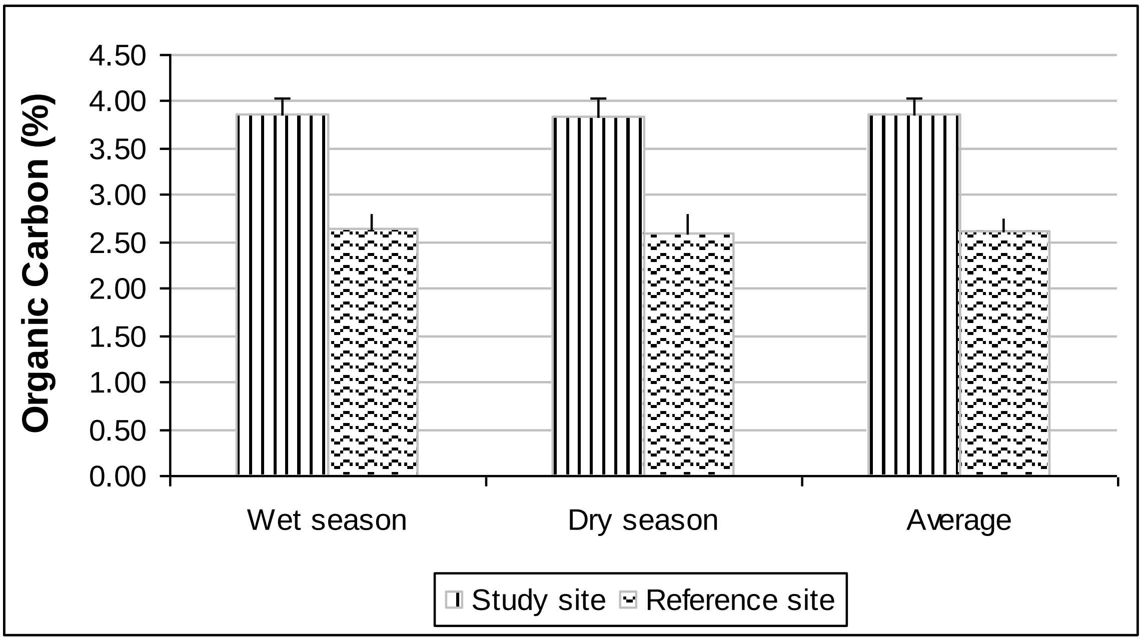

Figure 4-3 Histogram of the percentage of organic carbon

3) Organic carbon: O.C. (%) of sediment: The average percentage of organic carbon at a depth of 0-30 in study site was minimum percentage of organic carbon at 0.43 and maximum percentage concentration of 8.53. From the reference site had minimum percentage of organic matter at 1.20 and maximum percentage concentration of 3.85(Table A-5 and A-6). The comparison the maximum of O.C. (%) values between study site and reference site found that in study site has higher than reference site almost twice times meanwhile the minimum of OC (%) values found at reference site has higher than study site almost three times.(see in figure 4-3) The result of O.C.values were no significant difference between the seasons.

4.1.2 SOC sequestration rates estimation

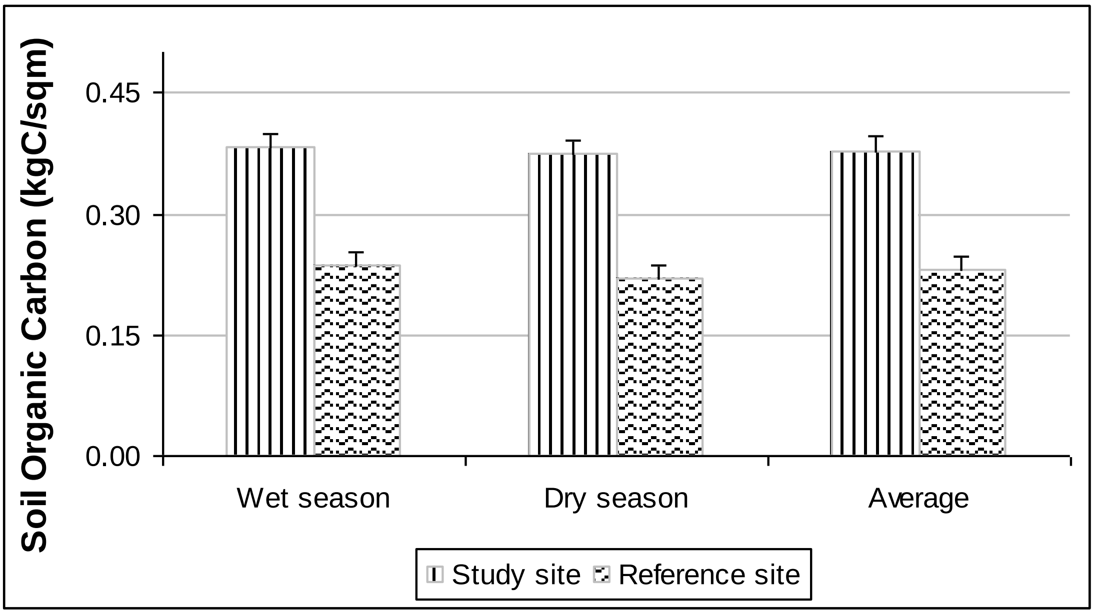

Figure 4-4 Histogram of the percentage of soil organic carbon sequestration

From table A-7 and A-8, these results showed the minimum SOC sequestration rate (kg of carbon per sq.m.) was observed in study site was 55.81 kgC/m^2 and maximum was 682.97 kgC/m^2. For the reference site had minimum was 104.35 kgC/m^2 and maximum was 306.6 kgC/m^2. Wherever compared between study site and reference site on the maximum SOC sequestration rates found that in study site has higher than reference site almost twice times meanwhile the minimum of SOC sequestration rates found at reference site has higher than study area almost twice times.(see in figure 4-4) The average of SOC accumulation in the study site to a depth of 0-30 cm was estimated as 283.36 tons. From the reference site, the average of SOC accumulation was about 66.5 tons. The total area found the average of SOC accumulation was about 349.87 tons. The comparison between study site and reference site on the average values of SOC sequestration found that the SOC sequestration rate in study site higher than reference site more than four times (see in figure 4-4that according to Matsui,1998 and Fujimoto et al., 1999 concluded that mangrove ecosystems are able to store large amounts of organic carbon.

4.1.3. Seasonal variation of soil properties

From study site was analyzed by One-way ANOVA and found that the pH value and the percentage of O.C. no significant differential from seasonal but found only O.M. has significant differential from seasonal .This season was preferred because rainfall stimulates the transport of organic matter (Meziane and Tsuchiya,2002). The percentage of O.M. value in rainy has higher than summer at 2.76 and 0.14, respectively, whereas winter has lower percentage of OM value than summer at 2.62. From reference site, which assess pH value by One-way ANOVA the results demonstrated that has significant differential from seasonal whereas pH in summer higher than rainy and winter were 0.19 and 0.29, respectively, whereas rainy has pH value higher than summer at 0.01. For the assessment of OM and OC by One-way ANOVA the results demonstrated that no significantly differential. For the assessment of SOC by One-way ANOVA the results demonstrated that no significantly differential both in study and reference site.

4.1.4. Soil properties and soil organic carbon relationship

The results showed a significant linear relationship ($p<0.05$) of the study site was found between the percentage of pH value and the percentage of OM and OC with the same result at a R^2 of 0.63.(figure A-1 and figure A-2) This research had analyzed linear relationship strong between the percentage of O.M and O.C found a

R^2 of 0.99 . (figure A-4) The result of a significant linear relationship between pH values and SOC (kg/sq.m.) values was with a R^2 of 0.58. (figure A-3) It showed that a significant linear relationship between the OM (%) and SOC (kg/sq.m.) values was with a R^2 of 0.80. (figure A-5) The result shows that relationships nearly strong and statistically significant relationships of OC (%) and SOC values with a R^2 0.81. (figure A-6) While, the reference site was shown resulted of percentage of pH value, percentage of OM and OC at R^2 of 0.02. (figure A-1 and figure A-2) The analyses on linear relationship strong between the percentage of OM and OC found a R^2 of 0.98. (figure A-4) The results of a significant linear relationship between pH values and SOC (kg/sq.m.) values were shown a R^2 at 0.005. (figure A-3) The result showed that a significant linear relationship between the percentages of OM and SOC (kg/sq.m.) values was with a R^2 of 0.81, (kg/sq.m.) while, the result showed that relationships nearly strong and statistically significant relationships percentages of OC and SOC values with a R^2 0.76. (figure A-6)

4.1.5. Spatial distribution of SOC content

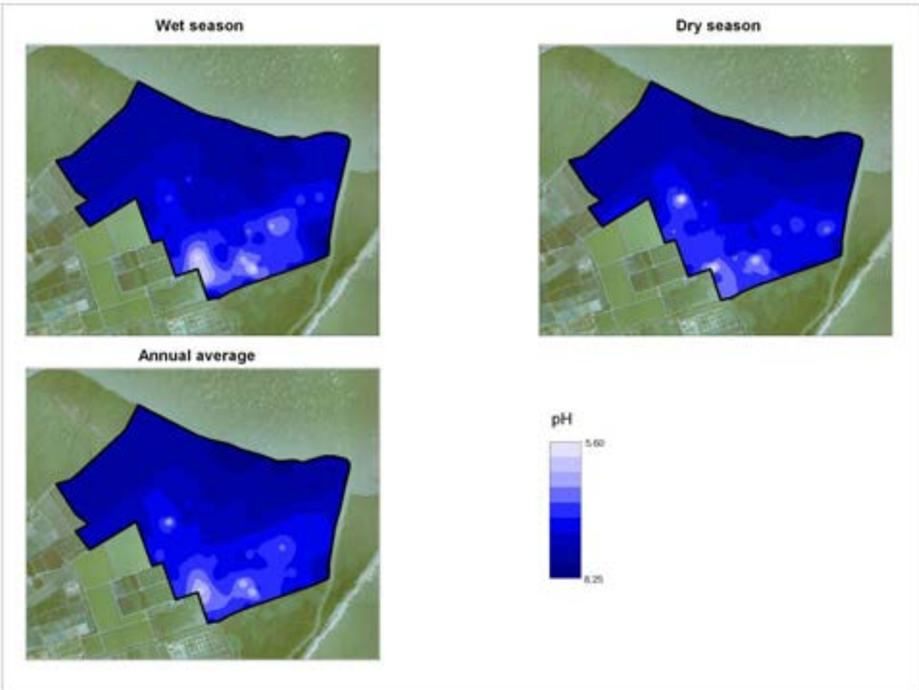

Figure 4-5 Spatial distribution map of pH sediment

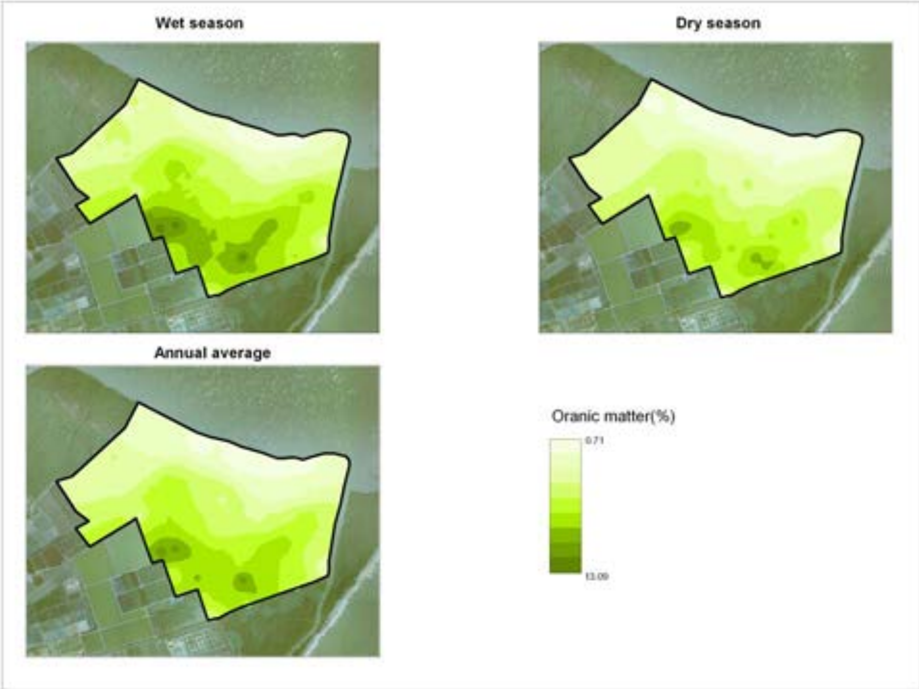

Figure 4-6 Spatial distribution map of the percentage of organic matter

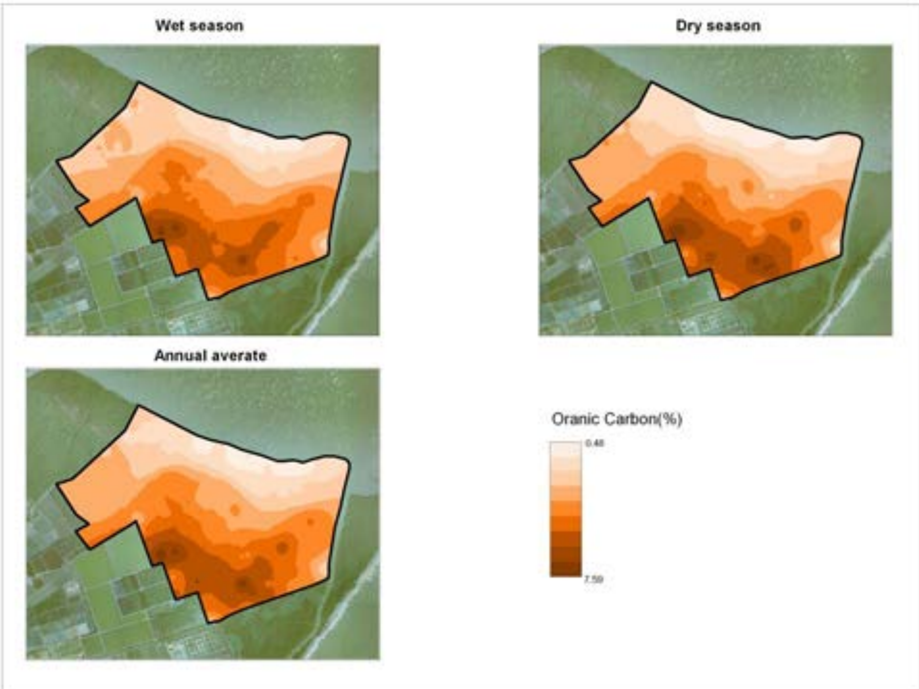

Figure 4-7 Spatial distribution map of the percentage of organic carbon

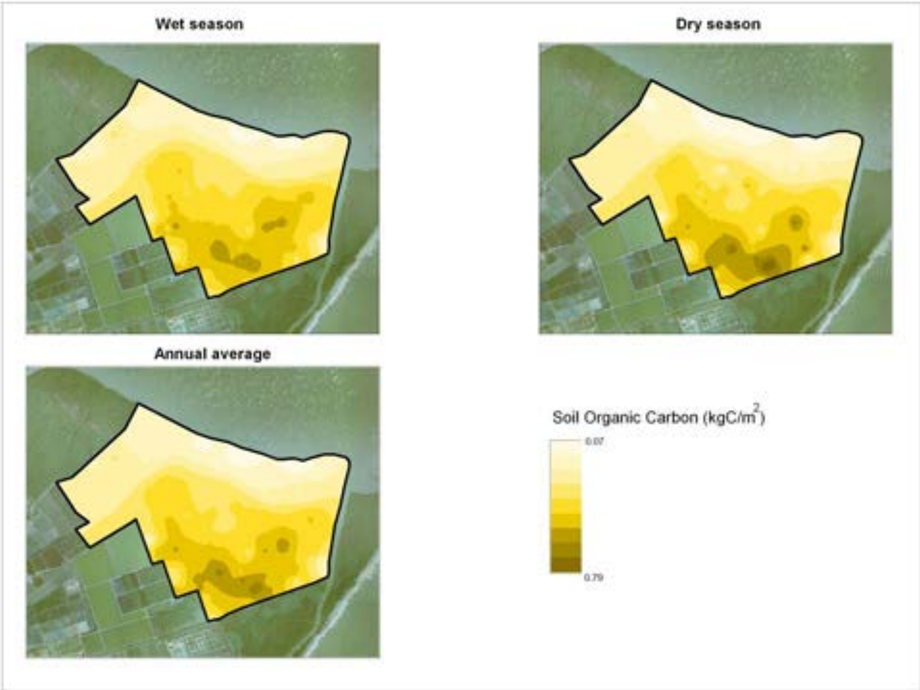

Figure 4-8 Spatial distribution map of the soil organic carbon

Figures 4-5, 4-6, 4-7 and 4-8 illustrate the spatial distribution of pH unit value, the percentage of organic matter, the percentage of organic carbon accumulation and soil sequestration accumulation respectively, demonstrated that the SOC sequestration value in study area (Figure 4-8) has obviously higher than reference area whereas in the *Rhizophora mucronata* specie area found the highest SOC sequestration. The SOC sequestration distribution has the same pattern in all season. Moreover, the parameters distribution map at study site reach maximum values in discharge point and become low.

4.2 Estimation of Total Organic Carbon Concentration Accumulated in Mangrove Forest Filtration System

4.2.1 The Qualities of water parameters

The field study of physical and chemical water qualities in filed performed for 98 sampling points which cover dry and wet seasons. The sampling water were analyzed for pH, temperature, DO,BOD, salinity, conductivity parameters. The statistic values see in Table 4-1

Table 4-1 The parameters values of water samples

Parameters	Study Site[1]				Reference Site[2]			
	Maximum	Minimum	Mean±SD	CV (%)	Maximum	Minimum	Mean±SD	CV (%)
pH	9.17	6.67	7.663±0.463	6.04	8.18	6.76	7.700±0.2091	2.72
DO (mg/l)	15.07	-0.02	2.192±1.796	81.93	9.08	0.01	3.201±2.4361	76.10
BOD (mg/l)	47.58	-1.68	5.704±5.142	90.15	29.88	1.44	7.063±5.070	71.79
Temperature(C)	38.40	27.10	31.775±2.150	6.77	34.00	25.30	30.140±3.256	10.80
Conductivity (mS)	75.28	2.59	49.091±9.722	19.80	79.77	39.93	52.746±9.765	18.51
Salinity (ppt)	52.63	1.30	29.766±6.956	23.37	52.50	25.53	31.246±6.172	19.75

Remarks: Study Site[1] is the mangrove filtration system area where is directly affected from the municipal waste water.

Reference Site[2] is the mangrove forest area where is indirectly affected from the municipal waste water at Ban Pranaen is located in the north of the cape.

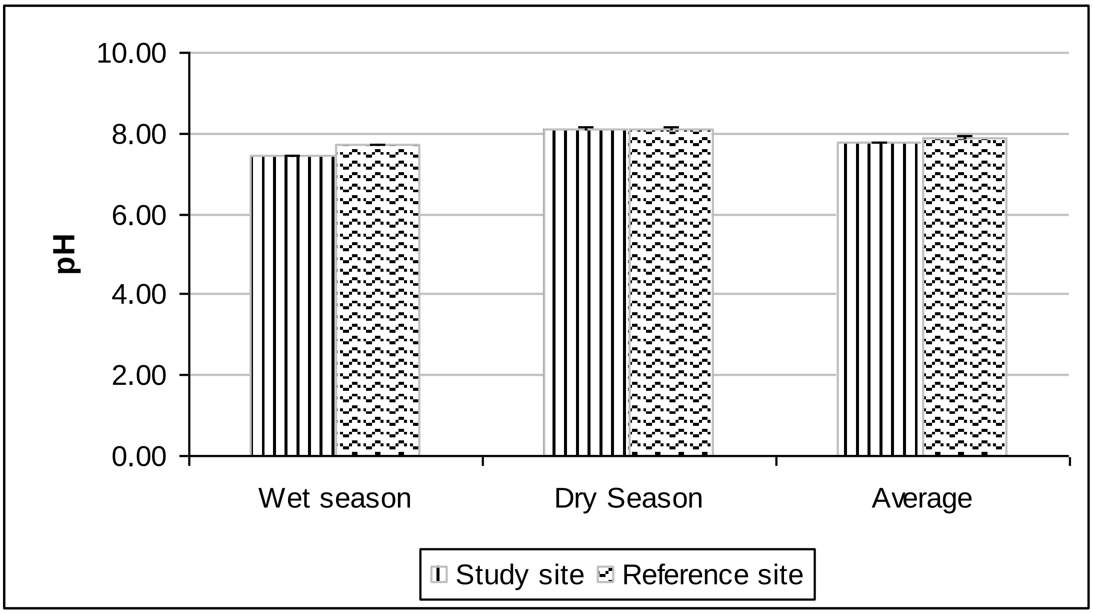

Figure 4-9 Histograms of the pH values in water

1) pH values in water

The annual average of pH value equal 8.47, 7.69, 7.70 and 7.59 unit for the wastewater discharge point in mangrove forest, study area , reference site, and outlet respectively.(Table B-1 and B-2) The finding of highest pH value at discharge point in mangrove forest because that in the study site where have wastewater already passed from lagoon wastewater treatment site moreover, the other site have the anaerobic process of organic carbon decomposition then it occurred the lower pH value than discharge point in mangrove forest site. When we compare the standard of surface water type 4 as determine the pH shall be during 5-9 unit, where as standard of pH for coastal area shall be during 5-9 unit for the natural conservation, which the pH of study are complied with these standards.(see in Table F-3 and table F-4)

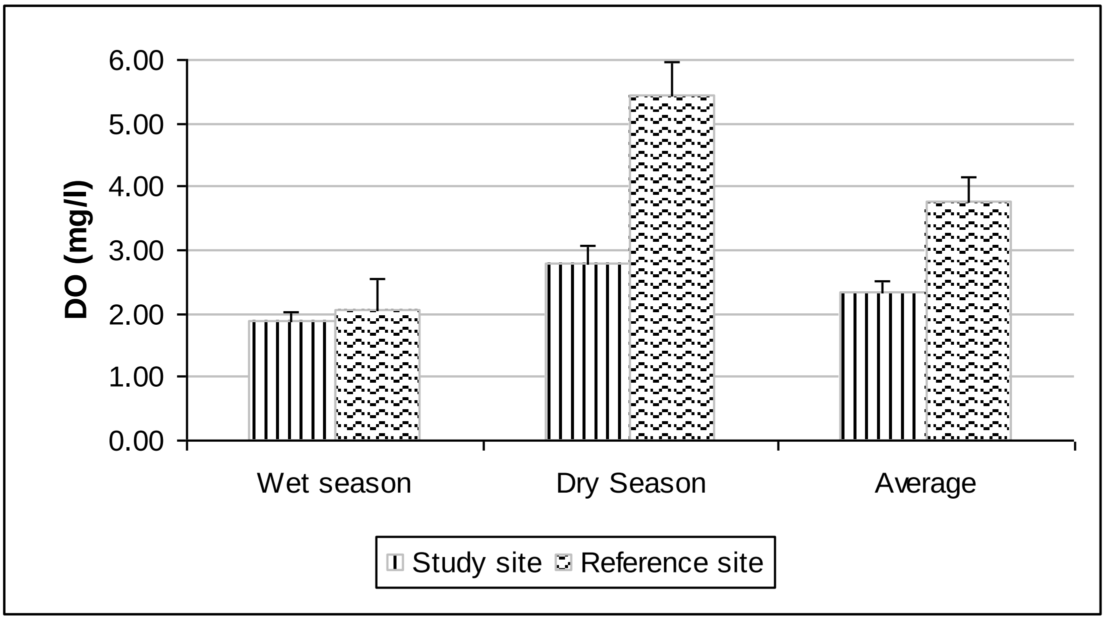

Figure 4-10 Histograms of the DO values in water

2) DO values in water

Table B-3 and TableB-4 found the annual average of DO equal to 4.32, 2.38,3.20 and 1.72 mg/l for the wastewater discharge point in mangrove forest, study area ,reference site, and outlet respectively. The finding of highest DO at wastewater discharge point because that wastewater already passed from lagoon wastewater treatment site and when we compare the standard of surface water type 4 as determine the DO shall be higher than 2 mg/l, where as standard of DO for coastal area shall not lower than 4.0 mg/l, which the DO of study are complied with these standards.(see in Table F-3 and table F-4)

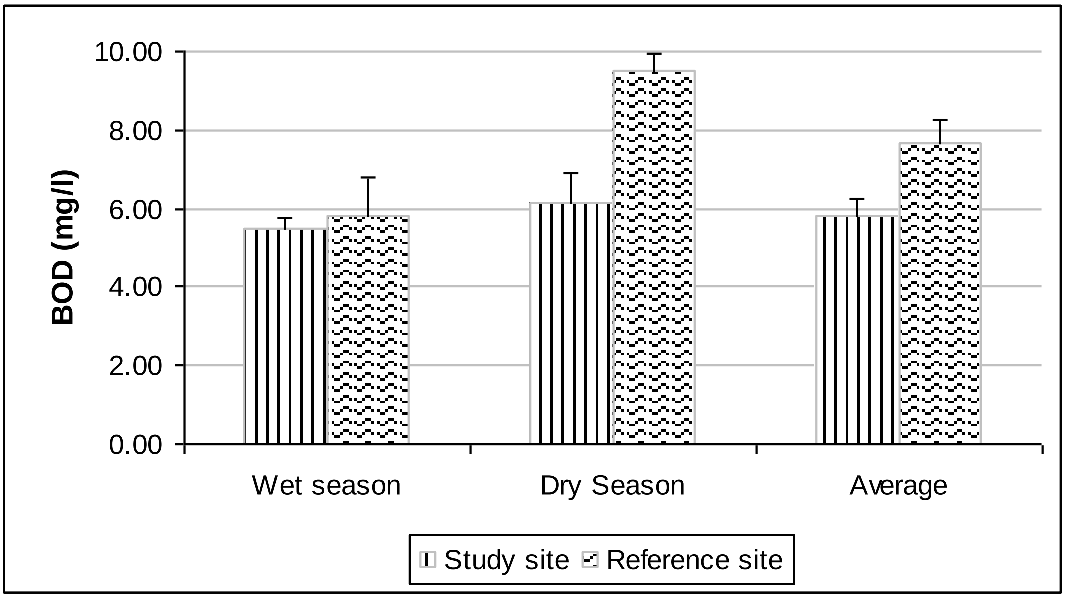

Figure 4-11 histograms of the BOD values in water

3) BOD values in water

The annual average of BOD equal to 5.9, 5.66, 7.06 and 5.74 mg/l for the wastewater discharge point in mangrove forest, study area, reference site, and outlet respectively (Table B-5 and Table B-6). The finding of highest BOD at reference area because that in the study site where have wastewater already passed from lagoon wastewater treatment site moreover, the anaerobic process of organic carbon decomposition was used oxygen.

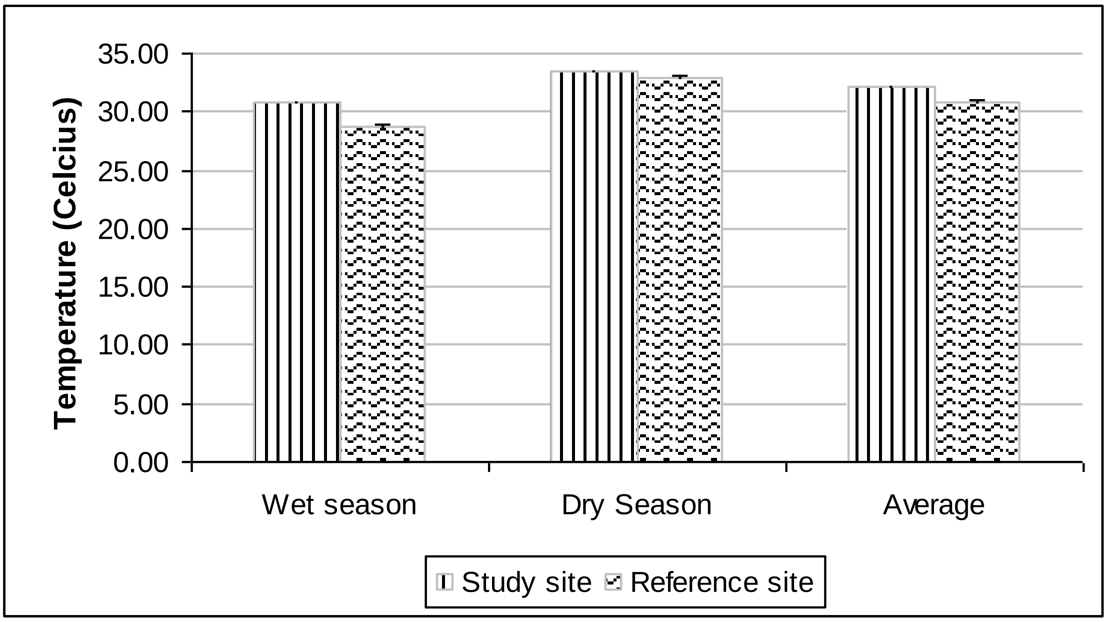

Figure 4-12 Histograms of the temperature values in water

4) Temperature values in water

The annual average of temperature equal 31.10,31.62, 30.14 and 32.20 degree Celsius for the wastewater discharge point in mangrove forest, study area , reference site, and outlet respectively (Table B-7 and Table B-8). The finding of slightly difference temperature values the whole areas and in all seasons. When we compare the standard of surface water type 4 as determine the temperature shall be not higher than 3 degree Celsius, where as standard of temperature for less than 33 degree Celsius for the natural conservation, which the temperature of study are complied with these standards.

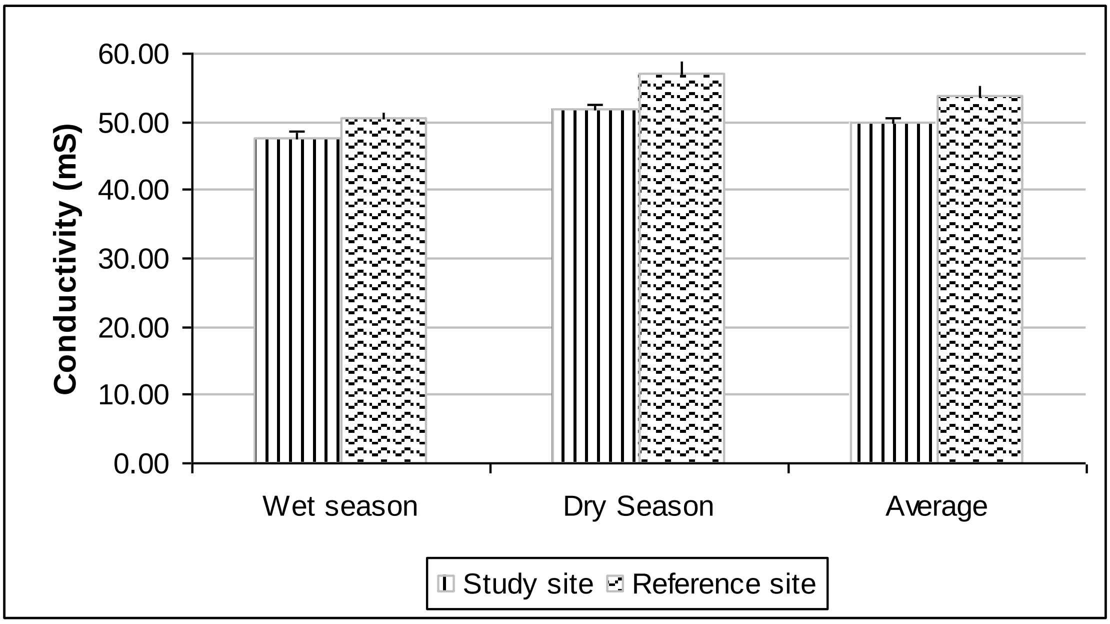

Figure 4-13 Histograms of the conductivity values in water

5) Conductivity values in water

The annual average of conductivity equal 135.60 , 49.33, 52.75 and 48.42 mS for the wastewater discharge point in mangrove forest, study area , reference site, and outlet respectively(Table B-9 and Table B-10).   The finding of slightly difference conductivity values the whole areas and in all seasons except for the wastewater discharge point in mangrove forest.

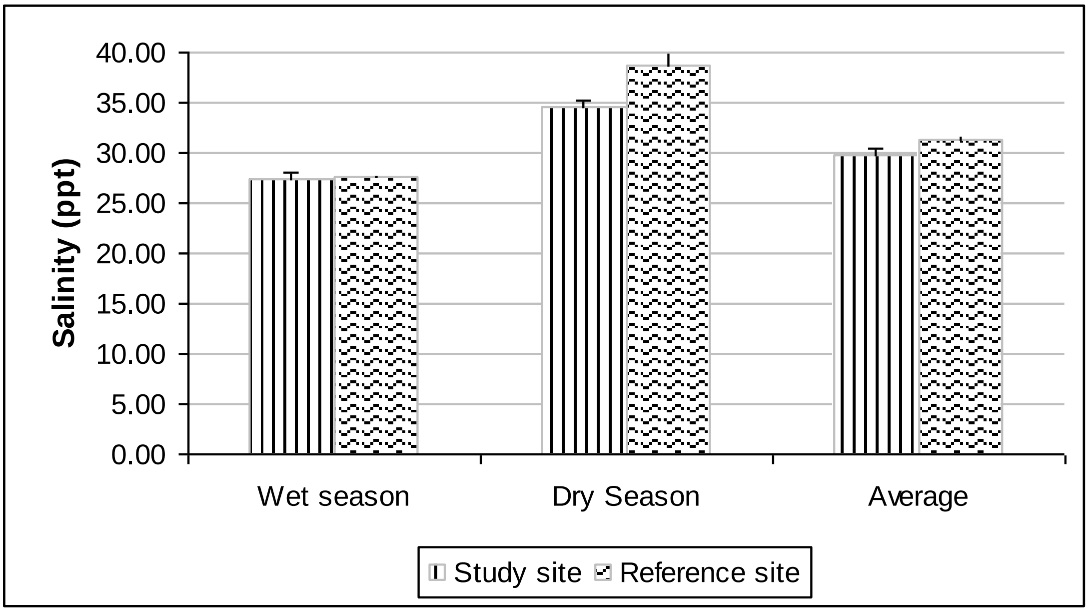

Figure 4-14 Histograms of the salinity values in water

6) Salinity values in water

The annual average of salinity equal 21.89 , 29.70, 31.25 and 73.03 ppt for the wastewater discharge point in mangrove forest, study area , reference site, and outlet respectively(Table B-11 and Table B-12). The finding of highest salinity values outlet because this area was influenced from the sea water. When we compare the standard of costal water where as standard of salinity for during 29-35 ppt, which the salinity of study are complied with these standards except for outlet site.

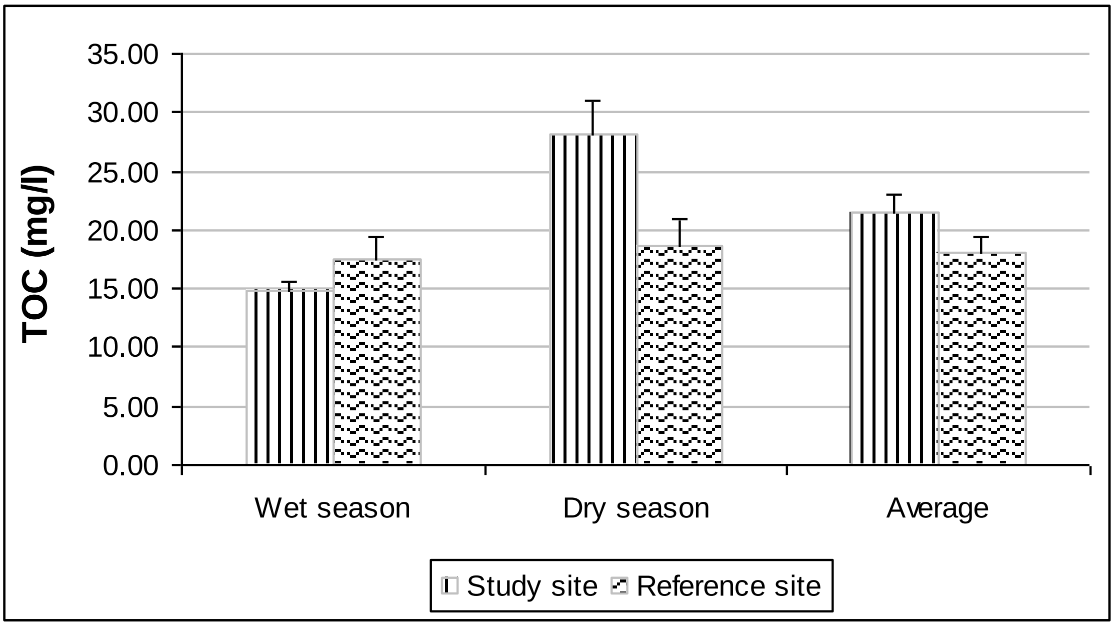

Figure 4-15 Histograms of the total organic carbon values in water

7) Total organic carbon values in water

The annual average of total organic carbon equal 17.10, 21.54, 17.81 and 12.06 mg/l for the wastewater discharge point in mangrove forest, study area, reference site, and outlet respectively (Table B-13 and Table B-14). The finding of highest total organic carbon values outlet because this area was the highest rate of organic carbon decomposition.

4.2.2 Comparison of water qualities in this area in the past 10 years.

Comparison of water qualities were compared between results of the present study and Sawangchat[cc] study who studied Heavy metals concentration in water at Leam Pak Bier mangrove area, Phetchaburi province, receiving effluent from municipal wastewater treatment system and analyzed the same water parameters, methods and the areas. The results follow as Table 4-2

This comparison showed the differential significant changing of water quality in present from the past 10 years where the results showed that the almost parameter of water quality (Temperature, Conductivity, and Sanility) were higher than the past where as DO was less than in the past. However, these researches found the significant changing of two parameters were the enormous increasing of temperature and decreasing of DO. These changing of water qualities were related to climate change phenomenal.

Table 4-2 Comparison in the average of water parameters between the present study and the past 10 years of Sawangchat" s research (Sawangchat, S. 2001)

Parameters	Areas	Average					
		Dry season		Wet season		Annual	
		Sureeporn	Sawangchat	Sureeporn	Sawangchat	Sureeporn	Sawangchat
DO (mg/l)	Input	3.31	4.61	4.83	8.25	4.32	7.04
	Study area	1.69	1.13	2.73	4.01	2.38	3.05
	Reference area	1.99	2.64	3.81	9.50	3.2	4.05
	Outlet	1.28	2.06	1.94	7.01	1.72	5.36
BOD (mg/l)	Input	4.29	4.29	6.70	6.70	5.9	5.9
	Study area	6.55	6.55	5.22	5.22	5.66	5.66
	Reference area	8.72	8.72	6.24	6.24	7.06	7.06
	Outlet	5.48	5.48	5.88	5.88	5.74	5.74
pH	Input	8.19	9.48	8.62	9.09	8.47	9.22
	Study area	7.19	7.49	7.94	7.60	7.69	7.56
	Reference area	7.76	7.7	7.74	7.68	7.7	7.69
	Outlet	7.1	7.97	7.83	7.86	7.59	7.89
Temperature (C)	Input	31.13	28	31.1	24.20	31.1	25.5
	Study area	31.62	26.5	31.63	25.15	31.62	25.6
	Reference area	31.61	26.7	29.41	24.60	30.14	25.3
	Outlet	32.07	25.5	32.27	26.30	32.2	26
Conductivity (mS)	Input	43.59	1	181.60	1.10	135.6	1.1
	Study area	54.94	32.3	46.53	29.15	49.33	30.2
	Reference area	58.85	29.8	49.69	28.40	52.75	28.9
	Outlet	52.6	27.6	46.33	36.90	48.42	33.8
Salinity (ppt)	Input	19.96	0.5	22.85	1.00	21.89	0.8
	Study area	28.01	22.5	30.55	22.75	29.7	22.7
	Reference area	28.12	20.7	32.81	20.25	31.25	20.4
	Outlet	15.86	20.2	30.24	25.80	73.03	24

4.2.3 The relationships between the qualities' water parameters and mangrove forest biological parameters (LAI, biomass and above ground carbon sequestration)

The regression equation models for each predictor variables of the sample plots. The regression equation linear model presented relating to each predictor variable namely; pH, temperature, DO, BOD, salinity, conductivity with R^2 values.

The correlation of pH and LAI in the studied site and reference site showed R^2 equal to 0.0209 and 0.1232 respectively where as temperature and LAI in the in the studied site and reference site showed R^2 equal to 0.0704 and 0.1191 respectively and DO and LAI in the in the studied site and reference site showed R^2 equal to 0.0111 and 0.2118 respectively. BOD and LAI in the in the studied site and reference site showed R^2 equal to 0.0059 and 0.0127 respectively. Salinity and LAI in the in the studied site and reference site showed R^2 equal to 0.0158 and 0.2876 respectively. Conductivity and LAI in the in the studied site and reference site showed R^2 equal to 0.024 and 0.3199 respectively.

The correlation of pH and biomass in the studied site and reference site showed R^2 equal to 0.0001 and 0.137 respectively where as temperature and biomass in the in the studied site and reference site showed R^2 equal to 0.0013 and 0.0771 respectively and DO and biomass in the in the studied site and reference site showed R^2 equal to 0.00005 and 0.0289 respectively. BOD and biomass in the in the studied site and reference site showed R^2 equal to 0.0003 and 0.0215 respectively. Salinity and biomass in the in the studied site and reference site showed R^2 equal to 0.0013 and 0.1915 respectively. Conductivity and biomass in the in the studied site and reference site showed R^2 equal to 0.0001 and 0.1786 respectively.

The correlation of pH and above ground carbon in the studied site and reference site showed R^2 equal to 0.0984 and 0.137 respectively where as temperature and above ground carbon in the in the studied site and reference site showed R^2 equal to 0.0005 and 0.0771 respectively and DO and above ground carbon in the in the studied site and reference site showed R^2 equal to 0.0795 and 0.0289 respectively. BOD and above ground carbon in the in the studied site and reference site showed R^2 equal to 0.0013 and 0.0215 respectively. Salinity and above ground carbon in the in the studied site and reference site showed R^2 equal to 0.0051 and 0.1915 respectively. Conductivity and above ground carbon in the in the studied site and reference site showed R^2 equal to 0.0207 and 0.1786 respectively.

These correlations showed the less relationships of water qualities in present study.

4.2.4 Integrating ecological data into the mapping model

The seven parameters of the exponential model were used for the Kring method to produce the spatial distribution map of pH, temperature, DO,BOD , salinity, conductivity and total organic carbon parameters of study area. For the spatial interpolation, a cell size of 100 meter x 100 meter was chosen to divide the study area into a grid system. The final result of this spatial interpolation process was shown as Figure 33 to 39 Geostatistics (Matheron, 1963) uses the semi-variogram to quantify the spatial variation of a regionalized variable, and provides the input parameters for the spatial interpolation method of Kriging (Krige,1951).The Geostatistical analyses and the interpolated map were produced with the Geographic information system(GIS) software.

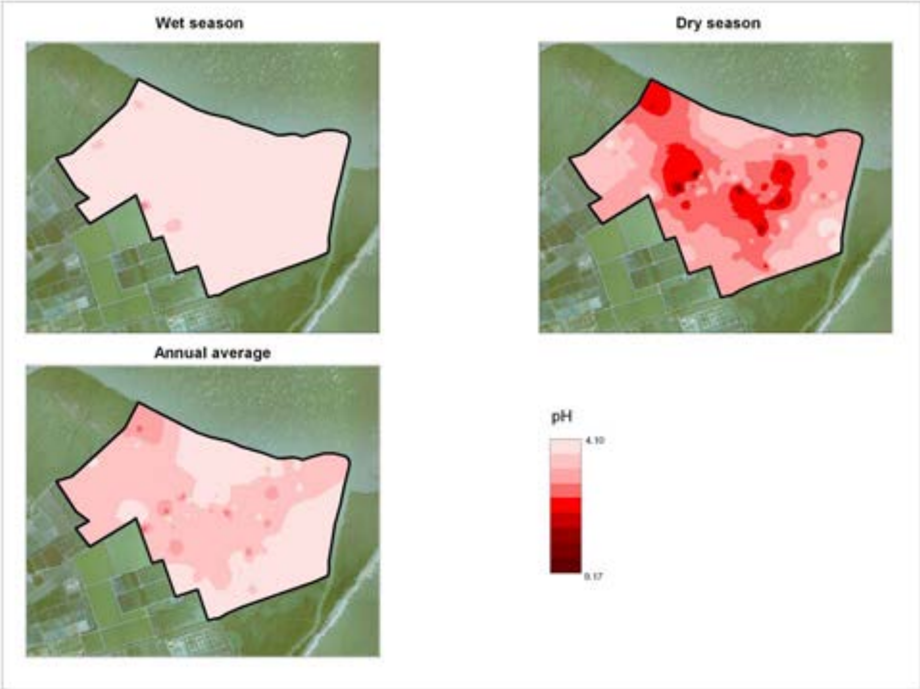

Figure 4-16 Spatial distribution map of the pH unit in water

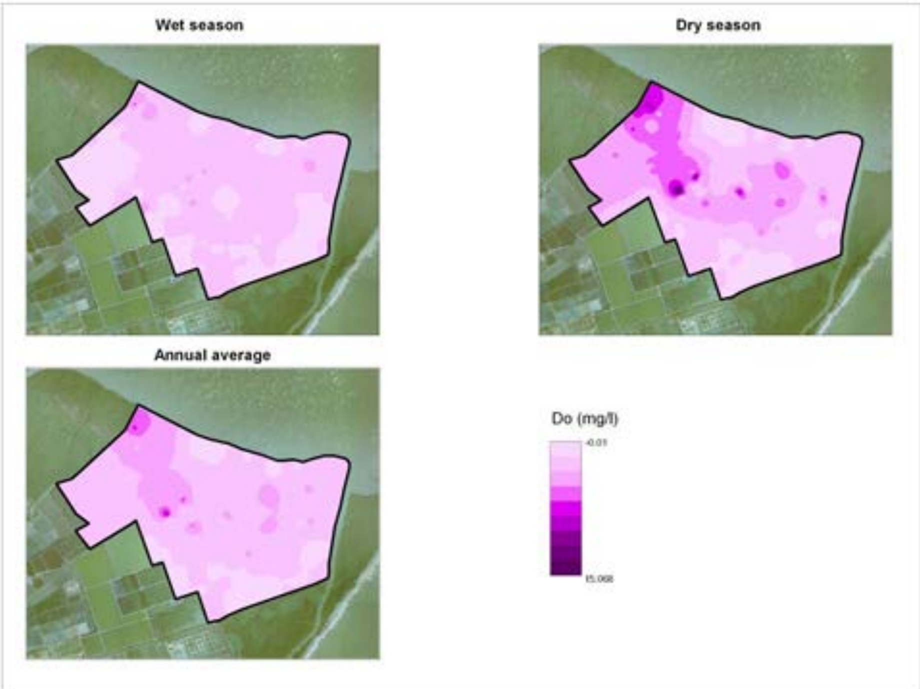

Figure 4-17 Spatial distribution map of the DO values in water

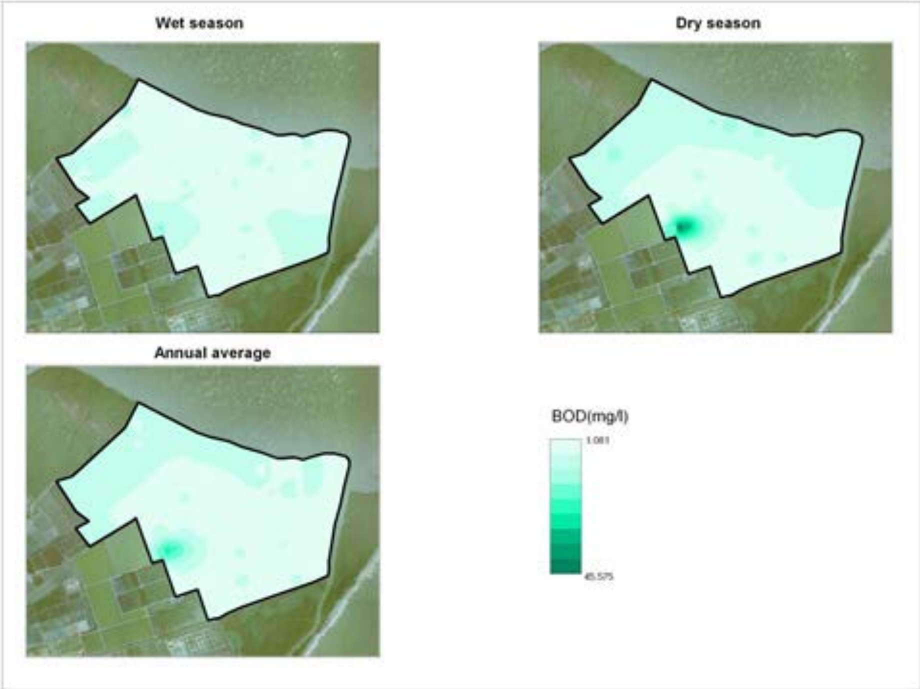

Figure 4-18 Spatial distribution map of the BOD values in water

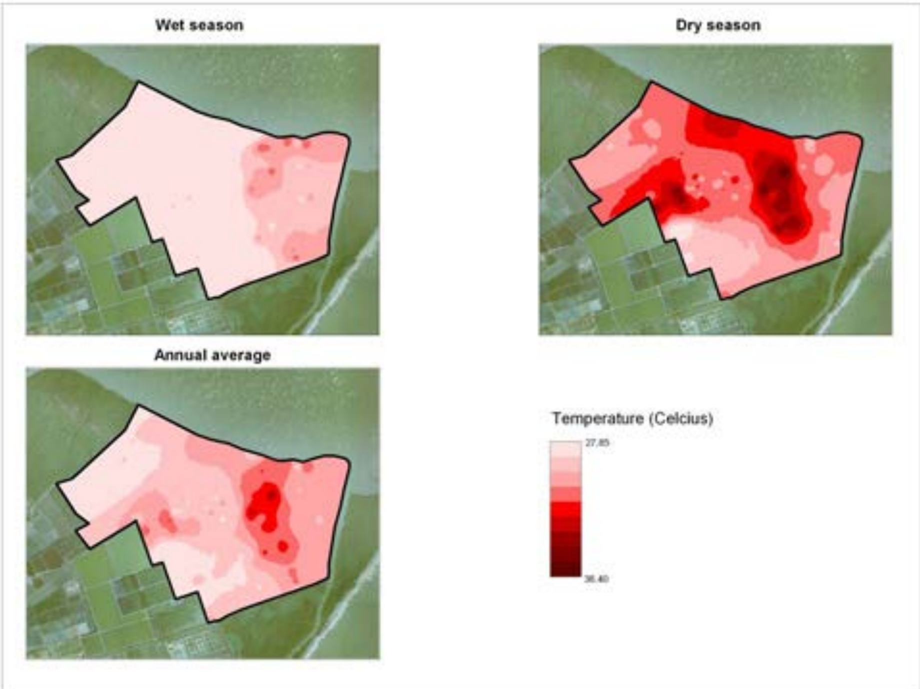

Figure 4-19 Spatial distribution map of the temperature in water

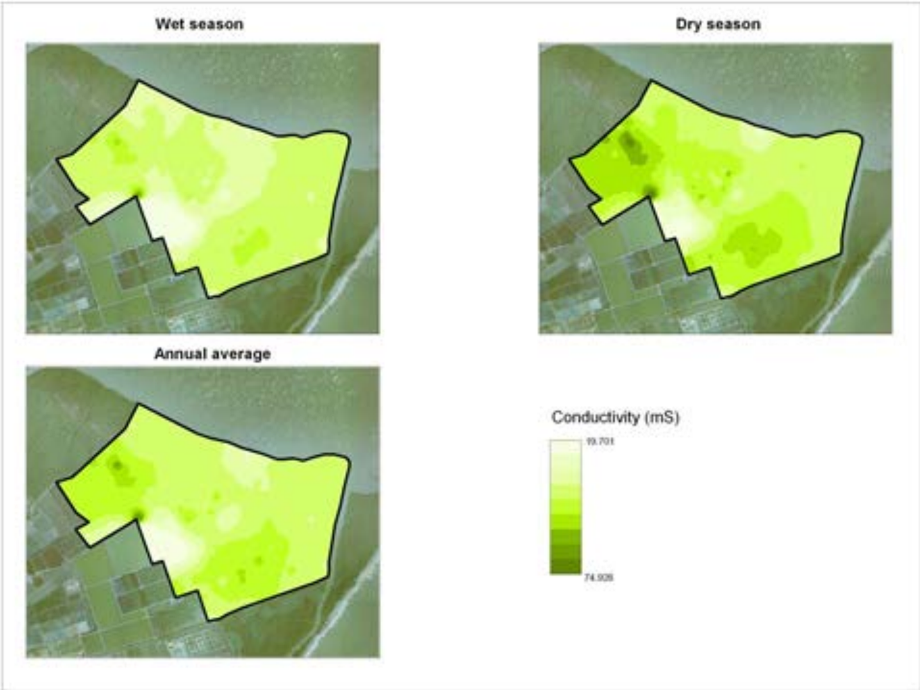

Figure 4-20 Spatial distribution map of the conductivity values in water

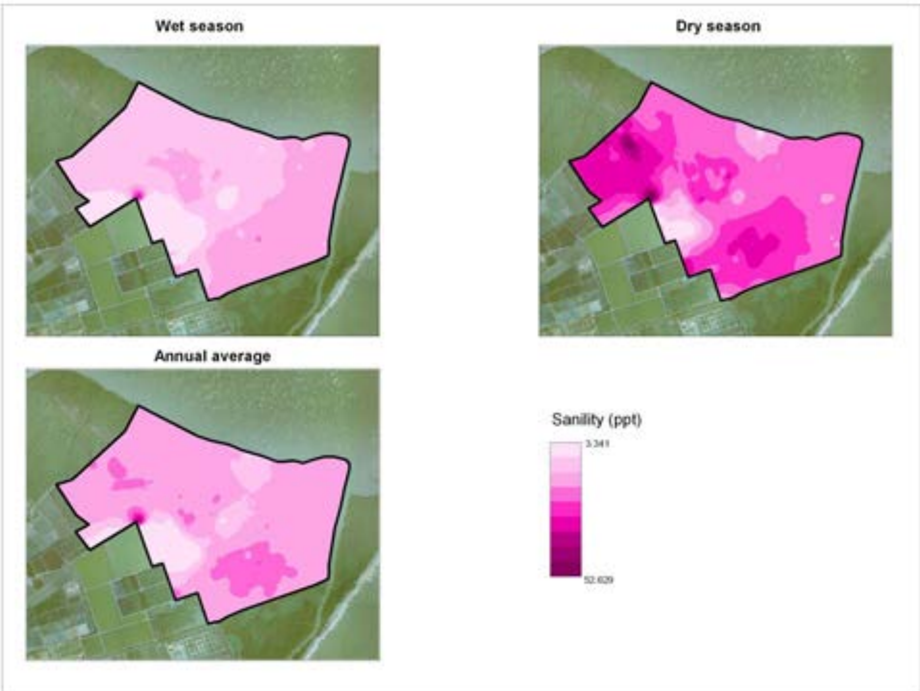

Figure 4-21 Spatial distribution map of the salinity values in water

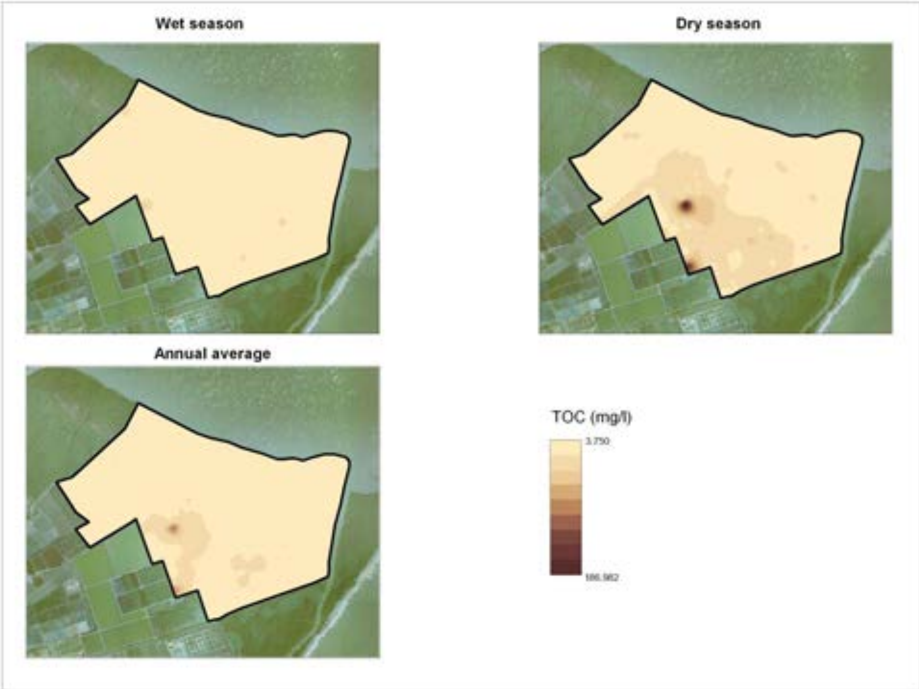

Figure 4-22 Spatial distribution map of the total organic values in water

4.3 Estimation of above-ground carbon sequestration in Mangrove Forest Filtration System

4.3.1 Tree Parameters Inventory Data

Table 4-3 Structural characteristics of the studies mangrove forests filtration system.

Parameter	Study area	Reference area
Mean height± SD (m)	4.40±2.68	2.58±2.66
Mean DBH± SD (cm)	9.07±5.33	6.23±6.06
Mean crown area± SD (m)	4.10±3.07	4.25±4.94
Mean volume± SD)(m^3)	0.75±0.43	0.54±0.52

From the field survey, the data demonstrated that the mean of tree high were 4.40 and 2.58 meters for study site and reference site respectively. These results showed significant of the higher of mean of tree high which found in study site higher than reference site approximately twice time. The mean of DBH found 9.07 and 6.23 centimeters for study site and reference site respectively, the finding of DBH showed the slightly higher value in study site. For crown area (meter) found the similar value in study and reference site with no significant of different were 4.10 and 4.25 square meters respectively. For the volume of tree found slightly higher in study site than reference site were 0.75 and 0.54 respectively. (Table 4-3)

4.3.2 Estimation of LAI

1) LAI equations

Table 4-4 Allometry Equations for Leaf Area estimation of the two species of dominance mangrove

Species of Mangrove	**Allometry Equations**	R^2
Avicennia marina	$U = 0.0102(D^2H)^{2.2034}$	0.98 (n=6)
Rhizophora mucronata	$U = 0.0499(D^2H)^{1.6692}$	0.88 (n=6)

Remarks: U = Leaf area (m^2)

D = diameters at breast height (cm)

H = height (m)

Two LAI equations are developed by field data collection which a method of on the basic of Japanese national forest surveys and satellite data analysis (Ishii et al ., 2001). The LAI measurements were calculated by measuring the DBH and the total of leaf area of each tree in the field plots and analyzed the strongly relationship between leaf area and diameter at breast high and tree high. The results of two algometry equations follow as Table 4-4

2) LAI values

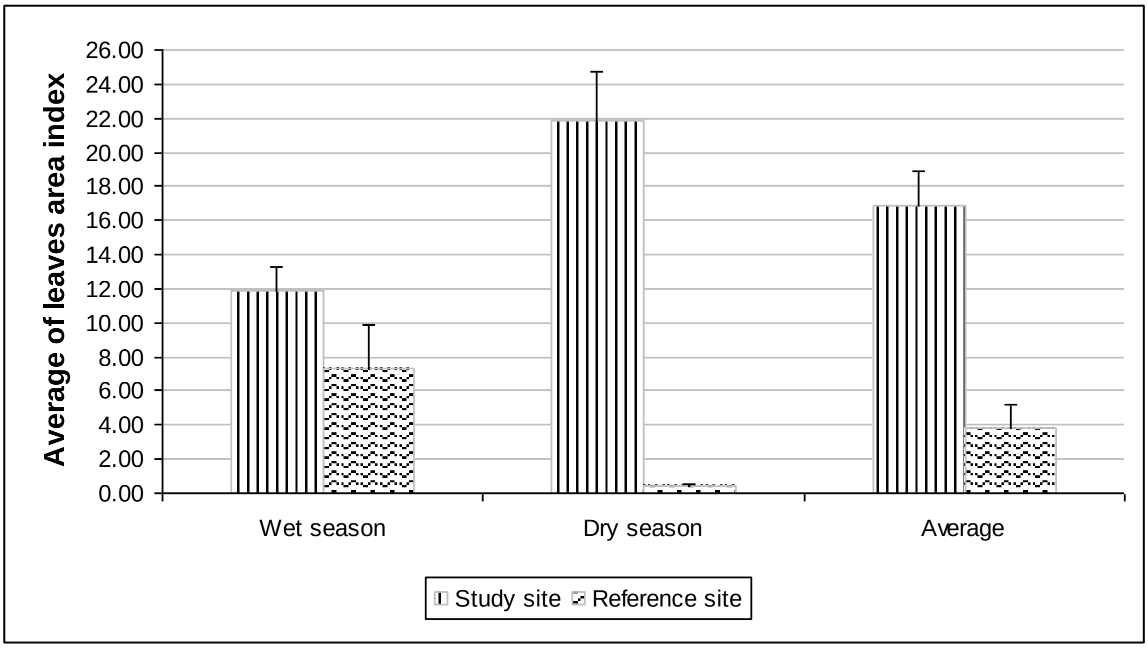

Figure 4-23 Histograms of leaf area index unit

The model was then used to estimate value of mangrove LAI for the entire image. For study site, LAI ranged from 0.00 to 28.01,with a mean value of 4.75 and 0.00 to 10.86, with a mean value of 1.909 . Thus this results demonstrated that the LAI in study site was higher than reference site (figure4-23). For results of seasonal variation showed that LAI was the highest in dry season in the both area. For finding of LAI was 0.00 value because of the died of mangrove tree (figure 1) From table 3, when we compare LAI results with the previously studies it demonstrated that this study have the highest and lowest LAI value with the nearly value of mean. The results of LAI of this studied have average maximum 17.67 and average minimum 0.00 and mean 4.757 meanwhile other studies showed as; Clough et al ., (1997) have previously published LAI values for mangrove from the west coast of peninsular Malaysia. They obtained indices ranging from 2.2 to 7.4 (mean 4.9) by direct measurement, and a mean value of 5.1 when LAI was estimated indirectly from light transmission measurements over four transects. Values of LAI derived from satellite data of Caribbean mangroves (0.83-7.00, mean 3.96). Clough and Phuong (2000) has studied canopy leaf area index of the mangrove *Rhizophora apiculata* in the Mekong data, Vietnam. They found that LAI ranging from 3.3 to 4.9. (Table4-5)

Table 4-5 Comparison of the average of LAI

References	Leaf area index(LAI)		
	Minimum	Maximum	Mean
Present paper	0.0	17.7	4.8
Araujo et al(1997)	3.0	5.7	-
Clough et al(1997)	2.2	7.4	4.9
Clough and Phuong(2000)	3.3	4.9	-

3) LAI Statistics values

Table 4-6 Statistic values of Leaf Area

Sites	**Season**	**Mean**	**S.D.**	**D**	**S.D.$_D$**	**t**	**Sig.**
Study site [1]	Wet season	11.94	11.64	9.91	15.46	5.73	0.000
	Dry season	21.85	25.50				
Reference site [2]	Wet season	7.34	9.40	6.96	9.05	2.34	0.010
	Dry season	0.38	0.39				

Remarks: N^1= 80

N^2= 15

Mean of LAI in study site was 11.94 and 21.85 in wet and dry season respectively, and Standard Deviation was 11.64 and 25.50 respectively. Testing of LAI values different between wet and dry season by t-test. The LAI in dry season is significantly higher (t-test, $P<0.01$) than in wet season.

Mean of LAI in reference site was 7.34 and 0.38 in wet and dry season respectively, and Standard Deviation was 9.40 and 0.39 respectively. Testing of LAI values different between wet and dry season by t-test. The LAI in wet season is significantly higher (t-test, $P<0.05$) than in dry season. (Table 4-6)

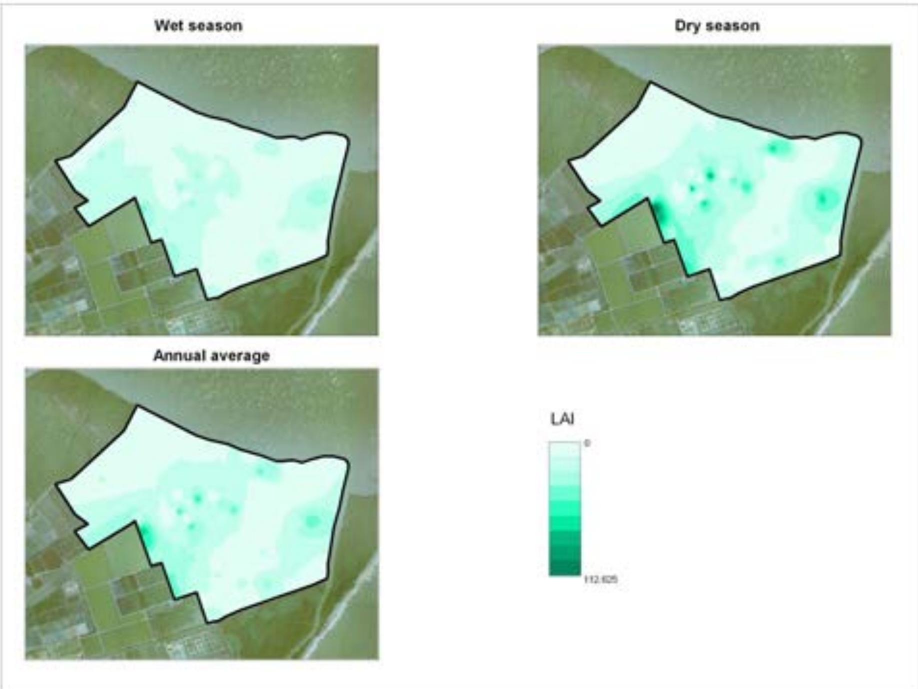

Figure 4-24 Spatial distribution map of Leaf Area Index values

4) Integrating Leaf Area Index into the mapping model

The parameters of the exponential model were used for the Kring method to produce the spatial distribution map of LAI content in soils of study area. For the spatial interpolation, a cell size of 100) m x 100 m was chosen to divide the study area into a grid system. A technique is presented here by which thematic maps of mangrove LAI can be derived accurately and precisely from remote sensed satellite data. The final result of this spatial interpolation process was shown as Figure 4-24 From the spatial distribution map of LAI. We can see that LAI values are highest lay on in Western and Eastern respectively. The density of LAI found the highest in dry season. From LAI spatial distribution map trend showed low density of LAI in area where has less of tree.

4.3.3 Above ground biomass estimation

1) The percentage of Carbon Content in each parts of tree.

Table 4-7 Average of carbon content (%) of *Rhizophora mucronata*

parts of tree	Average of carbon content (%) of *Rhizophora mucronata*	
	Study site	**Reference site**
roots	45.35	46.51
trunks	45.99	44.04
branches	45.87	43.73
leaves	43.19	48.23

Table 4-8 Average of carbon content (%) of *Avicennia marina*

parts of tree	Average of carbon content (%) of *Avicennia marina*	
	Study site	Reference site
trunks	44.55	44.18
branches	43.45	42.92
leaves	42.8	44.42

From Table 4-6 and Table 4-7 The results showed Carbon Content Percentage found in each part of tree in both study in reference site were have similar value and the comparison of Carbon Content Percentage in each part of study in reference site also found similar value in all parts.

2) Algometry Equations of the two species of dominance mangrove in the study

Allometric equations for the two species of dominance mangroves are developed from the field data of two mangrove species for the various regressions to compute common regressions based on the comparison results then determining the best regression model to estimate the total above- ground biomass and compartment biomass follow by law of allometric method. The results of two allometric equations are created follow in Table 4-9

Table 4-9 Algometry Equations for biomass estimation of the two species of dominance mangrove

Species of Mangrove	Allometry Equations	R^2
Avicennia marina	$W_L = 0.3161(D^2H)^{0.5119}$	0.97
	$W_B = 0.3737(D^2H)^{0.5186}$	0.97
	$W_S = 0.0019(D^2H)^{2.4514}$	0.77
	$D_{max} = 4.14$ cm, n=6	
Rhizophora mucronata	$W_L = 0.459(D^2H)^{0.4487}$	0.90
	$W_B = 0.6797(D^2H)^{0.276}$	0.97
	$W_S = 0.9926(D^2H)^{0.2141}$	0.99
	$W_R = 0.2838(D^2H)^{0.8308}$	0.99
	$D_{max} = 3$ cm, n=6	

Remarks: D = diameters at breast height (cm) H = height (m)

W_S = biomass of stem (kg) W_B= biomass of branches (kg)

W_L = biomass of leaf (kg) W_R= biomass of tree roots (kg)

3) Above ground biomass value

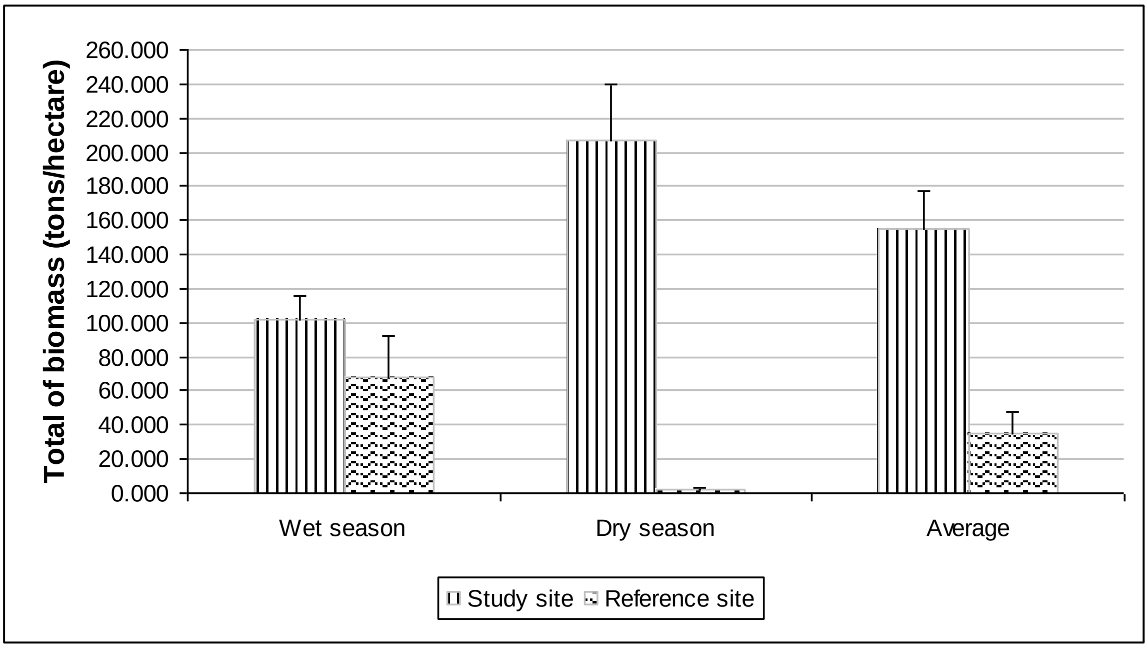

Figure 4-25 Histograms of above ground biomass

From above Algometry equations, (Table 4-9) they were calculated the above ground biomass. For the estimation of the total biomass has maximum valve 3.63 and 5.77 tons per hectare for study site and reference site respectively and has the similar value on minimum value 0.00 for both study and reference site. The seasonal variation of above ground biomass found that in winter and summer biomass have significantly higher in rainy season.

From the spatial distribution map of above ground biomass We can see that above ground biomass values are highest in fresh water outlet area where found the content of above ground biomass the highest in dry season whereas slightly in wet esason.

4) Above Ground Biomass (AGB) (t ha^{-1}) Statistics values

Table 4- 10 Above Ground Biomass (AGB) (t ha^{-1}) Statistics values

Sites	Season	Mean	S.D.	D	$S.D._D$	t	Sig.
Study site [1]	Wet season	102.30	121.33	104.63	183.50	5.1	0.000
	Dry season	206.93	290.59				
Reference site [2]	Wet season	67.68	90.560	65.18	88.21	2.86	0.013
	Dry season	2.50	2.66				

Remarks: N^1= 80

N^2= 15

Mean of Above Ground Biomass in study site was 102.30 and 206.93 t ha^{-1} in wet and dry season respectively, and Standard Deviation was 121.33 and 290.59 respectively. Testing of AGB values different between wet and dry season by t-test. The AGB in dry season is significantly higher (t-test, $P<0.01$) than in wet season.

Mean of Above Ground Biomass in reference site was 67.68 and 2.50 t ha^{-1} in wet and dry season respectively, and Standard Deviation was 90.56 and 2.66 respectively. Testing of AGB values different between wet and dry season by t-test. The AGB in wet season is significantly higher (t-test, $P<0.05$) than in dry season.

5) Integrating Above Ground Biomass into the mapping model

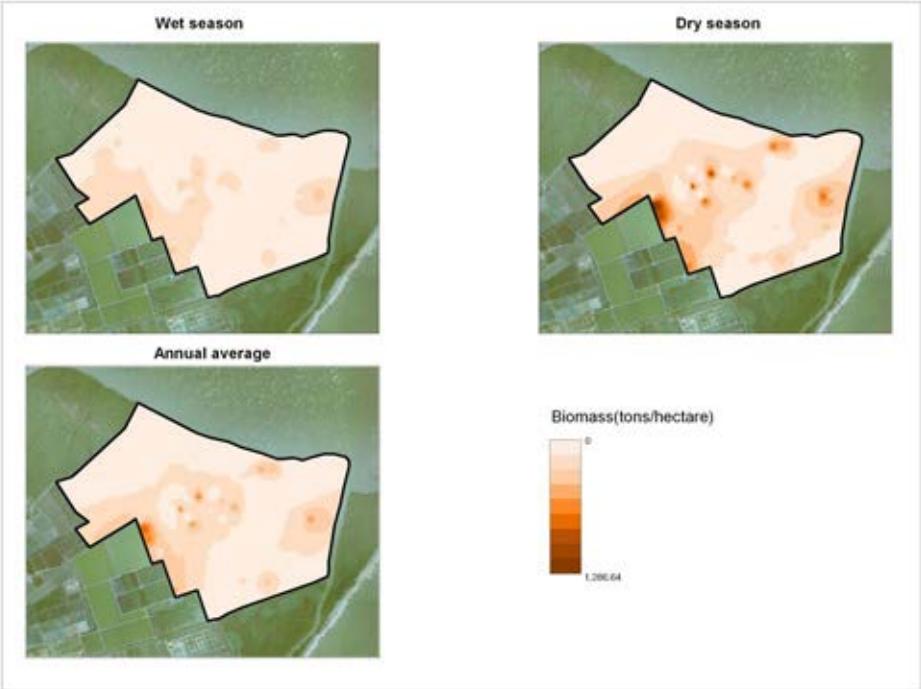

Figure 4-26 Spatial distribution map of Above Ground Biomass

The parameters of the exponential model were used for the Kring method to produce the spatial distribution map of AGB content in study area. For the spatial interpolation, a cell size of 100) m x 100 m was chosen to divide the study area into a grid system. A technique is presented here by which thematic maps of mangrove AGB can be derived accurately and precisely from remote sensed satellite data. The final result of this spatial interpolation process was shown as Figure 4-26 From the spatial distribution map of AGB. We can see that AGB values are highest lay on in Western and Eastern respectively. The density of AGB found the highest in dry season. From AGB spatial distribution map trend showed low density of LAI in area where has less of tree.

4.3.4 Above ground carbon estimation

1) Above ground carbon sequestration

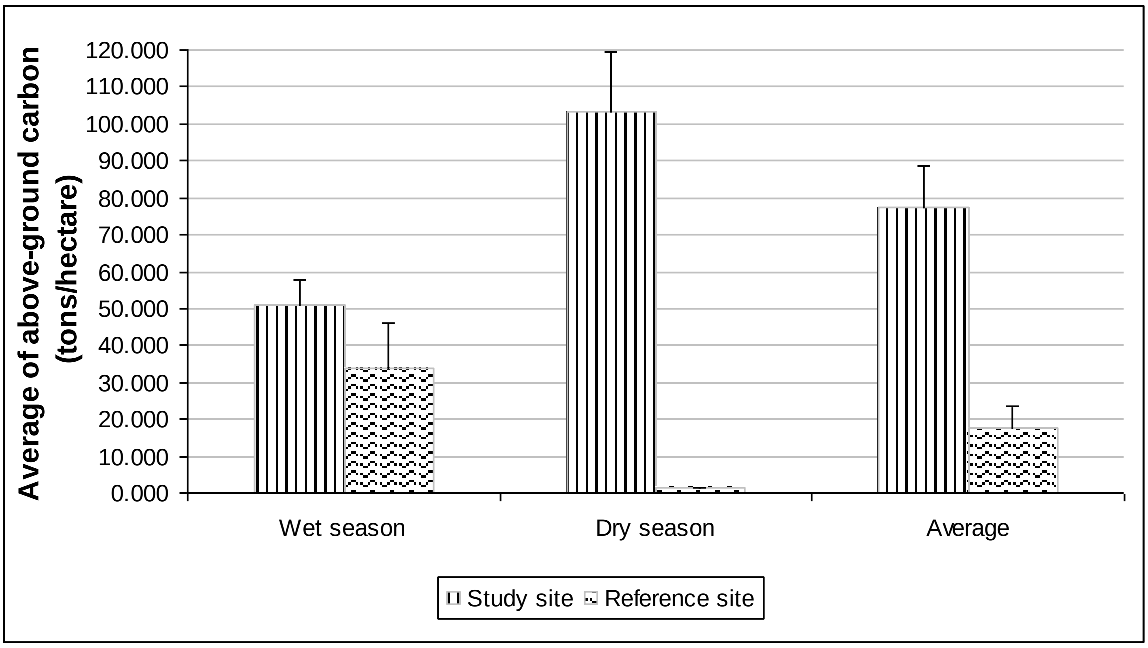

Figure 4-27 Histograms of above ground carbon

From above ground biomass and carbon content were conducted to above ground carbon. The highest of above ground carbon was found in study site with maximum 14.58 tons per hectare in rainy whereas found only 2.78 tons per hectare in summer for reference site. When we compare the average of above ground carbon between study and reference site found the study site have higher above ground carbon than reference site reach to five times. When we calculate the total of above ground carbon in study area found the above ground carbon sequestration in this area was 320.11 tons. When we compare with the previously researches, the results of this research showed the above ground carbon sequestration higher than all researches as showed in Table C-16,C-17,C-18andC-19.

2) Above Ground Carbon (AGC) (t ha^{-1}) Statistics values

Table 4-11 Above Ground Carbon (AGC) (t ha^{-1}) Statistics values

Sites	Season	Mean	S.D.	D	S.D.$_D$	t	Sig.
Study site [1]	Wet season	51.15	60.67	104.63	183.50	5.10	0.000
	Dry season	103.38	145.31				
Reference site [2]	Wet season	33.84	45.28	52.23	91.77	5.10	0.013
	Dry season	1.24	1.32				

Remarks: N^1= 80

N^2= 15

Mean of Above Ground Carbon in study site was 51.15 and 103.38 t ha^{-1} in wet and dry season respectively, and Standard Deviation was 60.67 and 145.31 respectively. Testing of AGC values different between wet and dry season by t-test. The AGC in dry season is significantly higher (t-test, $P<0.01$) than in wet season.

Mean of Above Ground Carbon in reference site was 33.84 and 1.24 t ha^{-1} in wet and dry season respectively, and Standard Deviation was 45.28 and 1.32 respectively. Testing of AGB values different between wet and dry season by t-test. The AGC in wet season is significantly higher (t-test, $P<0.05$) than in dry season.

3) **Integrating Above Ground Carbon into the mapping model**

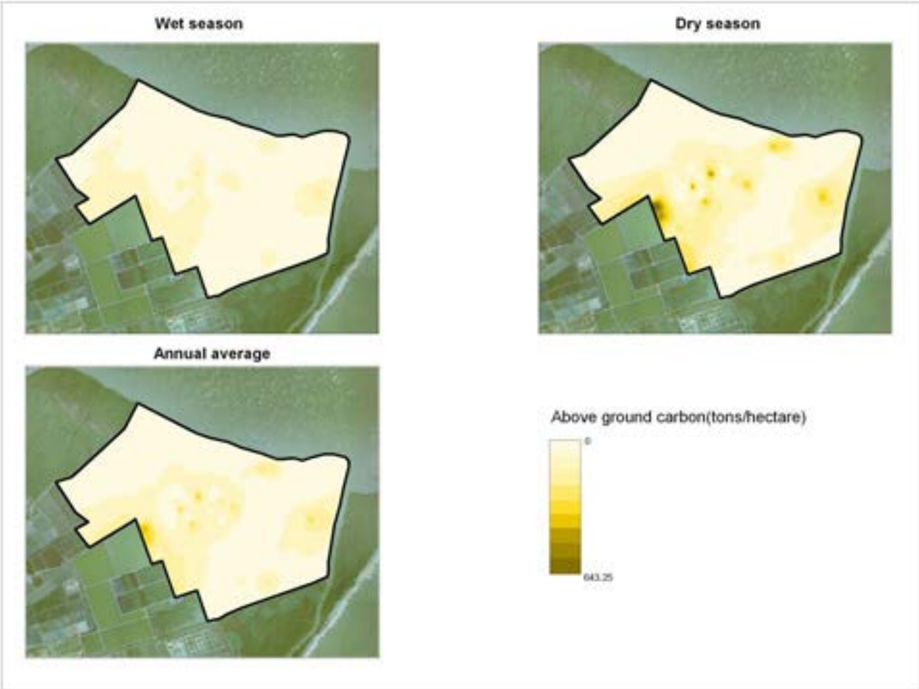

Figure 4-28 Spatial distribution map of Above Ground Biomass

From the spatial distribution map of above ground carbon We can see that above ground carbon values are highest in fresh water outlet area where found the content of above ground carbon highest in dry season whereas slightly in rainy same as above ground biomass.

4.4 Application of the high resolution satellite imaginary for the estimation of above -ground carbon sequestration in the mangrove forest filtration system

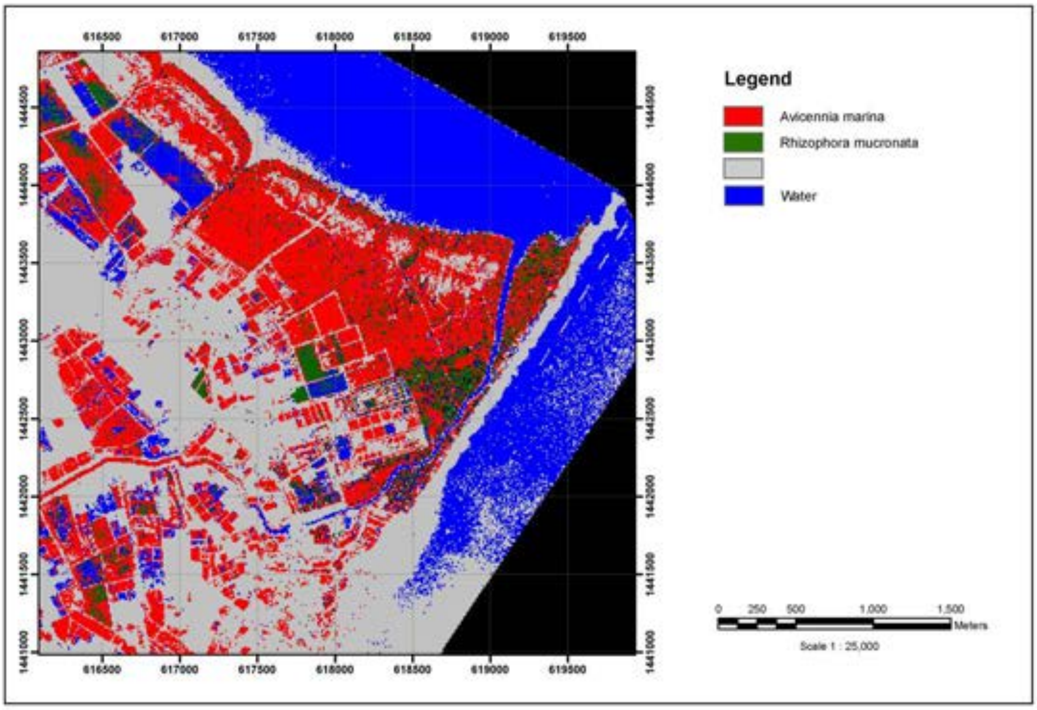

Figure 4-29 Classification mapping of the two dominant species in the study area from Quickbird satellite image.

4.4.1 Data Analysis Results

When we taken the carbon sequestrations equations from three satellite images to calculate the quantities of carbon sequestration. It was showed 320.11 ton-carbon per hectare (study area is 10.33 sq.kilometers). When we compared with Sridang (2008) who studied above ground carbon stock at Lanta Island, Krabi provence.(study area is 36.85 sq.kilometers) using we taken the carbon sequestrations equations from Landsat TM5 imaginary by the simple ratio and NDVI. The research showed the quantities of carbon sequestration was 71.10 ton-carbon per hectare. The present study was showed the quantities of carbon sequestration higher than Sridang"s research near three times.

This research also used Quickbird imaginary for classification of the two dominate species of mangroves, the classification map showed the distribution of two dominant species of *Rhizophora mucronata* and *Avicennia marina* where found the *Rhizophora mucronata* in brackish water near the cannel and the wastewater discharge point whereas *Avicennia marina* found its distribution in the almost studied area where the first stage of sediment area.

4.4.2 Vegetation indices value mapping

1) NDVI analysis

NDVI in the studied area where the dark green (0.51to1.00) means the abundance mangrove forest area, the slightly green (0.001to0.5) means the light mangrove forest area, and the orange (0-0.49 to0.00) means the water and bare area.

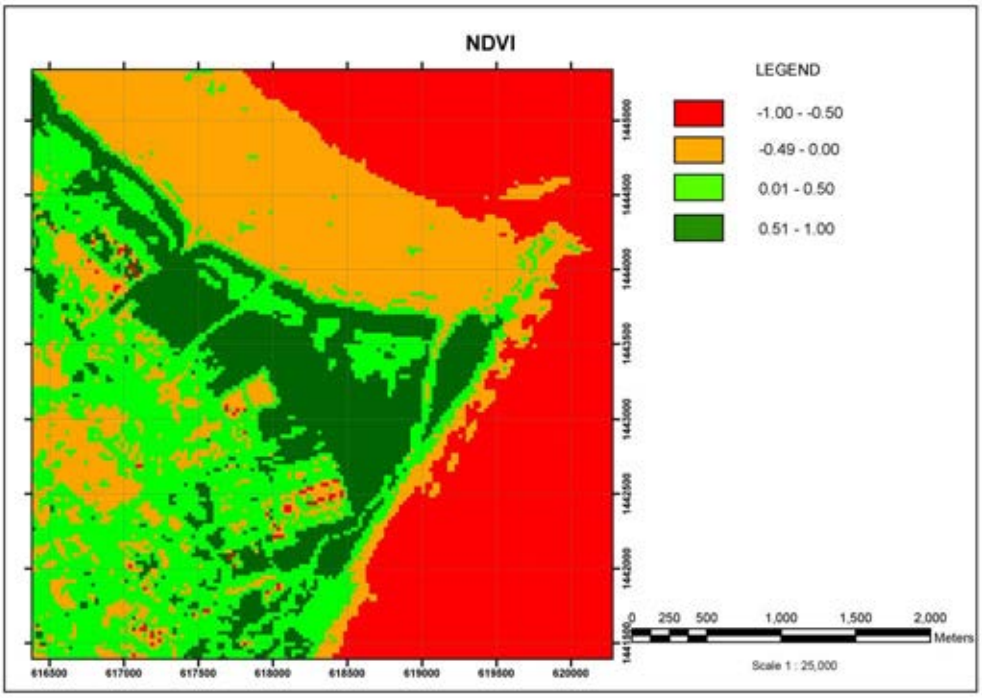

Figure 4-30 NDVI distribution mapping in the study area from Landsat TM5 satellite image

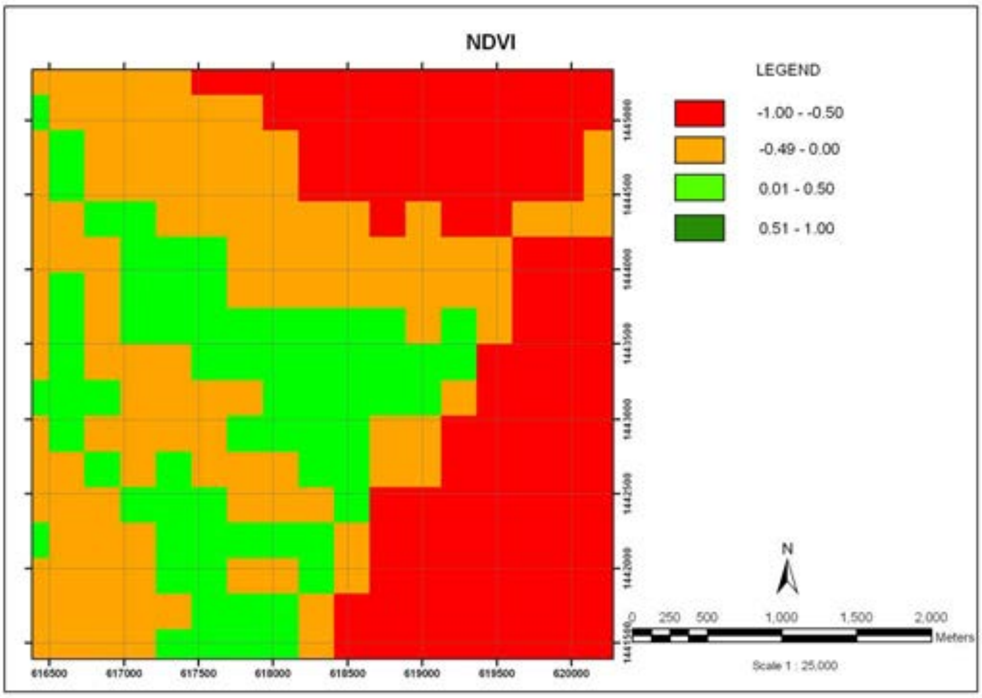

Figure 4-31 NDVI distribution mapping in the study area from THEOS satellite image

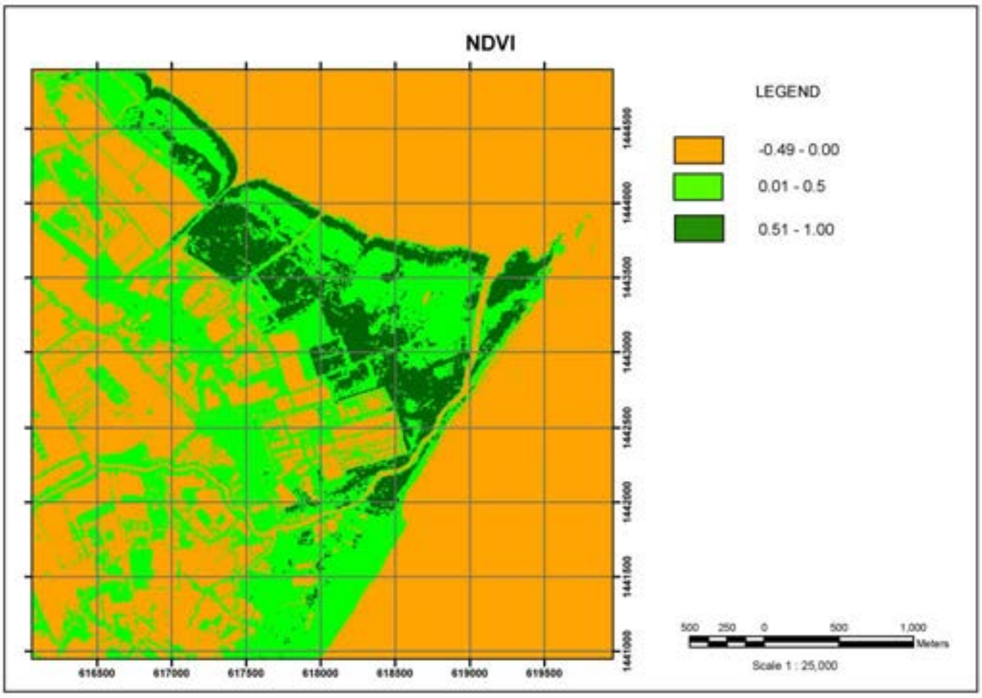

Figure 4-32 NDVI distribution mapping in the study area from Quickbird satellite image

2) DVI analysis

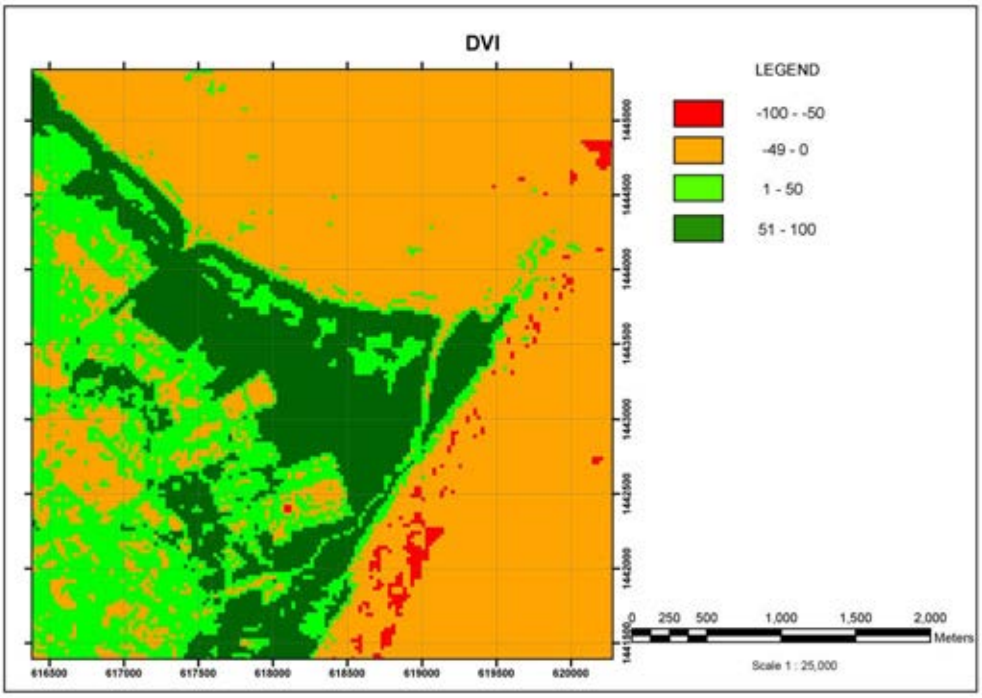

Figure 4-33 DVI distribution mapping in the study area from Landsat TM5 satellite image

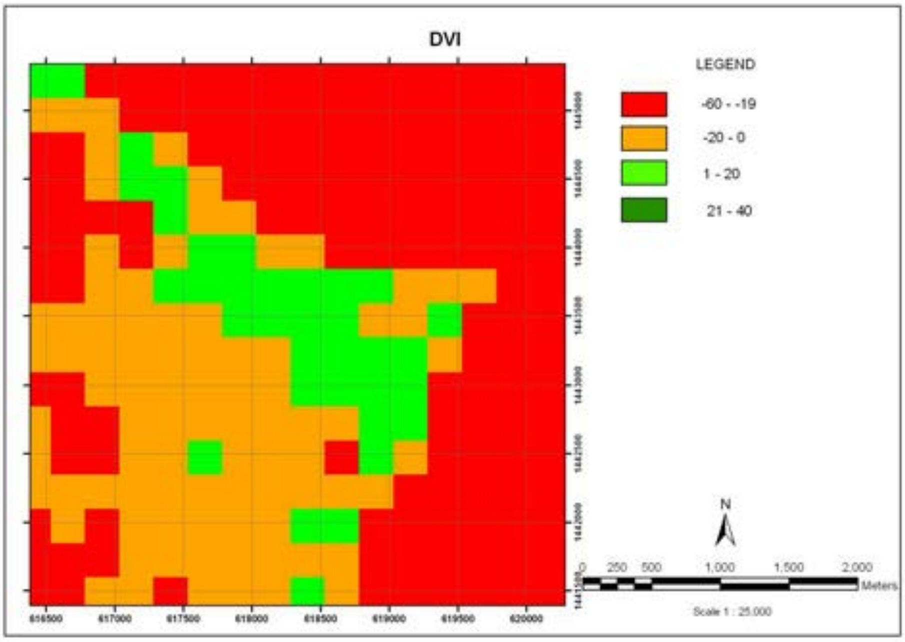

Figure 4-34 DVI distribution mapping in the study area from THOSE satellite image

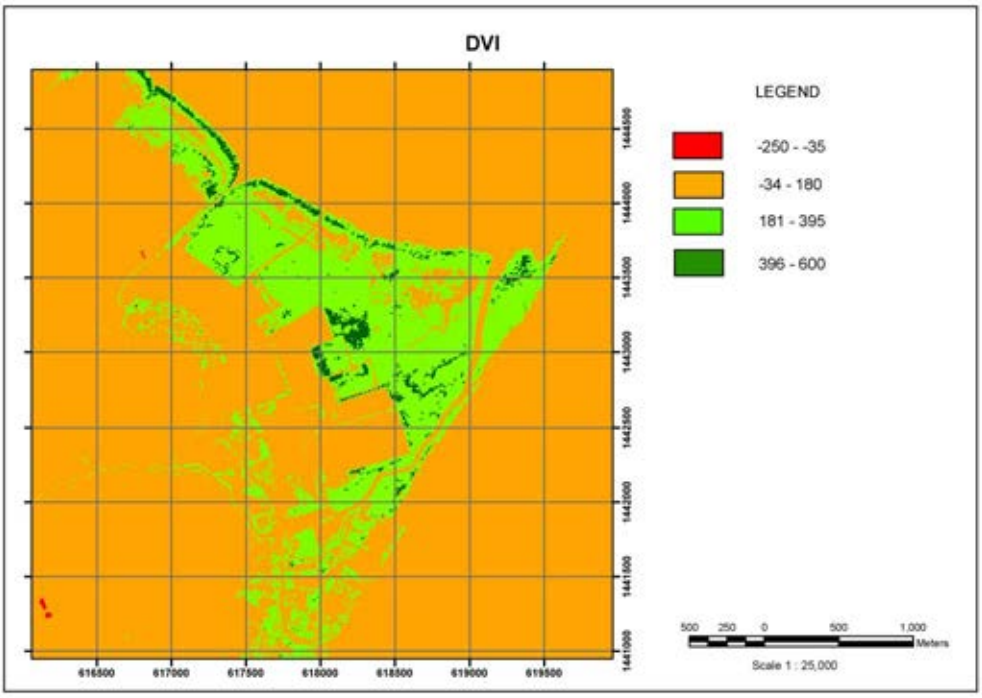

Figure 4-35 DVI distribution mapping in the study area from Quickbird satellite image

DVI in the studied area where the dark green (396to600) means the abundance mangrove forest area, the slightly green (181to395) means the light mangrove forest area, and the orange (-34 to 180) means the water and bare area.

3) **RVI analysis**

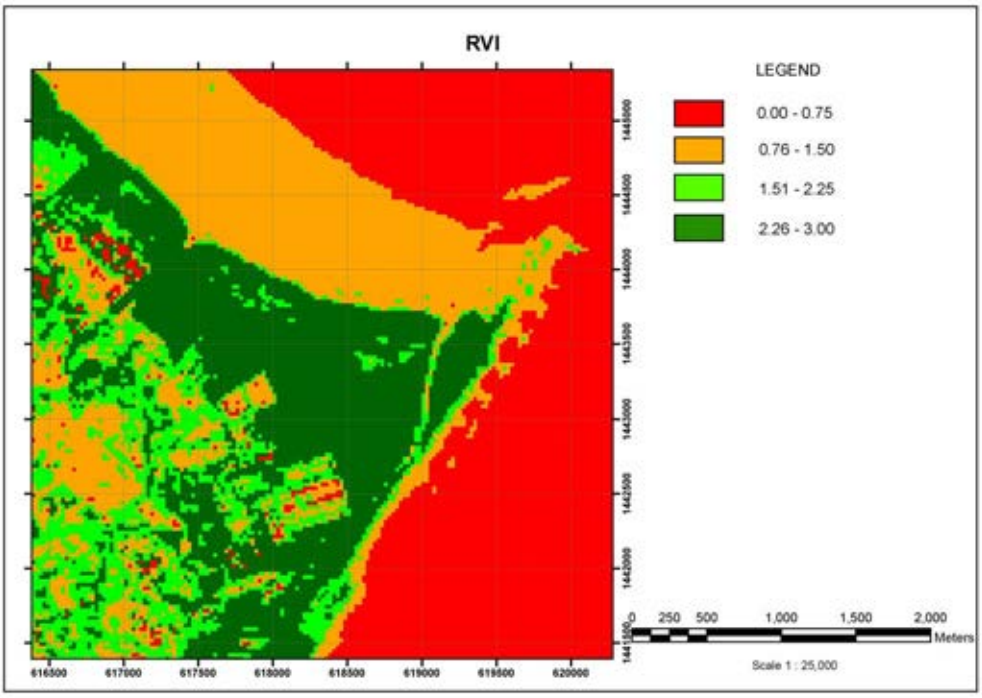

Figure 4-36 RVI distribution mapping in the study area from Landsat TM5 satellite image

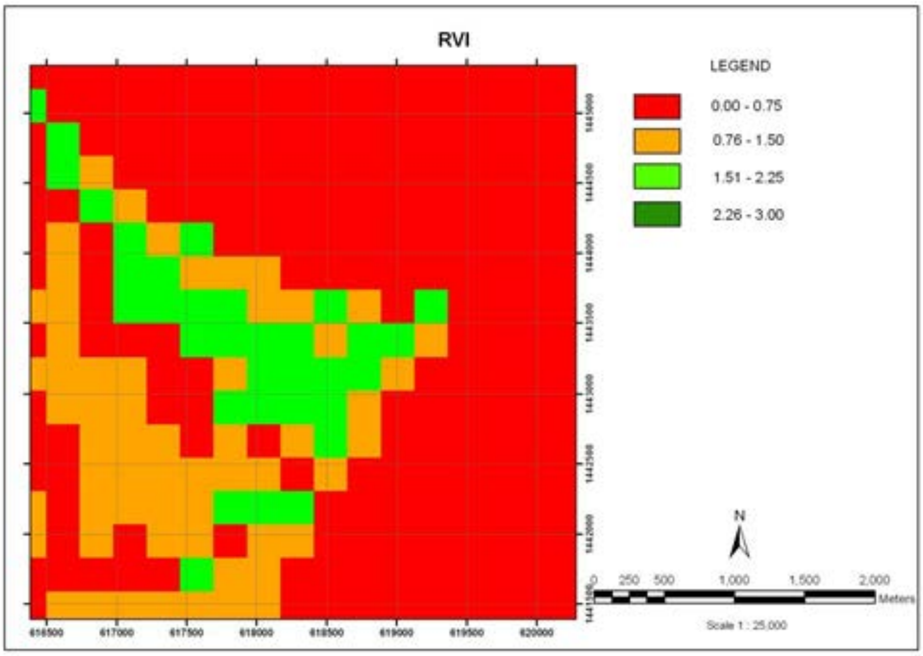

Figure 4-37 RVI distribution mapping in the study area from THOSE satellite image

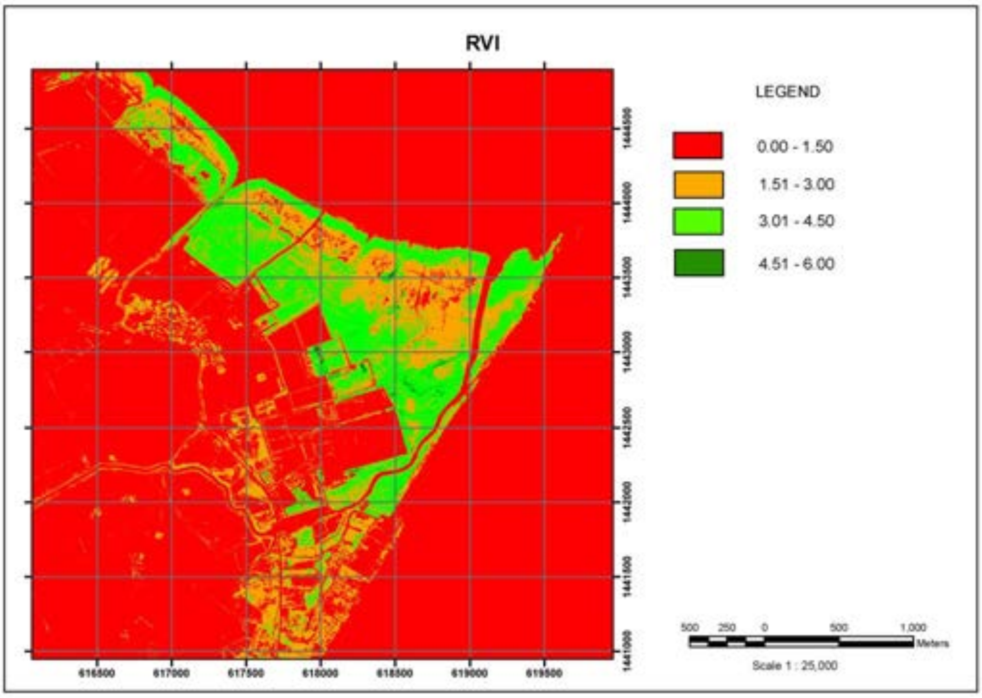

Figure 4-38 NDVI distribution mapping in the study area from Quickbird satellite image

RVI in the studied area where the dark green (4.51to6) means the dense mangrove forest area, the slightly green (3.01to4.5) means the sparsely mangrove forest area, and the orange (1.51to3.00) means the deepness flood area. The red (0.00to1.50) means the water and bare area.

4.4.3 The relationship between vegetation indices (VI) and mangrove biological parameters

The regression equation models for each predictor variables of the sample plots. The regression equation linear model presented relating to each predictor variable namely; NDVI, RVI and DVI with R^2 values. The correlation of NDVI and LAI in the studied site and reference site showed R^2 equal to 0.0134 and 0.1132 respectively where as DVI and NDVI in the in the studied site and reference site showed R^2 equal to 0.0151 and 0.1493 respectively,and RVI and LAI in the in the studied site and reference site showed R^2 equal to 0.016 and 0.097 respectively.

The correlation of NDVI and total biomass in the studied site and reference site showed R^2 equal to 0.0076 and 0.0983 respectively where as DVI and total biomass in the in the studied site and reference site showed R^2 equal to0.0005 and 0.0951 respectively and RVI and total biomass in the in the studied site and reference site showed R^2 equal to 0.0008 and 0.0698 respectively .

The correlation of NDVI and above ground carbon in the studied site and reference site showed R^2 equal to 0.1164 and 0.0983 respectively where as DVI and above ground carbon in the in the studied site and reference site showed R^2 equal to0.1119 and 0.0.0951 respectively and RVI and above ground carbon in the in the studied site and reference site showed R^2 equal to 0.1452 and 0.0.0698 respectively .

Using a geometrically corrected Quickbird satellite image, the mean values for all of the NDVI, TVI and DVI vegetation indices were also calculated for each plot. There were revealed no significant relationship between vegetation indices (VI) and mangrove biological parameters. On the other hand ,several authors have published positive correlations among in situ Leaf Area Index (LAI) estimates and vegetation indices derived from satellite imagery(Ramsey and Jensen,1996; Green et al ., 1997 and Kovacs et al.,2004)It was contrariwise theory may be occurs from measurement and field work including to band operation processing.

4.5 Development of predictive models for estimating carbon sequestration in mangrove forest filtration system.

4.5.1 Development of Soil Organic Carbon models

From the study of regression model and independent variables test for the estimation of soil organic carbon in the mangrove filtration system found the relationship between pH unit and SOC at R^2 equal to 0.5778 and 0.0047 for studied and reference site respectively, the relationship between O.M. and SOC at R^2 equal to

0.8046 and 0.8173 for studied and reference site respectively, and the relationship between O.C. and SOC at R^2 equal to 0.8126 and 0.7626 for studied and reference site respectively.

From the table 1, it demonstrated that in the studied site have stronger relation than reference site especially the percent of organic carbon had the positive correlation between soil organic carbon.

4.5.2 Development of Total Organic Carbon models

From the study of regression model and independent variables test for the estimation of total organic carbon in the mangrove filtration system found the relationship between pH unit and SOC at R^2 equal to 0.353 and 0.0202 for studied and reference site respectively, the relationship between TOC and BOD at R^2 equal to 0.0017 and 0.3844 for studied and reference site respectively, and the relationship between TOC and conductivity at R^2 equal to 0.0002 and 0.0043 for studied and reference site respectively, and the relationship between TOC and DO at R^2 equal to 0.0025 and 0.0177 for studied and reference site respectively, and the relationship between TOC and salinity at R^2 equal to 0.0068 and 0.00002 for studied and reference site respectively, and the relationship between TOC and temperature at R^2 equal to 0.0106 and 0.005 for studied and reference site respectively.

4.5.3 Development of Leaf Area Index models

From the study of regression model and independent variables test for the estimation of LAI in the mangrove filtration system found the relationship between LAI unit and NDVI at R^2 equal to 0.0134 and 0.1132 for studied and reference site respectively, the relationship between LAI and RVI at R^2 equal to 0.0160 and 0.0970 for studied and reference site respectively, and the relationship between LAI and DVI at R^2 equal to 0.0151 and 0.1493 for studied and reference site respectively(Table 3)

4.5.4 Development of Above ground biomass models

From the study of regression model and independent variables test for the estimation of biomass in the mangrove filtration system found the relationship between biomass and NDVI at R^2 equal to 0.0072 and 0.0983 for studied and reference site respectively, the relationship between biomass and RVI at R^2 equal to 0.0008 and 0.0698 for studied and reference site respectively, and the relationship between biomass and DVI at R^2 equal to 0.0005 and 0.0951 for studied and reference site respectively.(Table 4)

4.5.5 Development of Above ground carbon sequestration models

From the study of regression model and independent variables test for the estimation of above ground carbon in the mangrove filtration system found the relationship between above ground carbon and NDVI at R^2 equal to 0.1164 and 0.0983 for studied and reference site respectively, the relationship between above ground carbon and RVI at R^2 equal to 0.1452 and 0.0698 for studied and reference site respectively, and the relationship between above ground carbon and DVI at R^2 equal to 0.1190 and 0.0951 for studied and reference site respectively.(Table 5)

Table 4-12 Regression models and independent variables tested for the development of models for the estimation of mangrove species soil organic carbon

Sites	**Lineal regression model**	R^2
Study Site	SOC= -0.2436pH + 2.1815	0.5778
	SOC= 0.0557O.M. + 0.0628	0.8046
	SOC=0.0815O.C.+0.0661	0.8126
Reference Site	SOC= 0.07pH-0.3165	0.0047
	SOC= 0.0535O.M. + 0.0262	0.8173
	SOC=0.0727O.C.+0.042	0.7626

Table 4-13 Regression models and independent variables tested for the development of models for the estimation of mangrove species total organic carbon

Sites	Lineal regression model	R^2
Study Site	TOC= 0.1441BOD+18.435	0.0017
	TOC= -0.0237conductivity. +20.422	0.0002
	TOC=-0.4764DO+20.301	0.0025
	TOC=12.126pH-73.666	0.0353
	TOC=-0.1611sanility+24.0.53	0.0068
	TOC=-0.9116Temperature+48.222	0.0106
Reference Site	TOC= 1.298BOD+8.6417	0.3844
	TOC= 0.0746conductivity. +13.876	0.0043
	TOC=-0.4979DO+19.404	0.0177
	TOC= -6.0429pH+64.34	0.0202
	TOC= -0.0142sanility +18.254	0.00002
	TOC=-0.5996temperature+35.883	0.005

Table 4-14 Regression models and independent variables tested for the development of models for the estimation of mangrove species leaf area index

Sites	Lineal regression model	R^2
Study Site	LAI= -3.7022 NDVI+6.4106	0.0134
	LAI =-0.6608RVI+6.5577	0.0160
	LAI =-0.0047DVI+6.0033	0.0151
Reference Site	LAI= 5.8516NDVI-0.486	0.1132
	LAI =1.0955RVI-0.909	0.0970
	LAI =0.0089DVI-0.4589	0.1493

Table 4-15 Regression models and independent variables tested for the development of models for the estimation of mangrove species biomass

Sites	Lineal regression model	R^2
	Biomass = -71.702NDVI+47.72	0.0072
Study Site	Biomass =3.7481RVI+5.4718	0.0008
	Biomass =0.0225DVI+9.6339	0.0005
	Biomass = 3.9599NDVI+0.2734	0.0983
Reference Site	Biomass =0.6746RVI+0.1588	0.0698
	Biomass =0.0052DVI+0.5221	0.0951

Table 4-16 Regression models and independent variables tested for the development of models for the estimation of mangrove species above ground carbon

Sites	Lineal regression model	R^2
	Above-ground carbon = 789 NDVI-101.48	0.1164
Study Site	Above-ground carbon =144.12RVI-141.82	0.1452
	Above-ground carbon =0.923DVI+5.4882	0.1190
	Above-ground carbon = 176.41NDVI+12.181	0.0983
Reference Site	Above-ground carbon =30.054RVI+7.0758	0.0698
	Above-ground carbon =0.2308DVI+23.258	0.0951

Table 4-17 Final models for the estimation of total and by-compartments carbon sequestration for mangrove forest filtration system.

compartments	Lineal regression models	R^2
soil	Soil Organic Carbon = 0.0535 Organic Matter+0.0262	0.8173
water	Total Organic Carbon = 1.298 Biochemical Oxygen Demand+8.6417	0.3844
mangrove tree	Above Ground Carbon = 144.12 the Ratio Vegetation Index-141.82	0.1452

4.6 Application and management

In general, the field survey of mangrove biomass and productivity is rather difficult, destructive ecology system, take more time and use a lot money then this study is confirm about the potential of model which can be used for carbon sequestration prediction and it can be applied as a management tool for field survey data collection.

In the framework of the Kyoto mechanism, reforest and forest plantation are expected to be one of the choice of CDM project then the quantities of carbon sequestration in mangrove ecosystem is expected to sink CO_2 in atmosphere into it.

The influences factors for carbon sequestration can be apply for increasing of the rate of carbon accumulates in mangrove forests.

CHAPTER V
CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

This study showed the potential of the mangrove filtration system for above ground carbon sequestration and how to estimate above ground carbon from field data and high resolution satellite imaginary. The achieved results demonstrate the potential of carbon stock sources. The study proved that it is possible to apply the mangrove filtration system area for carbon sequestration projects.

The result that was determined shows very strong confirms. The biological potential for increasing soil organic carbon which according to Sangrungruang et. Al., 2006 who studied on water treatment of shrimp farms effluent by some mangrove plants in Kung Krabean Bay Royal Development study central area they strongly confirmed that mangrove forests can be absorb and discharge the nutrients particularly, carbon throughout the environment.

Moreover visualization tools are important because they provide readily understandable results. The model that was developed shows the relationships between the field data and above ground carbon estimation. However, It is essential that these models be tested against measured data, especially from long-term researches.

5.1 Estimation of Soil Organic Carbon Concentration Accumulated in Mangrove Forest Filtration System

This study demonstrated that mangrove filtration system site acts as a carbon sink in the accumulation of carbon in its sediment. Increasing the soil carbon sequestration capacity can benefit to the mitigation of global warming which potential decreasing the concentration of carbon emit to atmosphere. The SOC concentration was highly correlation with soil properties. It indicates that improvement of soil structure properties is important to sequestration of carbon. These findings confirmed that soil organic carbon depositions have positive effects on the mangrove filtration system. Moreover, the mangrove filtration system are potential strategies to increase SOC. Accordingly, Mckee and Faulkner, 2000 ; Bosire et al ., 2008 concluded that mangrove are also under increasing stress from anthropogenic pollution and nutrient inputs, and have been considered efficient systems for the removal of nutrients and other anthropogenic pollutants. Moreover, Kristensen et al ., 2008 confirmed that a more fundamental understanding of nutrient cycling and factors influencing the nutrient processing pathways will be important in enabling us to determine the carring capacity of these ecosystems and the long-term response to inevitable futher increased inputs of nutrients in tropical coastal ecosystems. Additional sampling and spatial statistical techniques such as the Kriging method can be applied to achieve the full picture. The results of this study highlight the differences associated with the spatial distribution od SOC between study and reference sites. The differences associated with the various factors within the area. In conclusion, this study demonstrated Soil Organic Carbon (SOC) conservation is important to sustainable management in tropical soils which potential decreasing the concentrations of carbon emit to atmosphere. Afforestation with fast-growing tree can produce large amounts of biomass can increase SOC content and be a feasible option for carbon sequestration in sustainable according to Zinn "s studing in 2002.

5.2 Impact of Municipal Waste Water on Leaf Area Index and Above-ground biomass in mangrove filtration system.

The present study demonstrated that the qualities of municipal waste water parameter were not impacted on leaf area index, above-ground biomass in mangrove filtration system and above-ground carbon sequestration. However, the results show that mangrove forests especially, mangrove filtration system plays a major role for the carbon exchange between continents and oceans. Trying to find a way for increasing of the potential of carbon exchanging is essential link between the land and ocean, with potential consequences for atmospheric composition and climate.

5.3 Potential of the mangrove forest filtration system for the above-ground carbon sequestration.

From the study of biological parameters of the two species of dominance mangrove in this study site demonstrated that in the mangrove filtration system has higher biological value than the natural mangrove in the reference site. And when we calculate the above ground carbon sequestration the results showed the positive potential for the above-ground carbon sequestration. The results of this study showed advantages on a function as the sink of carbon.

5.4 Application of the high resolution satellite imaginary for the estimation of above -ground carbon sequestration in the mangrove forest filtration system

Although Quickbird data is currently cheap in comparison to others high resolution satellite data, this research suggest that it can be used for classification and vegetation index mapping in mangrove forests. In addition to degraded mangrove forests, this can be particularly important when investigating mangrove forests that contain numerous dense but sparsely distributed stands. With such high spatial resolution, however, it is also necessary that a very precise and accuracy, and consequently expensive, GPS unit be employed when collecting the LAI or GCP locations. (Kovacs et al.,2004)

Previous researchers have suggested that their observations of the relationship positive correlations among in situ Leaf Area Index (LAI) estimates and vegetation indices derived from satellite imagery. This study demonstrates that remote sensing technology can be used to estimate the rate of above ground carbon sequestration within a mangrove forest filtration system. In the future, the research should be undertaken in different seasons is needed to enhance the efficiency and accuracy of the application of remote sensing for estimating above ground carbon sequestration. Understanding in different seasons is needed to enhance the high efficiency and accuracy of the application of remote sensing for estimating above-ground carbon sequestration.

If the highs resolution imagery in combination with in situ data achieved, it can provide scientists and resource managers with a rapid, yet highly accurate method for LAI , biomass and above ground carbon predicted over vast area in less than ideal condition mangrove forest.(Kovacs et al.,2004)

5.5 Development of predictive models for estimating carbon sequestration in mangrove forest filtration system.

From these results, the best relationships of equations between soil organic carbon versus the percentage of organic carbon in study area as Soil Organic Carbon=0.0815 Organic carbon+0.0661 at R^2 equal to 0.8126 where as the best relationships of equations between soil organic carbon versus the percentage of organic matter in reference area as Soil Organic Carbon = 0.0535Organic Matter+ 0.0262 at R^2 equal to 0.8173 Soil organic carbon models are useful tools to better understand SOC dynamics and to indentify the main factors that drive the changes which according to Lugato et al., 2007. For the present study showed the Final models for the estimation of total and by-compartments carbon sequestration for mangrove forest filtration system follow as Table 6 . The results of theses analysis can be benefit for preparing a management plan for the carbon sequestration in the area.

5.6 Outstanding elements of the research

5.6.1 Development of an inventory of new predictive models for estimating the rate of carbon sequestration.

5.6.2 The estimation of the quantity of carbon sequestration in the Mangrove Forest Filtration System.

5.6.3 The first ever application of high-resolution satellite imagery (Quickbird) for estimating the rate and quantity of carbon sequestration.

5.7 Benefits of this work

5.7.1 The new predictive models can be used to predict the rate of carbon sequestration in the future.

5.7.2 The increased rate of carbon sequestration in the mangrove forest filtration system should be help to control and reduce CO_2 in the atmosphere.

5.7.3 These research would be benefits of increasing the potential of CO_2 sequestration using by the municipal wastewater.

5.8 Suggestions for future work

5.8.1 When we considered the size of study area, we found that 95 plots of the present study is about 0.0855 % of the total mangrove area. Thus we suggested that increasing the percentage of study plots are benefit in the next study .

5.8.2 Tree cutting sampling for study the carbon content should be a greater number of samples for representation the best analysis for the average content of carbon.

5.8.3 The available high resolution satellite data in all season are essential for the accuracy of development of the predictive model.

5.8.4 The next study should be doing continuously the trends of carbon sequestration changing in mangrove areas.

5.8.5 The future study should be regard to the underground of carbon stock sand leaf-litter fall traps to be associated with the real carbon storage.

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APPENDICES

APPENDIX A

Table A-1 pH values in the study area

Sampling plots	Wet season	Dry season	Annual average
S1	6.18	4.39	5.29
S2	6.31	4.06	5.18
S3	6.07	4.36	5.21
S4	8.42	5.40	6.91
S5	7.52	6.14	6.83
S6	8.26	5.49	6.87
S7	7.72	6.05	6.88
S8	7.99	6.14	7.07
S9	6.44	6.67	6.56
S10	7.92	5.79	6.86
S11	7.38	6.31	6.85
S12	8.12	7.32	7.72
S13	13.09	9.56	11.33
S14	10.41	10.28	10.35
S15	12.40	9.20	10.80
S16	7.89	5.90	6.89
S17	8.32	6.23	7.28
S18	4.87	4.36	4.61
S19	8.79	7.83	8.31
S20	10.81	6.82	8.82
S21	8.99	7.18	8.09
S22	7.32	5.06	6.19
S23	8.32	6.31	7.31
S24	8.42	7.44	7.93
S25	7.55	5.53	6.54
S26	8.79	7.69	8.24
S27	9.40	7.63	8.51
S28	5.77	4.23	5.00
S29	7.52	7.19	7.36
S30	6.51	4.64	5.57

Table A-1 pH values in the study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S31	10.00	8.63	9.31
S32	6.51	5.40	5.96
S33	9.40	9.51	9.45
S34	4.83	4.42	4.62
S35	8.46	9.18	8.82
S36	5.64	4.01	4.83
S37	7.99	7.39	7.69
S38	7.18	5.02	6.10
S39	9.13	7.21	8.17
S40	6.28	5.83	6.05
S41	5.67	4.51	5.09
S42	9.73	7.87	8.80
S43	8.02	6.63	7.32
S44	7.75	5.65	6.70
S45	6.34	4.53	5.43
S46	7.62	5.91	6.77
S47	7.82	5.93	6.88
S48	10.10	8.00	9.05
S49	7.28	6.70	6.99
S50	12.50	10.26	11.38
S51	3.78	2.47	3.13
S52	5.88	4.55	5.21
S53	7.22	5.52	6.37
S54	9.20	6.56	7.88
S55	9.67	6.53	8.10
S56	9.03	8.10	8.57
S57	5.44	3.88	4.66
S58	5.24	3.88	4.56
S59	6.28	4.54	5.41
S60	2.48	2.69	2.58

Table A-1 pH values in the study area (Cont.)

Sampling plots	**Wet season**	**Dry season**	**Annual average**
S61	3.42	2.05	2.73
S62	4.23	2.71	3.47
S63	1.98	1.67	1.82
S64	2.28	2.04	2.16
S65	1.68	1.67	1.67
S66	6.85	5.31	6.08
S67	8.59	5.83	7.21
S68	7.86	5.58	6.72
S69	4.46	3.00	3.73
S70	3.89	2.42	3.15
S71	3.72	2.78	3.25
S72	2.26	1.29	1.78
S73	1.54	1.01	1.27
S74	1.26	0.72	0.99
S75	0.92	0.80	0.86
S76	3.19	1.61	2.40
S77	1.02	0.71	0.87
S78	3.32	1.70	2.51
S79	2.15	0.95	1.55
S80	2.25	0.87	1.56

Table A-2 pH values in the reference area

Sampling plots	Wet season	Dry season	Annual average
R1	7.75	7.75	7.75
R2	7.84	7.85	7.85
R3	7.67	7.75	7.71
R4	7.95	7.85	7.90
R5	7.75	7.95	7.85
R6	7.84	7.85	7.85
R7	7.80	7.80	7.80
R8	7.83	7.90	7.87
R9	7.80	7.85	7.83
R10	7.83	7.90	7.87
R11	7.85	7.85	7.85
R12	7.90	7.85	7.88
R13	7.63	7.80	7.72
R14	7.70	7.80	7.75
R15	7.75	7.80	7.78

Table A-3 The percentage of Organic Matter sediment the study area

Sampling plots	Wet season	Dry season	Annual average
S1	7.81	7.85	7.83
S2	7.78	8.00	7.89
S3	7.75	7.90	7.83
S4	7.48	7.80	7.64
S5	7.84	7.65	7.75
S6	6.83	7.45	7.14
S7	7.20	7.20	7.20
S8	7.44	7.40	7.42
S9	7.66	7.40	7.53
S10	7.50	7.60	7.55
S11	7.69	7.70	7.70
S12	7.39	6.95	7.17
S13	7.07	6.75	6.91
S14	7.63	6.90	7.27
S15	7.19	7.30	7.25
S16	7.97	7.50	7.74
S17	7.41	7.35	7.38
S18	7.44	7.65	7.55
S19	7.35	7.50	7.43
S20	7.37	7.35	7.36
S21	6.88	7.20	7.04
S22	7.35	7.10	7.23
S23	6.99	7.00	7.00
S24	6.85	5.60	6.23
S25	7.51	7.05	7.28
S26	7.35	6.85	7.10
S27	6.03	5.75	5.89
S28	7.58	7.30	7.44
S29	5.89	6.95	6.42
S30	7.36	7.25	7.31

Table A-3 The percentage of Organic Matter sediment the study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S31	5.86	7.05	6.46
S32	7.64	7.55	7.60
S33	5.83	6.45	6.14
S34	7.80	7.60	7.70
S35	6.91	7.30	7.11
S36	7.58	7.60	7.59
S37	6.81	7.30	7.06
S38	7.27	7.50	7.39
S39	7.26	6.70	6.98
S40	7.63	7.45	7.54
S41	7.51	6.70	7.11
S42	7.42	7.25	7.34
S43	7.37	7.10	7.24
S44	6.65	7.15	6.90
S45	7.63	7.60	7.62
S46	7.49	7.65	7.57
S47	6.81	7.35	7.08
S48	6.75	7.20	6.98
S49	6.79	7.25	7.02
S50	6.31	6.05	6.18
S51	8.10	7.50	7.80
S52	7.72	7.40	7.56
S53	7.62	6.60	7.11
S54	7.08	6.80	6.94
S55	6.34	7.40	6.87
S56	6.55	6.90	6.73
S57	7.73	7.65	7.69
S58	7.83	7.65	7.74
S59	7.48	7.25	7.37
S60	8.14	7.75	7.95

Table A-3 The percentage of Organic Matter sediment the study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S61	7.85	7.90	7.88
S62	7.38	7.90	7.64
S63	7.53	7.95	7.74
S64	7.81	8.05	7.93
S65	7.95	8.10	8.03
S66	6.94	7.70	7.32
S67	7.32	7.45	7.39
S68	6.97	7.35	7.16
S69	7.62	7.80	7.71
S70	7.72	7.90	7.81
S71	7.67	7.90	7.79
S72	7.59	8.05	7.82
S73	7.48	8.15	7.82
S74	8.09	8.25	8.17
S75	8.02	8.25	8.14
S76	7.81	8.20	8.01
S77	7.94	8.20	8.07
S78	7.97	8.10	8.04
S79	7.53	8.25	7.89
S80	7.85	8.05	7.95

Table A-4 The percentage of Organic Matter sediment in the reference area

Sampling plots	**Wet season**	**Dry season**	**Annual average**
R1	6.01	1.78	3.89
R2	3.19	1.83	2.51
R3	3.71	2.07	2.89
R4	1.95	2.75	2.35
R5	3.64	2.34	2.99
R6	3.93	3.09	3.51
R7	5.44	4.11	4.77
R8	5.50	3.81	4.65
R9	5.55	3.77	4.66
R10	4.82	3.35	4.09
R11	6.18	4.49	5.33
R12	4.58	4.31	4.45
R13	3.71	4.81	4.26
R14	5.13	4.84	4.99
R15	4.93	4.88	4.90

Table A-5 The percentage of Organic Carbon sediment the study area

Sampling plots	Wet season	Dry season	Annual average
S1	3.58	3.19	3.39
S2	3.66	2.84	3.25
S3	3.52	3.16	3.34
S4	4.88	3.92	4.40
S5	4.36	4.49	4.42
S6	4.79	4.13	4.46
S7	4.48	4.57	4.53
S8	4.63	4.63	4.63
S9	3.73	4.91	4.32
S10	4.59	4.30	4.44
S11	4.28	4.57	4.42
S12	4.71	5.35	5.03
S13	7.59	7.59	7.59
S14	6.04	7.29	6.66
S15	7.19	6.79	6.99
S16	4.57	4.22	4.39
S17	4.83	4.64	4.73
S18	2.82	3.21	3.02
S19	5.1	5.94	5.52
S20	6.27	5.23	5.75
S21	5.21	5.36	5.29
S22	4.24	3.88	4.06
S23	4.82	4.53	4.68
S24	4.88	5.55	5.21
S25	4.38	4.09	4.23
S26	5.1	5.69	5.39
S27	5.45	5.87	5.66
S28	3.35	3.05	3.20
S29	4.36	5.10	4.73
S30	3.77	3.47	3.62

Table A-5 The percentage of Organic Carbon sediment the study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S31	5.8	6.45	6.13
S32	3.77	3.99	3.88
S33	5.45	6.99	6.22
S34	2.8	3.24	3.02
S35	4.91	6.95	5.93
S36	3.27	3.01	3.14
S37	4.63	5.53	5.08
S38	4.16	3.65	3.90
S39	5.29	5.32	5.31
S40	3.64	4.50	4.07
S41	3.29	3.38	3.33
S42	5.64	5.76	5.70
S43	4.65	4.73	4.69
S44	4.49	4.05	4.27
S45	3.68	3.41	3.55
S46	4.42	4.28	4.35
S47	4.53	4.25	4.39
S48	5.85	5.86	5.86
S49	4.22	4.93	4.58
S50	7.25	7.50	7.37
S51	2.19	1.80	2.00
S52	3.41	3.24	3.33
S53	4.19	3.94	4.07
S54	5.34	4.87	5.10
S55	5.61	4.75	5.18
S56	5.24	5.97	5.60
S57	3.16	2.85	3.01
S58	3.04	2.79	2.92
S59	3.64	3.33	3.49
S60	1.44	1.91	1.68

Table A-5 The percentage of Organic Carbon sediment the study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S61	1.98	1.49	1.74
S62	2.45	2.04	2.24
S63	1.15	1.27	1.21
S64	1.32	1.66	1.49
S65	0.97	1.19	1.08
S66	3.97	3.81	3.89
S67	4.98	4.39	4.68
S68	4.59	4.03	4.31
S69	2.59	2.23	2.41
S70	2.25	1.80	2.03
S71	2.16	2.03	2.09
S72	1.31	0.90	1.10
S73	0.89	0.71	0.80
S74	0.73	0.49	0.61
S75	0.53	0.57	0.55
S76	1.85	1.14	1.49
S77	0.59	0.48	0.54
S78	1.92	1.29	1.61
S79	1.25	0.60	0.93
S80	1.3	0.68	0.99

Table A-6 The percentage of Organic Carbon sediment in the reference area

Sampling plots	Wet season	Dry season	Annual average
R1	3.49	1.35	2.42
R2	1.85	1.36	1.61
R3	2.15	1.47	1.81
R4	1.13	1.96	1.54
R5	2.11	1.75	1.93
R6	2.28	2.44	2.36
R7	3.15	3.11	3.13
R8	3.19	2.65	2.92
R9	3.22	2.67	2.95
R10	2.79	2.44	2.62
R11	3.58	3.32	3.45
R12	2.66	3.30	2.98
R13	2.15	3.75	2.95
R14	2.97	3.64	3.30
R15	2.86	3.64	3.25

Table A-7 Soil Organic Carbon sequestrations (tons/hectare) in the study area

Sampling plots	**Wet season**	**Dry season**	**Annual average**
S1	0.03	0.03	0.03
S2	0.04	0.03	0.03
S3	0.04	0.03	0.03
S4	0.05	0.04	0.04
S5	0.04	0.04	0.04
S6	0.04	0.04	0.04
S7	0.04	0.04	0.04
S8	0.05	0.05	0.05
S9	0.04	0.05	0.04
S10	0.04	0.03	0.03
S11	0.04	0.05	0.04
S12	0.04	0.05	0.04
S13	0.05	0.05	0.05
S14	0.04	0.05	0.05
S15	0.06	0.06	0.06
S16	0.04	0.03	0.04
S17	0.05	0.05	0.05
S18	0.03	0.04	0.03
S19	0.06	0.07	0.07
S20	0.02	0.02	0.02
S21	0.05	0.05	0.05
S22	0.04	0.04	0.04
S23	0.04	0.03	0.03
S24	0.05	0.06	0.05
S25	0.03	0.03	0.03
S26	0.05	0.05	0.05
S27	0.05	0.06	0.06
S28	0.04	0.03	0.03
S29	0.04	0.05	0.04
S30	0.03	0.03	0.03

Table A-7 Soil Organic Carbon sequestrations (tons/hectare) in the study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S31	0.05	0.06	0.06
S32	0.04	0.05	0.05
S33	0.06	0.08	0.07
S34	0.03	0.04	0.03
S35	0.06	0.08	0.07
S36	0.04	0.03	0.03
S37	0.05	0.06	0.05
S38	0.04	0.04	0.04
S39	0.06	0.06	0.06
S40	0.04	0.05	0.04
S41	0.03	0.04	0.04
S42	0.05	0.05	0.05
S43	0.04	0.05	0.04
S44	0.03	0.03	0.03
S45	0.04	0.04	0.04
S46	0.04	0.04	0.04
S47	0.04	0.04	0.04
S48	0.05	0.05	0.05
S49	0.05	0.06	0.05
S50	0.06	0.07	0.06
S51	0.02	0.02	0.02
S52	0.03	0.03	0.03
S53	0.05	0.04	0.04
S54	0.06	0.05	0.06
S55	0.06	0.05	0.05
S56	0.06	0.07	0.06
S57	0.04	0.04	0.04
S58	0.05	0.04	0.04
S59	0.05	0.04	0.05
S60	0.02	0.02	0.02

Table A-7 Soil Organic Carbon sequestrations (tons/hectare) in the study area (Cont.)

Sampling plots	**Wet season**	**Dry season**	**Annual average**
S61	0.02	0.02	0.02
S62	0.03	0.02	0.03
S63	0.02	0.02	0.02
S64	0.02	0.02	0.02
S65	0.01	0.02	0.01
S66	0.04	0.04	0.04
S67	0.05	0.05	0.05
S68	0.05	0.04	0.05
S69	0.03	0.02	0.03
S70	0.03	0.02	0.02
S71	0.03	0.02	0.03
S72	0.02	0.01	0.01
S73	0.01	0.01	0.01
S74	0.01	0.01	0.01
S75	0.01	0.01	0.01
S76	0.02	0.01	0.01
S77	0.01	0.01	0.01
S78	0.02	0.02	0.02
S79	0.02	0.01	0.01
S80	0.02	0.01	0.01

Table A-8 Soil Organic Carbon sequestrations (tons/hectare) in the reference area

Sampling plots	Wet season	Dry season	Annual average
R1	0.03	0.01	0.02
R2	0.02	0.01	0.02
R3	0.02	0.01	0.02
R4	0.01	0.02	0.02
R5	0.02	0.02	0.02
R6	0.02	0.02	0.02
R7	0.03	0.03	0.03
R8	0.03	0.03	0.03
R9	0.03	0.03	0.03
R10	0.02	0.02	0.02
R11	0.04	0.03	0.03
R12	0.02	0.03	0.03
R13	0.02	0.03	0.02
R14	0.02	0.03	0.02
R15	0.02	0.03	0.03

Table A-9 A comparison statistical values between study site and reference site.

Soil properties	Study Site[1]			Reference Site[2]		
	pH	Organic carbon (%)	Organic Matter (%)	pH	Organic carbon (%)	Organic Matter (%)
Maximum	.17	.59	1.38	.90	.45	.53
Minimum	.89	.54	.86	.71	.54	.35
Mean±SD	.39±0.48	.84±1.70	.94±2.59	.39±0.48	.61±0.61	.02±0.92
C.V. (%)	.54	4.18	3.60	.54	3.53	2.97

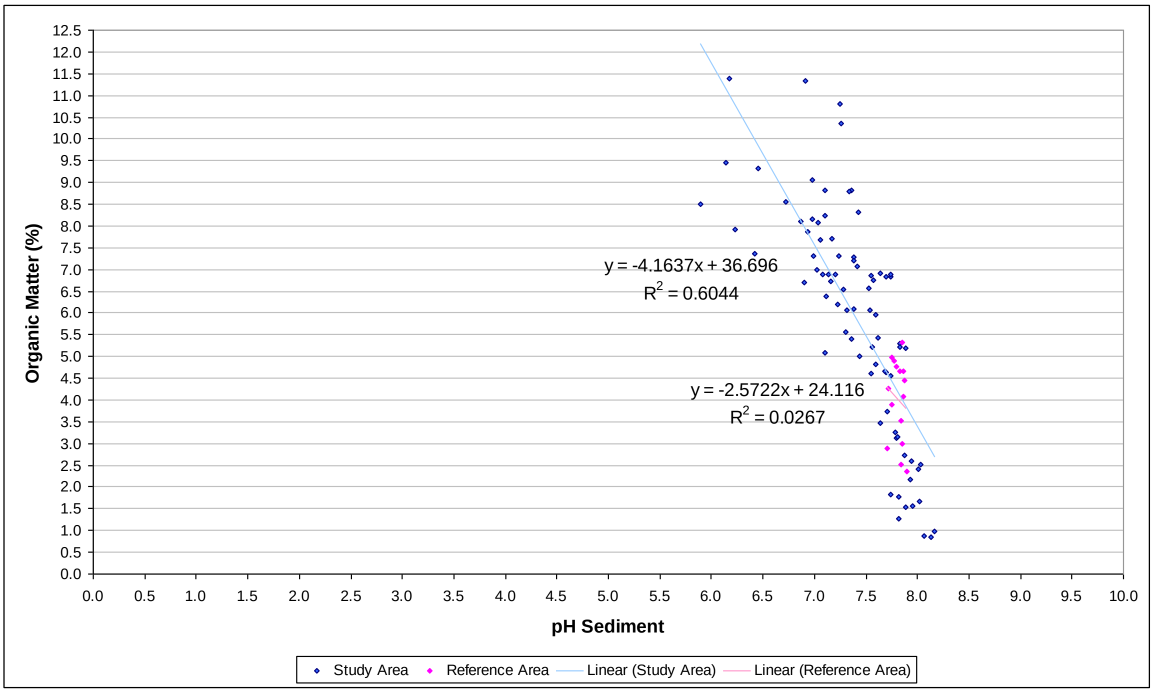

Figure A-1 Relationship between pH sediment values and the percentage of organic matter by the linear model

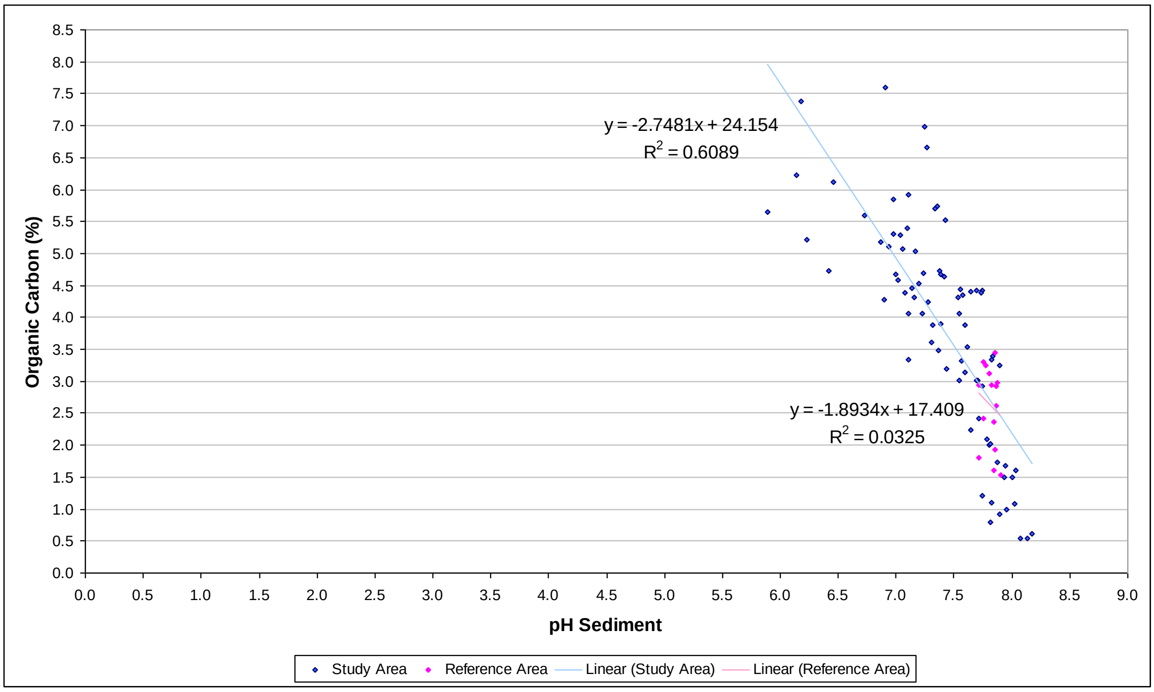

Figure A-2 Relationship between pH sediment values and the percentage of organic carbon by the linear model

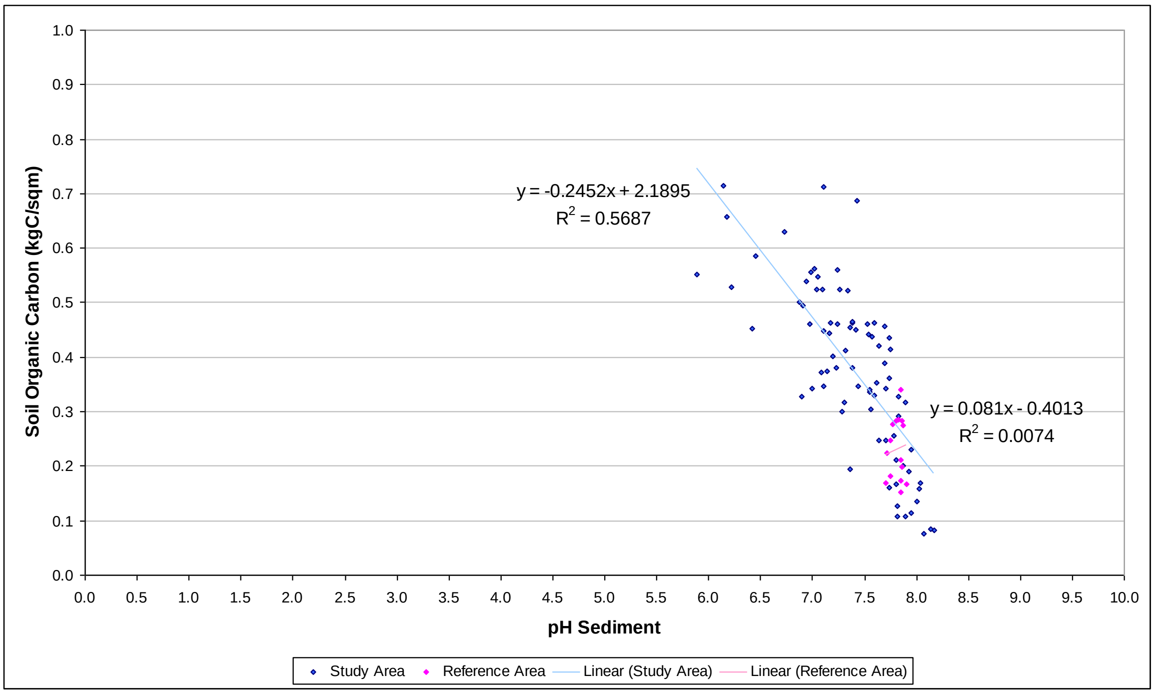

Figure A-3 Relationship between pH sediment values and the percentage of soil organic carbon sequestration by the linear model

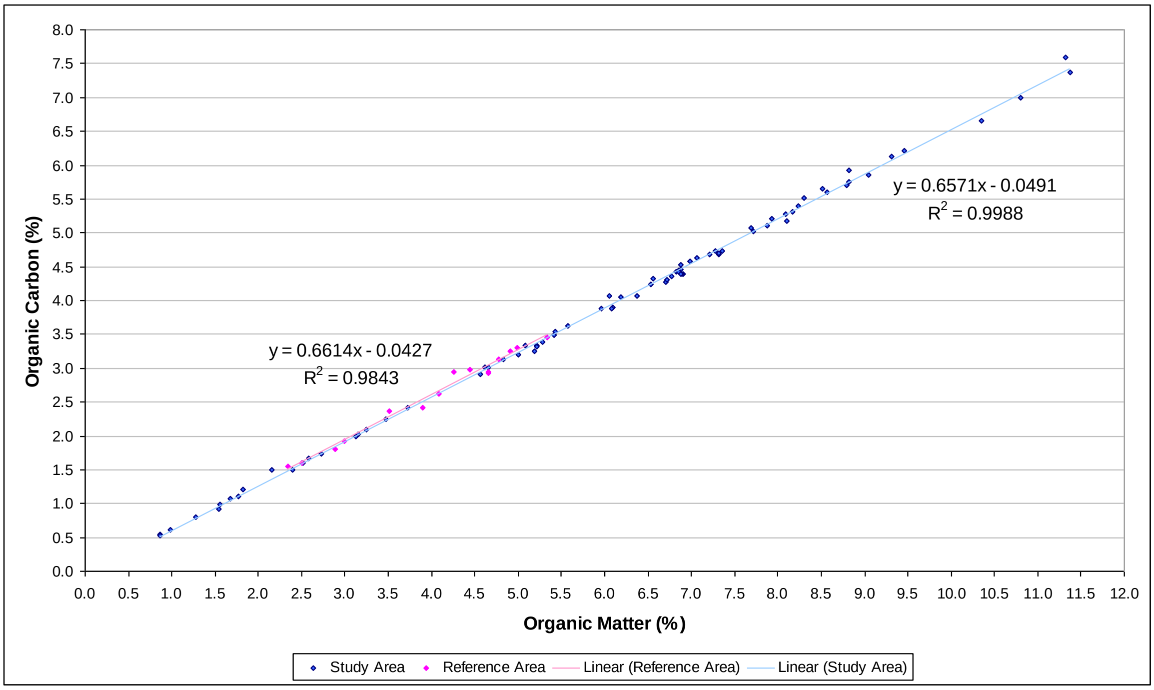

Figure A-4 Relationship between the percentage of soil organic matter and the percentage of soil organic carbon by the linear model

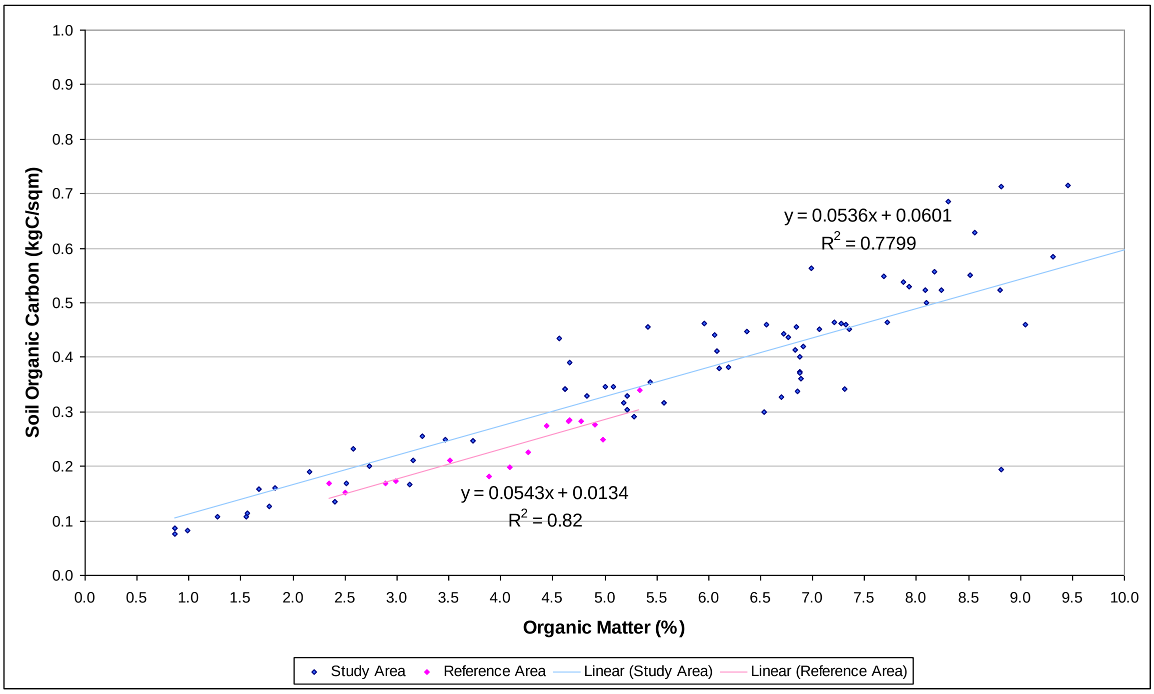

Figure A-5 Relationship between the percentage of organic matter in sediment and the percentage of soil organic carbon sequestrations by the linear model

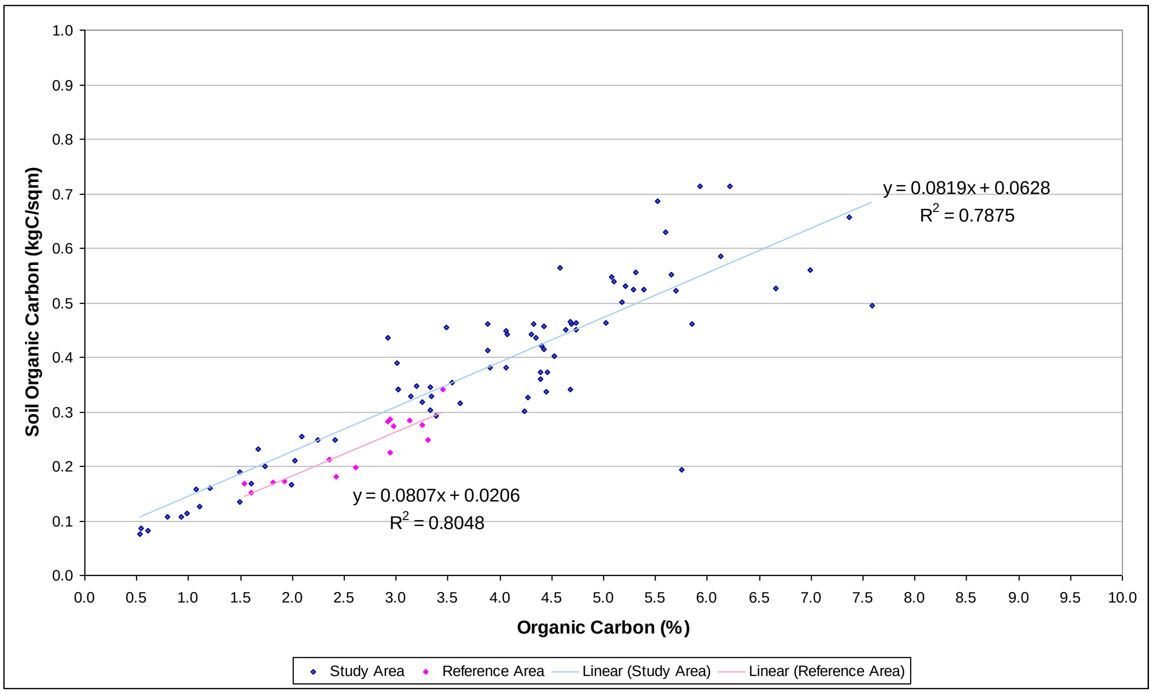

Figure A-6 Relationship between the percentage of soil organic carbon in sediment and the percentage of soil organic carbon sequestrations by the linear model

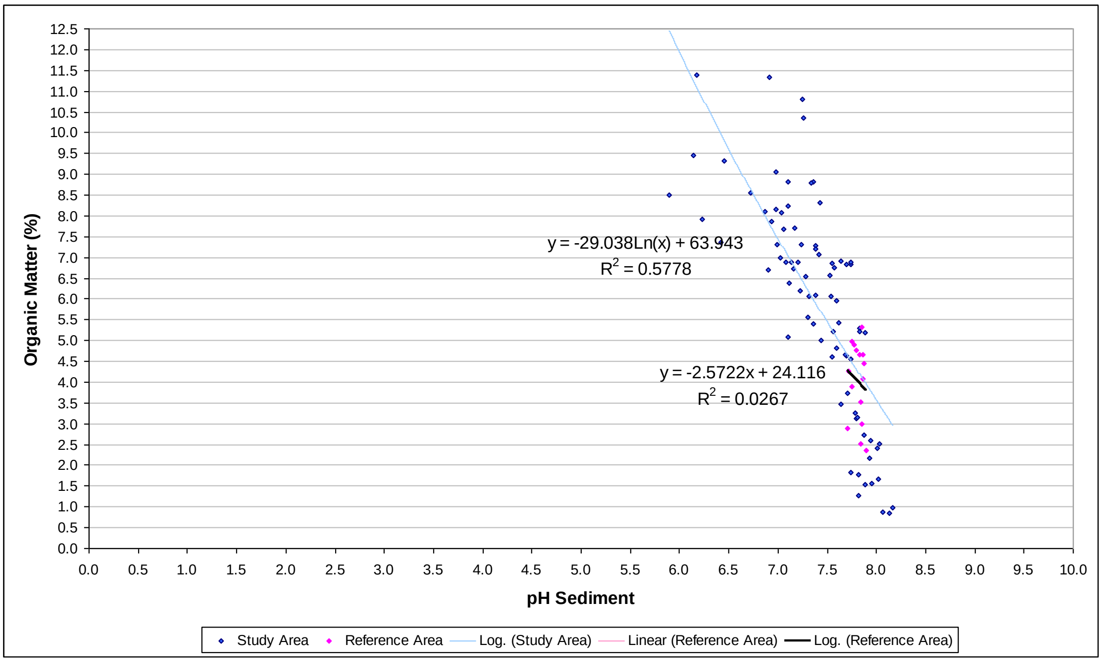

Figure A-7 Relationship between pH sediment values and the percentage of organic matter by the Logarithmic model

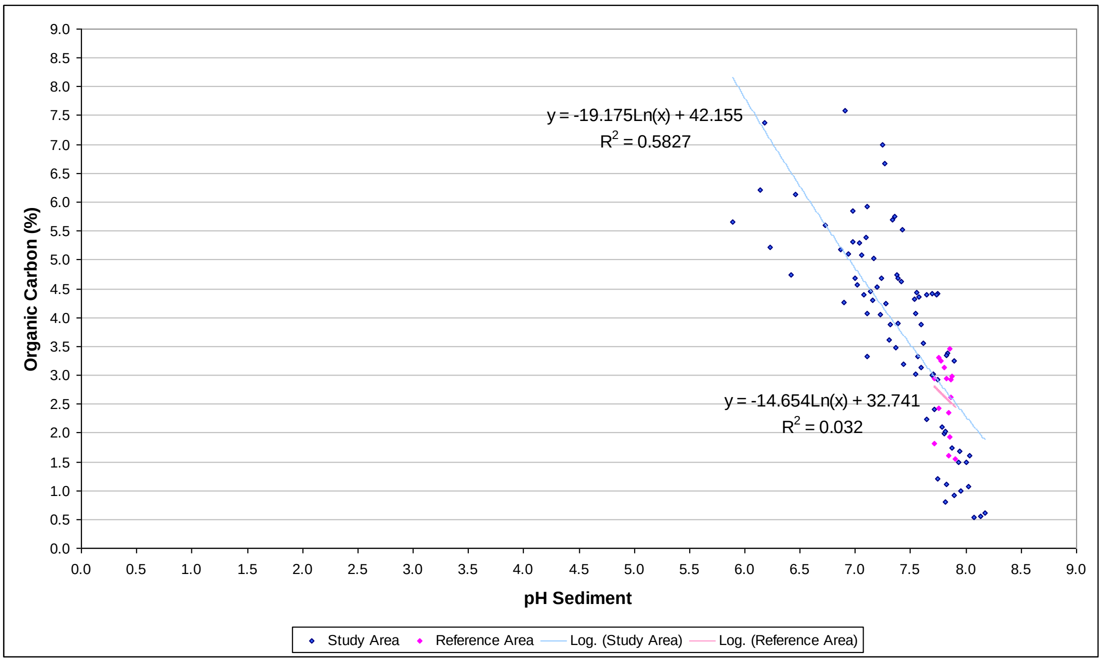

Figure A-8 Relationship between pH sediment values and the percentage of organic carbon by the Logarithmic model

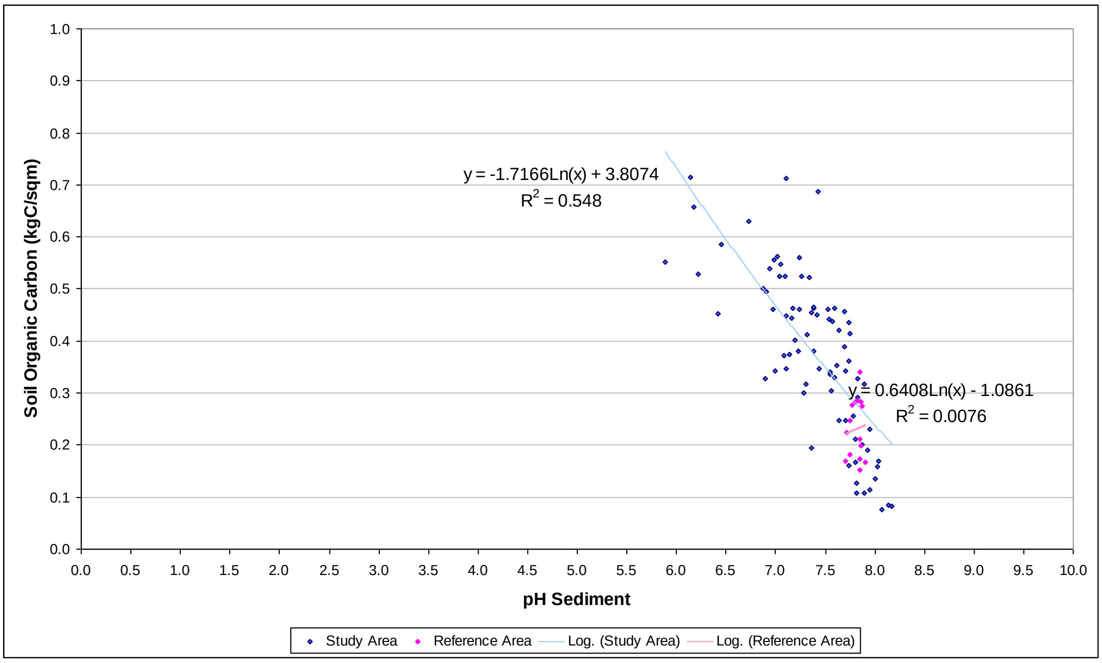

Figure A-9 Relationship between pH sediment values and the percentage of soil organic carbon sequestration by the Logarithmic model

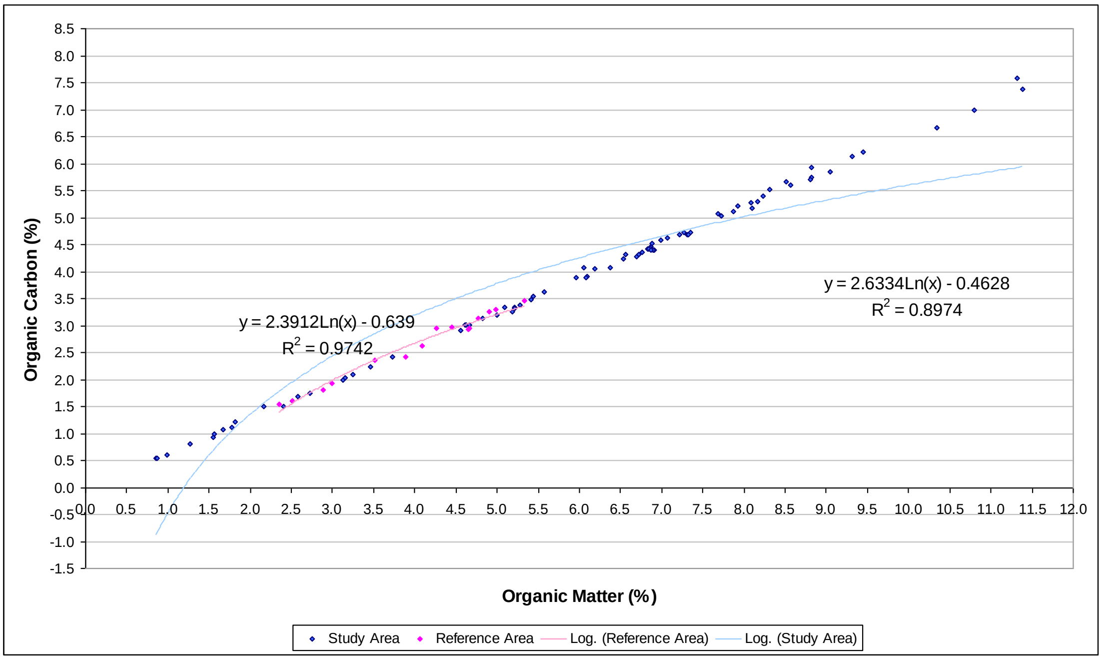

Figure A-10 Relationship between the percentage of soil organic matter and the percentage of soil organic carbon by the Logarithmic model

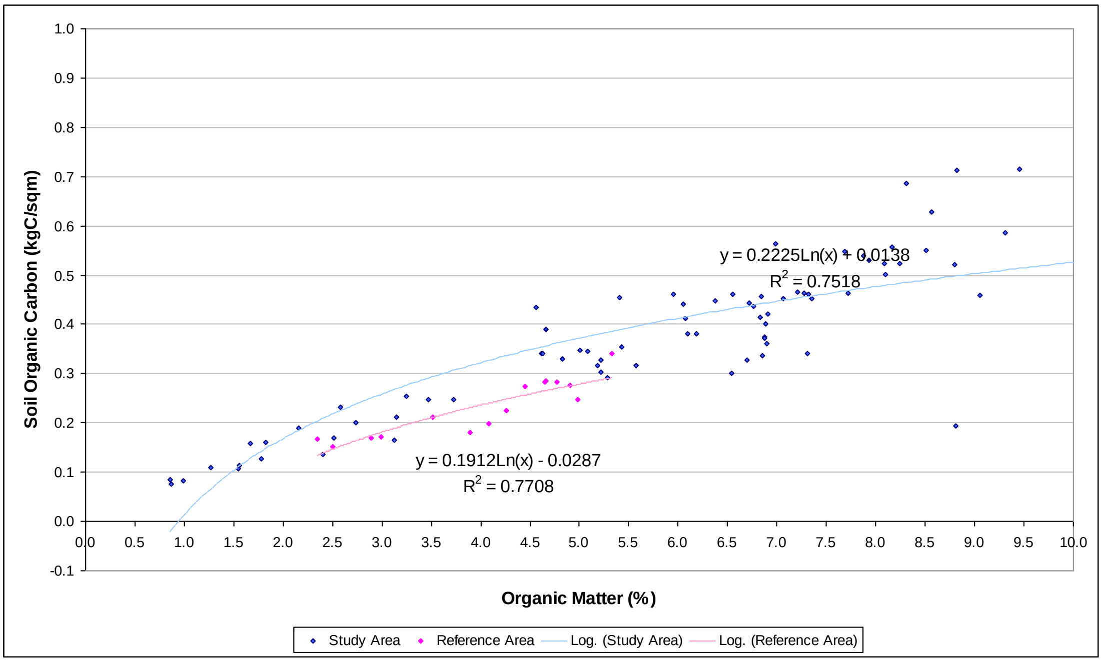

Figure A-11 Relationship between the percentage of organic matter in sediment and the percentage of soil organic carbon sequestrations by the Logarithmic model

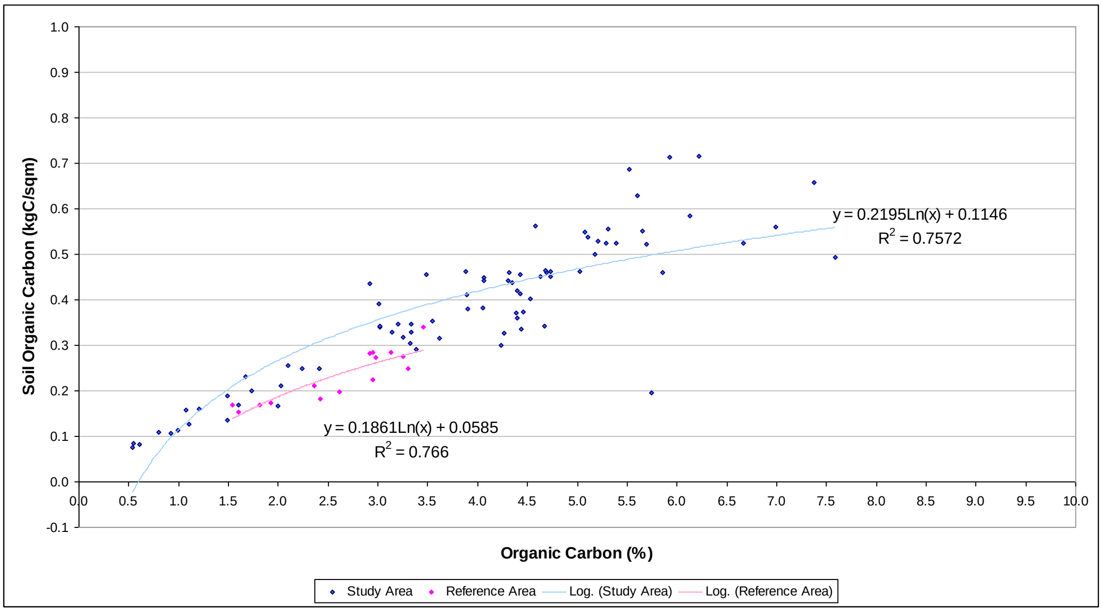

Figure A-12 Relationship between the percentage of soil organic carbon in sediment and the percentage of soil organic carbon sequestrations by the Logarithmic model

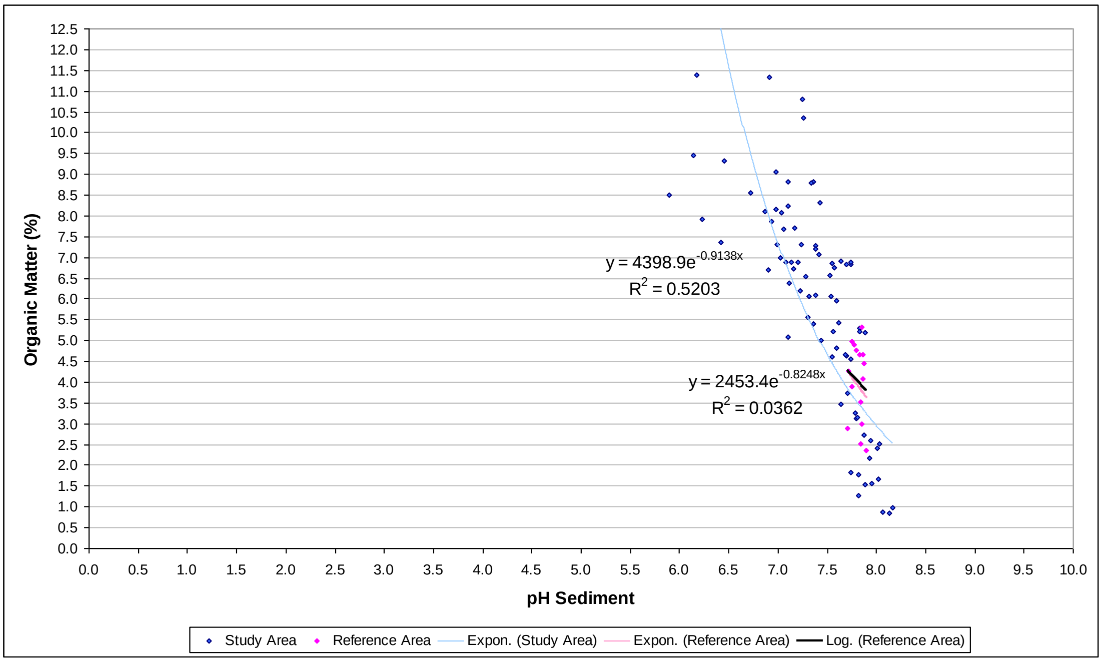

Figure A-13 Relationship between pH sediment values and the percentage of organic matter by the Exponential model

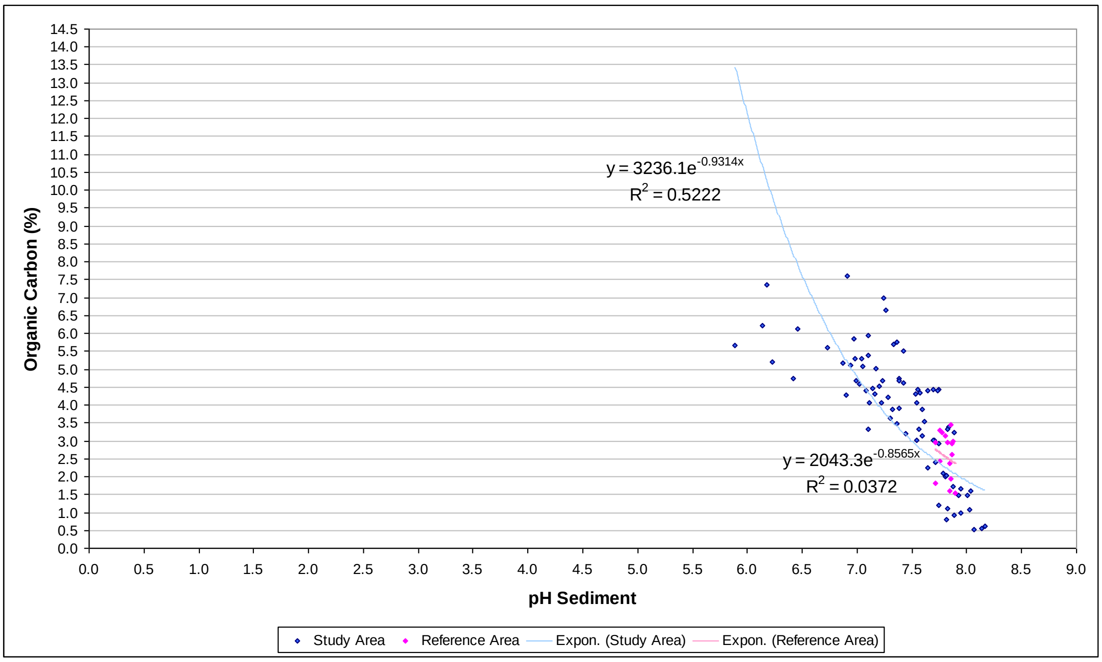

Figure A-14 Relationship between pH sediment values and the percentage of organic carbon by the Exponential model

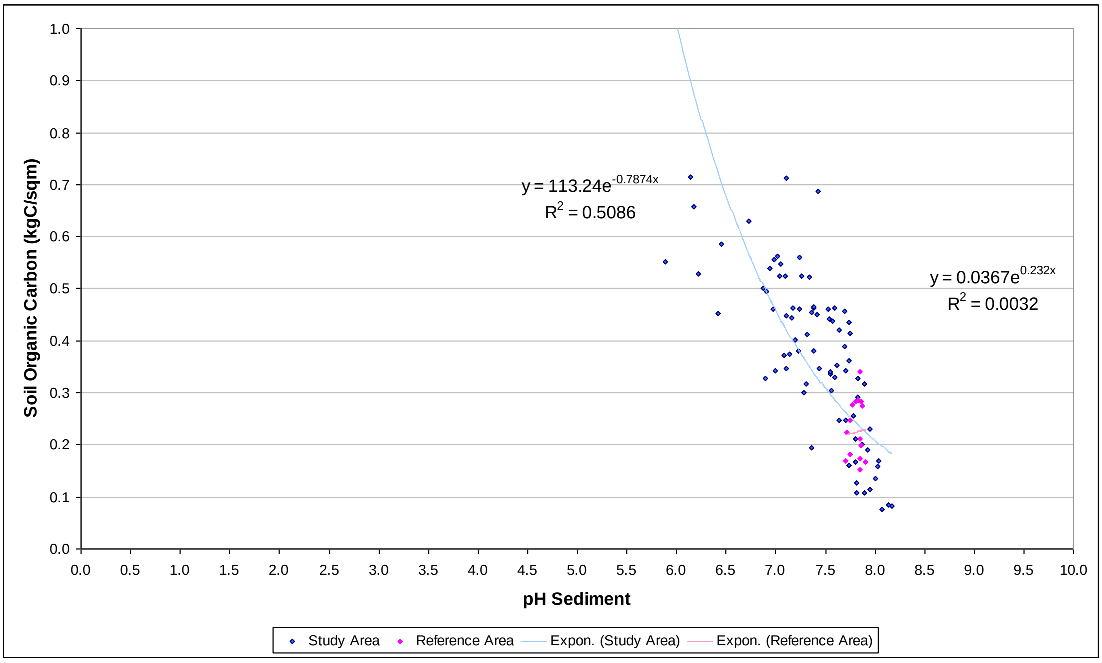

Figure A-15 Relationship between pH sediment values and the percentage of soil organic carbon sequestration by the Exponential model

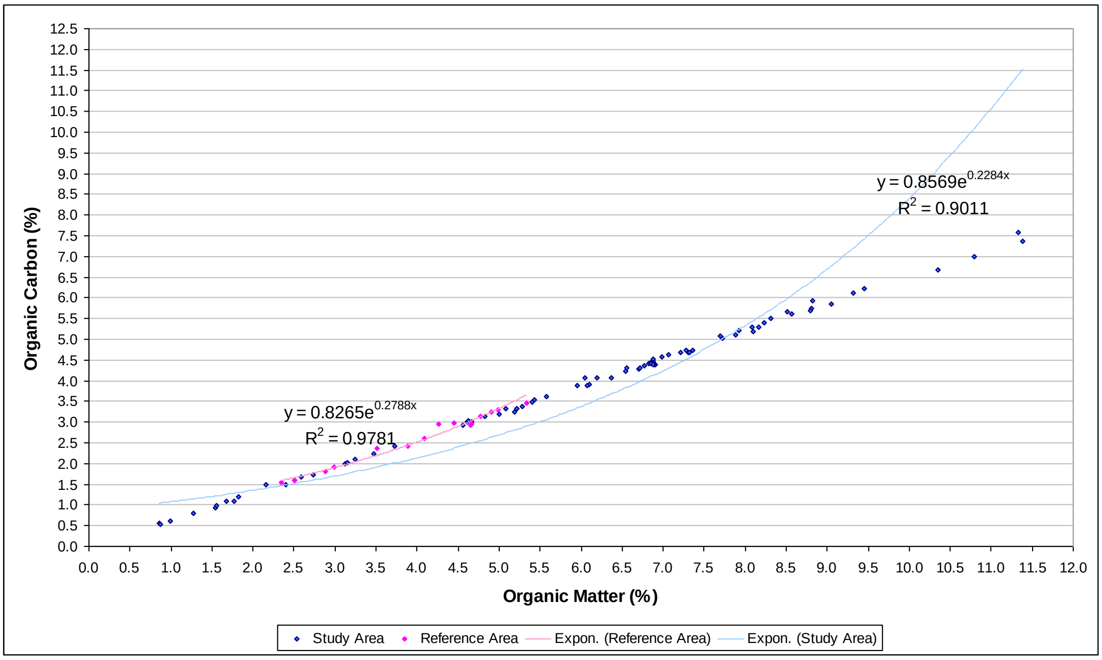

Figure A-16 Relationship between the percentage of soil organic matter and the percentage of soil organic carbon by the Exponential model

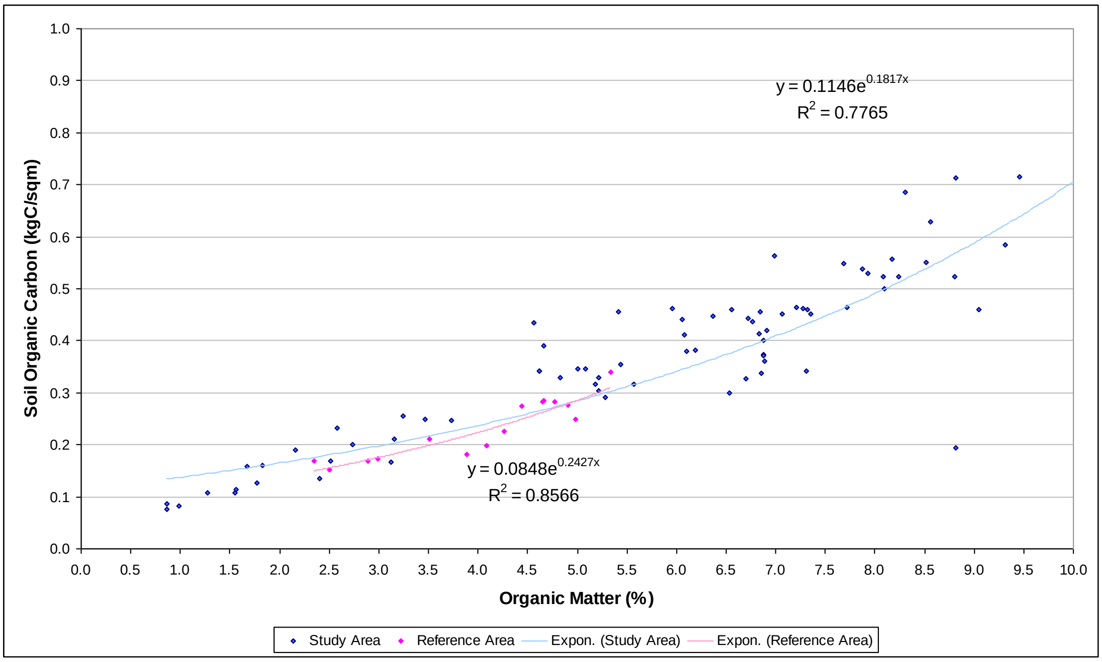

Figure A-17 Relationship between the percentage of organic matter in sediment and the percentage of soil organic carbon sequestrations by the Exponential model

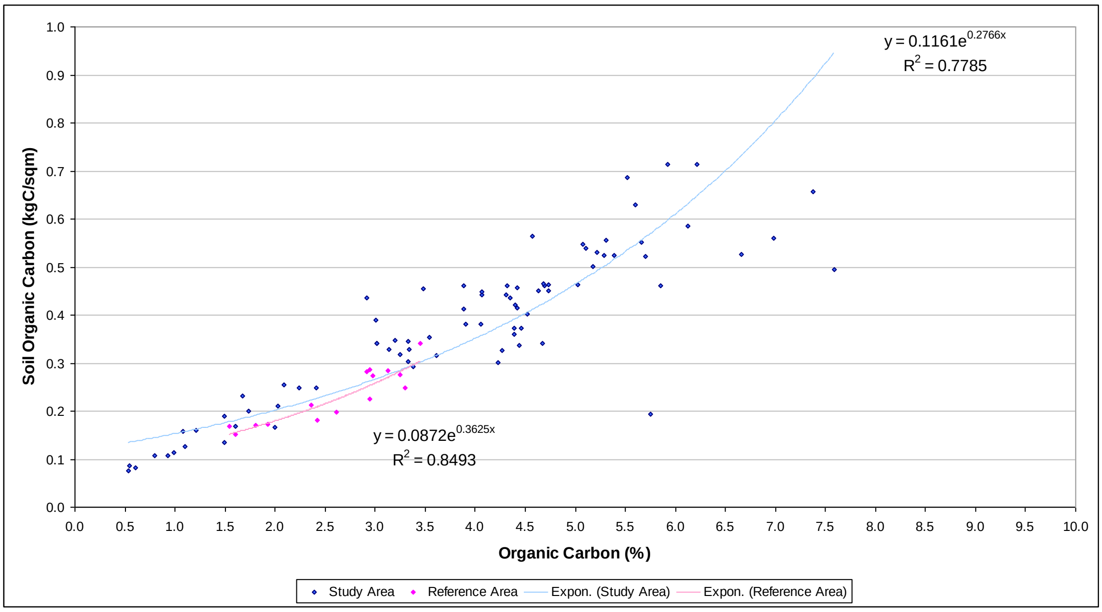

Figure A-18 Relationship between the percentage of soil organic carbon in sediment and the percentage of soil organic carbon sequestrations by the Exponential model

APPENDIX B

Table B-1 pH water values in the study area

Sampling plots	Wet season	Dry season	Annual average
S1	7.13	8.23	7.68
S2	7.41	8.00	7.70
S3	7.44	8.17	7.80
S4	7.43	8.40	7.92
S5	7.32	9.17	8.24
S6	7.40	7.97	7.68
S7	7.80	8.10	7.95
S8	7.51	8.33	7.92
S9	7.50	8.10	7.80
S10	7.62	7.83	7.73
S11	7.53	8.20	7.87
S12	7.51	8.23	7.87
S13	7.42	8.13	7.78
S14	7.93	8.00	7.96
S15	7.93	8.23	8.08
S16	8.17	8.20	8.19
S17	7.24	8.10	7.67
S18	7.09	7.73	7.41
S19	7.69	8.00	7.85
S20	7.63	8.00	7.81
S21	7.31	8.10	7.71
S22	7.48	8.97	8.22
S23	7.36	7.80	7.58
S24	7.30	8.10	7.70
S25	7.35	7.90	7.63
S26	7.54	8.40	7.97
S27	7.39	8.07	7.73
S28	7.30	8.00	7.65
S29	7.52	8.00	7.76
S30	7.44	8.07	7.75

Table B-1 pH water values in the study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S31	7.52	8.10	7.81
S32	7.78	8.20	7.99
S33	7.38	8.37	7.87
S34	7.49	7.80	7.64
S35	7.47	7.77	7.62
S36	7.52	8.90	8.21
S37	7.47	7.80	7.64
S38	7.35	8.37	7.86
S39	7.52	8.17	7.85
S40	7.52	8.00	7.76
S41	7.53	8.00	7.77
S42	7.32	8.10	7.71
S43	7.37	7.80	7.59
S44	7.56	8.77	8.16
S45	7.49	7.83	7.66
S46	7.23	8.17	7.70
S47	7.20	7.83	7.52
S48	7.34	8.23	7.79
S49	7.27	7.90	7.59
S50	7.22	8.17	7.69
S51	7.61	7.73	7.67
S52	7.33	7.83	7.58
S53	7.43	7.60	7.52
S54	7.37	8.30	7.83
S55	7.42	7.70	7.56
S56	7.45	8.10	7.78
S57	7.46	8.33	7.90
S58	7.36	8.10	7.73
S59	7.40	8.67	8.03
S60	7.47	8.10	7.78

Table B-1 pH values in the study area (Cont.)

Sampling plots	**Wet season**	**Dry season**	**Annual average**
S61	7.48	8.40	7.94
S62	7.63	8.57	8.10
S63	7.36	8.03	7.69
S64	7.56	8.20	7.88
S65	7.16	7.73	7.45
S66	7.24	7.90	7.57
S67	7.16	8.20	7.68
S68	7.22	7.90	7.56
S69	7.66	8.17	7.92
S70	7.48	7.97	7.72
S71	7.53	8.30	7.91
S72	7.71	8.20	7.95
S73	7.50	7.90	7.70
S74	7.72	8.10	7.91
S75	7.35	7.83	7.59
S76	7.22	7.97	7.59
S77	7.19	7.90	7.55
S78	7.40	7.80	7.60
S79	7.30	7.83	7.57
S80	7.28	7.80	7.54

Table B-2 pH values in the reference area

Sampling plots	**Wet season**	**Dry season**	**Annual average**
R1	7.79	8.47	8.13
R2	7.84	8.57	8.20
R3	7.73	8.33	8.03
R4	7.68	8.27	7.97
R5	7.69	8.20	7.94
R6	7.33	8.13	7.73
R7	7.59	8.17	7.88
R8	7.59	8.10	7.84
R9	7.73	8.10	7.92
R10	7.74	7.90	7.82
R11	7.78	8.10	7.94
R12	7.77	7.87	7.82
R13	7.68	7.80	7.74
R14	7.92	7.67	7.79
R15	7.66	7.97	7.82

Table B-3 DO (mg/l) values in the study area

Sampling plots	Wet season	Dry season	Annual average
S1	4.17	1.69	2.93
S2	1.97	2.76	2.37
S3	2.17	2.64	2.40
S4	2.53	4.48	3.50
S5	2.12	11.83	6.97
S6	4.55	2.85	3.70
S7	3.76	4.45	4.10
S8	1.43	2.64	2.03
S9	1.32	2.40	1.86
S10	2.54	0.79	1.67
S11	1.54	4.23	2.88
S12	4.38	6.38	5.38
S13	1.08	2.13	1.60
S14	2.49	0.03	1.26
S15	2.54	2.43	2.49
S16	5.02	1.69	3.35
S17	2.09	1.68	1.89
S18	1.36	2.50	1.93
S19	1.44	0.33	0.88
S20	0.04	0.68	0.36
S21	0.21	2.43	1.32
S22	2.40	15.07	8.74
S23	0.25	1.92	1.09
S24	0.28	2.40	1.34
S25	0.01	3.00	1.51
S26	-0.01	4.15	2.07
S27	1.55	1.15	1.35
S28	1.28	3.38	2.33
S29	2.22	2.02	2.12
S30	1.93	2.55	2.24

Table B-3 DO (mg/l) values in the study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S31	2.36	2.19	2.27
S32	1.89	2.99	2.44
S33	1.16	0.37	0.76
S34	2.41	2.35	2.38
S35	1.59	1.24	1.41
S36	0.21	9.31	4.76
S37	2.01	0.88	1.44
S38	0.86	3.22	2.04
S39	2.29	2.39	2.34
S40	2.33	2.29	2.31
S41	2.13	1.69	1.91
S42	1.38	2.51	1.95
S43	1.71	1.41	1.56
S44	2.42	5.28	3.85
S45	2.26	2.13	2.19
S46	2.15	2.97	2.56
S47	0.64	1.78	1.21
S48	0.42	1.59	1.01
S49	0.85	2.89	1.87
S50	2.04	1.30	1.67
S51	2.66	1.94	2.30
S52	0.84	2.30	1.57
S53	0.61	0.02	0.31
S54	2.81	3.54	3.18
S55	2.04	2.42	2.23
S56	2.72	2.58	2.65
S57	1.67	4.67	3.17
S58	2.27	3.21	2.74
S59	2.68	5.83	4.25
S60	2.12	3.05	2.59

Table B-3 DO (mg/l) in the study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S61	3.15	6.14	4.65
S62	2.65	6.59	4.62
S63	1.31	2.29	1.80
S64	1.84	1.38	1.61
S65	0.00	0.73	0.37
S66	1.66	1.74	1.70
S67	1.63	6.29	3.96
S68	1.45	1.57	1.51
S69	4.83	3.08	3.95
S70	1.93	3.01	2.47
S71	2.23	1.94	2.08
S72	1.65	2.06	1.85
S73	1.61	1.28	1.44
S74	2.03	2.11	2.07
S75	2.60	1.83	2.21
S76	1.19	0.68	0.94
S77	2.45	1.96	2.21
S78	2.23	0.98	1.60
S79	1.66	0.45	1.06
S80	0.96	0.82	0.89

Table B-4 DO (mg/l) in the reference area

Sampling plots	Wet season	Dry season	Annual average
R1	5.35	8.93	7.14
R2	2.33	9.08	5.71
R3	4.53	4.49	4.51
R4	2.07	7.99	5.03
R5	2.50	5.51	4.01
R6	3.10	3.12	3.11
R7	3.36	5.43	4.39
R8	0.20	7.23	3.72
R9	3.81	5.70	4.76
R10	0.02	4.43	2.22
R11	0.01	4.27	2.14
R12	0.13	3.43	1.78
R13	2.99	3.15	3.07
R14	0.60	3.87	2.24
R15	0.13	5.21	2.67

Table B-5 BOD (mg/l) values in the study area

Sampling plots	Wet season	Dry season	Annual average
S1	5.10	6.90	6.00
S2	4.16	1.38	2.77
S3	6.93	1.98	4.46
S4	4.37	2.10	3.23
S5	6.89	10.20	8.54
S6	4.95	8.28	6.62
S7	3.06	2.22	2.64
S8	5.40	2.64	4.02
S9	8.07	1.26	4.67
S10	4.65	5.94	5.30
S11	11.87	2.10	6.98
S12	1.34	8.70	5.02
S13	17.60	16.14	16.87
S14	8.10	47.58	27.84
S15	9.72	34.80	22.26
S16	6.57	1.98	4.28
S17	2.67	2.10	2.39
S18	2.36	1.65	2.00
S19	3.62	1.56	2.59
S20	8.63	1.08	4.85
S21	5.85	4.74	5.30
S22	3.36	3.84	3.60
S23	5.37	3.48	4.43
S24	5.88	2.94	4.41
S25	6.78	2.76	4.77
S26	7.05	1.68	4.37
S27	6.32	2.70	4.51
S28	2.99	2.58	2.78
S29	3.21	2.64	2.93
S30	6.24	2.76	4.50

Table B-5 BOD (mg/l) values in the study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S31	3.98	3.90	3.94
S32	4.43	6.00	5.21
S33	4.04	4.44	4.24
S34	3.59	3.42	3.50
S35	2.93	3.30	3.11
S36	2.78	3.84	3.31
S37	3.23	7.80	5.51
S38	2.82	3.42	3.12
S39	3.36	2.64	3.00
S40	7.80	2.88	5.34
S41	2.85	1.44	2.15
S42	4.02	4.14	4.08
S43	3.15	1.80	2.48
S44	6.69	1.44	4.07
S45	7.37	4.56	5.96
S46	6.83	11.16	8.99
S47	7.62	5.82	6.72
S48	6.57	3.12	4.85
S49	8.00	4.38	6.19
S50	6.78	12.60	9.69
S51	7.68	2.46	5.07
S52	7.61	2.64	5.12
S53	7.17	3.54	5.36
S54	5.99	3.84	4.91
S55	6.80	3.30	5.05
S56	10.47	2.52	6.50
S57	3.05	5.22	4.13
S58	5.81	4.92	5.36
S59	1.65	6.36	4.01
S60	8.42	4.86	6.64

Table B-5 BOD (mg/l) in the study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S61	5.39	7.08	6.23
S62	6.60	6.00	6.30
S63	2.91	7.20	5.06
S64	6.27	7.80	7.04
S65	2.85	7.38	5.12
S66	4.38	7.44	5.91
S67	3.86	7.86	5.86
S68	3.96	7.26	5.61
S69	6.57	6.72	6.65
S70	4.86	7.08	5.97
S71	6.30	7.44	6.87
S72	7.61	6.72	7.16
S73	3.05	6.72	4.88
S74	4.50	6.30	5.40
S75	12.32	7.14	9.73
S76	3.06	16.80	9.93
S77	2.55	11.04	6.80
S78	3.56	12.84	8.20
S79	2.39	10.98	6.68
S80	3.12	11.70	7.41

Table B-6 BOD (mg/l) in the reference area

Sampling plots	Wet season	Dry season	Annual average
R1	1.74	8.64	5.19
R2	5.18	7.26	6.22
R3	2.09	10.32	6.20
R4	15.95	10.98	13.46
R5	4.68	7.56	6.12
R6	2.88	8.28	5.58
R7	3.48	8.94	6.21
R8	3.14	9.24	6.19
R9	9.23	10.02	9.62
R10	5.22	9.30	7.26
R11	5.00	9.30	7.15
R12	9.35	9.72	9.53
R13	5.03	8.40	6.71
R14	6.87	11.58	9.23
R15	7.61	13.50	10.55

Table B-7 Temperature (ºC) values in the study area

Sampling plots	Wet season	Dry season	Annual average
S1	30.15	33.80	31.98
S2	30.35	33.00	31.68
S3	28.95	33.00	30.98
S4	30.70	33.60	32.15
S5	29.95	34.70	32.33
S6	29.80	32.40	31.10
S7	29.00	32.60	30.80
S8	29.55	32.60	31.08
S9	29.00	34.20	31.60
S10	31.15	32.50	31.83
S11	31.60	34.50	33.05
S12	30.90	34.20	32.55
S13	28.90	30.40	29.65
S14	28.85	30.50	29.68
S15	28.10	30.70	29.40
S16	31.20	36.40	33.80
S17	30.20	32.10	31.15
S18	30.30	33.60	31.95
S19	31.00	32.20	31.60
S20	30.65	34.80	32.73
S21	29.10	31.80	30.45
S22	30.10	37.50	33.80
S23	28.30	31.00	29.65
S24	31.15	36.90	34.03
S25	28.90	31.30	30.10
S26	31.40	35.70	33.55
S27	30.45	31.30	30.88
S28	29.70	33.40	31.55
S29	30.20	31.90	31.05
S30	30.20	32.20	31.20

Table B-7 temperature (ºC) values in the study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S31	31.35	32.20	31.78
S32	30.80	34.00	32.40
S33	31.15	33.00	32.08
S34	30.40	34.60	32.50
S35	30.10	32.20	31.15
S36	29.30	33.30	31.30
S37	31.15	32.40	31.78
S38	29.45	32.80	31.13
S39	30.15	31.70	30.93
S40	30.55	33.00	31.78
S41	31.25	33.50	32.38
S42	32.45	33.10	32.78
S43	31.55	32.30	31.93
S44	30.05	33.10	31.58
S45	30.60	32.20	31.40
S46	30.10	32.20	31.15
S47	33.40	33.20	33.30
S48	30.05	32.10	31.08
S49	33.10	33.30	33.20
S50	30.35	32.00	31.18
S51	32.55	32.10	32.33
S52	32.40	32.10	32.25
S53	32.05	33.20	32.63
S54	31.90	36.50	34.20
S55	30.90	35.80	33.35
S56	32.20	36.60	34.40
S57	33.20	37.50	35.35
S58	32.25	34.60	33.43
S59	32.05	36.70	34.38
S60	31.80	35.60	33.70

Table B-7 temperature (ºC) in the study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S61	31.95	36.50	34.23
S62	33.45	38.40	35.93
S63	33.80	34.20	34.00
S64	33.35	34.50	33.93
S65	32.25	34.50	33.38
S66	31.30	32.80	32.05
S67	32.55	32.60	32.58
S68	31.15	33.40	32.28
S69	32.25	32.70	32.48
S70	31.10	33.10	32.10
S71	31.60	32.90	32.25
S72	33.55	33.40	33.48
S73	31.70	31.70	31.70
S74	33.60	33.40	33.50
S75	29.60	34.20	31.90
S76	29.65	34.30	31.98
S77	29.85	34.70	32.28
S78	29.90	35.40	32.65
S79	29.80	35.30	32.55
S80	29.80	35.10	32.45

Table B-8 Temperature (ºC) in the reference area

Sampling plots	Wet season	Dry season	Annual average
R1	28.45	33.20	30.83
R2	30.20	33.80	32.00
R3	30.00	33.50	31.75
R4	28.45	32.90	30.68
R5	29.50	33.30	31.40
R6	28.30	32.50	30.40
R7	29.50	33.00	31.25
R8	28.25	33.60	30.93
R9	29.55	33.50	31.53
R10	28.20	32.60	30.40
R11	28.15	32.10	30.13
R12	28.45	33.20	30.83
R13	28.00	32.30	30.15
R14	27.85	32.00	29.93
R15	28.25	32.60	30.43

Table B-9 Salinity (ppt) in the study area

Sampling plots	Wet season	Dry season	Annual average
S1	28.88	36.90	31.55
S2	27.44	33.63	29.50
S3	32.28	43.13	35.90
S4	30.71	36.87	32.76
S5	28.34	33.67	30.12
S6	29.59	37.60	32.26
S7	28.72	35.70	31.04
S8	31.98	39.97	34.64
S9	29.39	36.90	31.89
S10	30.98	37.50	33.15
S11	31.75	42.87	35.45
S12	28.15	32.90	29.73
S13	3.64	23.37	10.22
S14	4.27	23.03	10.52
S15	6.47	22.40	11.78
S16	3.34	24.77	10.48
S17	29.97	39.17	33.03
S18	40.36	52.63	44.45
S19	30.46	40.97	33.96
S20	8.04	25.07	13.71
S21	32.10	41.13	35.11
S22	27.73	31.37	28.94
S23	19.52	42.03	27.03
S24	21.03	27.23	23.10
S25	28.29	30.03	28.87
S26	19.75	26.40	21.97
S27	28.93	33.90	30.59
S28	29.38	34.17	30.97
S29	29.06	36.83	31.65
S30	28.21	31.80	29.40

Table B-9 Salinity (ppt) in the study area (Cont.)

Sampling plots	**Wet season**	**Dry season**	**Annual average**
S31	29.16	39.20	32.51
S32	29.36	39.60	32.77
S33	29.71	37.43	32.28
S34	28.07	34.73	30.29
S35	29.93	37.27	32.38
S36	23.88	31.00	26.25
S37	29.92	38.30	32.71
S38	21.83	30.33	24.67
S39	29.34	34.37	31.02
S40	25.67	33.30	28.21
S41	29.45	31.27	30.05
S42	33.15	41.93	36.08
S43	29.68	33.47	30.94
S44	29.99	36.17	32.05
S45	29.87	32.67	30.80
S46	28.27	41.70	32.74
S47	30.34	32.60	31.09
S48	31.26	42.27	34.93
S49	31.13	37.23	33.17
S50	30.45	41.57	34.15
S51	29.12	32.40	30.21
S52	29.56	32.33	30.49
S53	29.95	35.20	31.70
S54	30.99	37.80	33.26
S55	29.93	36.87	32.24
S56	29.94	37.33	32.40
S57	26.83	33.63	29.10
S58	26.73	35.07	29.51
S59	30.12	37.73	32.65
S60	26.57	33.53	28.89

Table B-9 Salinity (ppt) in the study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S61	28.43	32.47	29.78
S62	29.01	32.80	30.27
S63	25.36	32.27	27.66
S64	26.23	32.77	28.41
S65	28.91	33.27	30.36
S66	29.61	32.43	30.55
S67	29.71	31.67	30.36
S68	30.52	35.17	32.07
S69	29.41	33.27	30.70
S70	29.00	32.67	30.22
S71	30.39	35.87	32.22
S72	28.93	33.53	30.46
S73	30.03	33.07	31.04
S74	30.20	33.83	31.41
S75	26.68	31.97	28.44
S76	25.86	23.60	25.10
S77	28.90	31.37	29.72
S78	28.79	32.83	30.14
S79	26.88	33.47	29.08
S80	27.96	34.03	29.98

Table B-10 Salinity (ppt) in the reference area

Sampling plots	Wet season	Dry season	Annual average
R1	28.18	32.63	29.66
R2	28.18	33.37	29.91
R3	28.20	36.73	31.04
R4	27.05	33.03	29.04
R5	27.55	33.80	29.63
R6	27.60	34.27	29.82
R7	27.75	42.23	32.58
R8	26.83	38.00	30.55
R9	27.22	38.67	31.03
R10	26.23	37.17	29.88
R11	27.20	46.73	33.71
R12	27.24	52.50	35.66
R13	27.73	43.47	32.98
R14	28.35	38.57	31.75
R15	28.25	37.87	31.45

Table B-11 Conductivity (mS) in the study area

Sampling plots	Wet season	Dry season	Annual average
S1	50.19	55.00	52.59
S2	47.09	50.73	48.91
S3	53.39	63.10	58.25
S4	49.62	55.07	52.34
S5	47.75	50.73	49.24
S6	50.74	56.07	53.40
S7	48.44	53.57	51.00
S8	53.33	59.03	56.18
S9	50.04	55.00	52.52
S10	52.02	55.90	53.96
S11	55.22	62.73	58.97
S12	46.39	49.73	48.06
S13	19.70	36.73	28.22
S14	20.07	36.20	28.13
S15	23.05	35.27	29.16
S16	22.40	38.43	30.42
S17	51.52	58.13	54.82
S18	66.44	74.93	70.69
S19	53.24	60.43	56.83
S20	27.27	38.90	33.08
S21	53.94	60.67	57.30
S22	45.54	47.50	46.52
S23	46.97	61.93	54.45
S24	38.47	41.83	40.15
S25	45.17	46.00	45.58
S26	37.98	40.77	39.37
S27	49.99	51.30	50.64
S28	48.04	51.47	49.75
S29	51.30	55.17	53.23
S30	46.71	48.33	47.52

Table B-11 Conductivity (mS) in the study area (Cont.)

Sampling plots	**Wet season**	**Dry season**	**Annual average**
S31	52.39	58.20	55.29
S32	52.06	58.53	55.29
S33	52.23	55.73	53.98
S34	48.37	52.07	50.22
S35	51.14	55.63	53.39
S36	42.79	47.17	44.98
S37	51.80	57.03	54.42
S38	40.64	46.27	43.45
S39	49.03	51.83	50.43
S40	46.32	50.33	48.33
S41	47.29	47.60	47.45
S42	56.69	61.63	59.16
S43	49.28	50.67	49.97
S44	51.04	54.03	52.54
S45	47.61	49.57	48.59
S46	53.29	61.40	57.34
S47	48.31	49.30	48.81
S48	55.39	62.13	58.76
S49	52.29	55.50	53.89
S50	54.99	61.27	58.13
S51	47.29	49.17	48.23
S52	48.67	49.07	48.87
S53	51.22	52.77	51.99
S54	52.97	56.07	54.52
S55	50.46	54.87	52.66
S56	51.47	55.43	53.45
S57	47.62	50.47	49.04
S58	48.31	52.67	50.49
S59	52.11	55.93	54.02
S60	47.22	50.53	48.88

Table B-11 Conductivity (mS) in the study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S61	46.75	48.97	47.86
S62	49.24	49.40	49.32
S63	44.42	48.87	46.64
S64	48.55	49.63	49.09
S65	49.16	50.23	49.70
S66	49.86	49.20	49.53
S67	47.21	48.17	47.69
S68	51.13	52.87	52.00
S69	49.57	50.27	49.92
S70	49.38	49.47	49.42
S71	51.60	53.73	52.67
S72	49.11	50.60	49.86
S73	49.86	50.07	49.96
S74	49.21	50.97	50.09
S75	45.59	48.53	47.06
S76	41.06	36.87	38.96
S77	46.06	47.60	46.83
S78	48.90	49.57	49.23
S79	47.84	50.43	49.14
S80	49.16	51.17	50.16

Table B-12 Conductivity (mS) in the reference area

Sampling plots	Wet season	Dry season	Annual average
R1	46.80	49.37	48.08
R2	47.17	50.33	48.75
R3	49.41	54.83	52.12
R4	46.35	49.87	48.11
R5	46.91	50.93	48.92
R6	47.55	51.67	49.61
R7	53.40	62.03	57.72
R8	50.01	56.53	53.27
R9	49.88	57.37	53.62
R10	48.67	55.40	52.03
R11	55.47	67.83	61.65
R12	60.70	74.77	67.73
R13	53.84	63.60	58.72
R14	51.19	57.37	54.28
R15	50.29	56.43	53.36

Table B-13 TOC (mg/l) in the study area

Sampling plots	Wet season	Dry season	Annual average
S1	16.46	9.59	13.02
S2	13.35	25.79	19.57
S3	11.00	38.75	24.87
S4	9.95	29.22	19.58
S5	9.61	25.38	17.50
S6	14.22	49.68	31.95
S7	6.96	23.51	15.23
S8	22.60	40.10	31.35
S9	21.69	22.19	21.94
S10	15.07	40.04	27.55
S11	27.92	48.71	38.31
S12	18.22	55.76	36.99
S13	20.14	20.99	20.57
S14	14.67	28.11	21.39
S15	17.49	25.59	21.54
S16	53.52	22.80	38.16
S17	13.10	59.48	36.29
S18	12.58	24.23	18.41
S19	10.16	30.86	20.51
S20	14.20	14.04	14.12
S21	20.30	149.30	84.80
S22	9.39	31.61	20.50
S23	17.98	67.34	42.66
S24	20.86	31.47	26.16
S25	19.07	13.20	16.13
S26	23.91	187.00	105.46
S27	11.45	23.94	17.70
S28	17.82	22.30	20.06
S29	8.44	27.10	17.77
S30	22.86	23.58	23.22

Table B-13 TOC (mg/l) in the study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S31	15.91	38.98	27.45
S32	18.26	38.21	28.23
S33	11.79	44.90	28.35
S34	13.55	16.85	15.20
S35	11.39	21.30	16.35
S36	12.70	10.13	11.42
S37	9.98	45.84	27.91
S38	17.19	15.60	16.40
S39	9.91	15.65	12.78
S40	20.22	15.12	17.67
S41	3.75	22.12	12.94
S42	25.52	53.76	39.64
S43	8.02	27.63	17.82
S44	12.49	24.02	18.26
S45	9.87	11.34	10.60
S46	17.06	39.37	28.22
S47	9.93	11.19	10.56
S48	18.79	32.71	25.75
S49	14.88	29.88	22.38
S50	32.91	31.16	32.03
S51	4.54	7.63	6.09
S52	7.22	13.59	10.41
S53	6.71	21.94	14.32
S54	11.44	20.59	16.01
S55	13.50	22.11	17.81
S56	32.63	23.88	28.25
S57	14.46	10.71	12.59
S58	14.87	11.76	13.31
S59	12.13	11.10	11.62
S60	9.41	9.12	9.26

Table B-13 TOC (mg/l) in the study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S61	8.08	34.10	21.09
S62	11.18	29.91	20.55
S63	13.07	18.57	15.82
S64	11.33	18.44	14.88
S65	7.67	9.68	8.68
S66	18.74	13.19	15.97
S67	11.27	12.81	12.04
S68	9.07	32.15	20.61
S69	16.81	11.93	14.37
S70	12.17	15.09	13.63
S71	15.75	20.99	18.37
S72	26.53	11.52	19.02
S73	8.07	10.01	9.04
S74	15.54	17.18	16.36
S75	12.18	10.74	11.46
S76	15.31	12.61	13.96
S77	13.06	12.84	12.95
S78	7.92	26.56	17.24
S79	7.83	13.13	10.48
S80	7.60	10.42	9.01

Table B-14 TOC (mg/l) in the reference area

Sampling plots	Wet season	Dry season	Annual average
R1	8.78	13.95	11.37
R2	12.84	9.53	11.18
R3	13.38	22.63	18.00
R4	41.88	14.70	28.29
R5	20.45	10.11	15.28
R6	13.14	19.82	16.48
R7	22.09	23.50	22.79
R8	18.89	16.76	17.83
R9	14.62	31.70	23.16
R10	19.57	10.96	15.26
R11	17.89	40.43	29.16
R12	11.79	24.92	18.36
R13	11.43	15.09	13.26
R14	14.92	13.26	14.09
R15	19.89	11.06	15.48

Table B-15 The quality of water in the study area from Sawangchat (2001)

Parameters	area	Average			
		Rainy	winter	Summer	annual
DO(mg/l)	Input	4.61	9.5	7.00	7.04
	Study area	1.13	4.17	3.84	3.05
	Reference area	2.64	5.30	4.20	4.05
	Outlet	2.06	8.55	5.47	5.36
pH	Input	9.48	8.85	9.32	9.22
	Study area	7.49	7.60	7.60	7.56
	Reference area	7.70	7.71	7.65	7.69
	Outlet	7.97	7.87	7.84	7.89
Temperature(C)	Input	28.0	24.4	24.0	25.5
	Study area	26.5	25.3	25.0	25.6
	Reference area	26.7	25.2	24.0	25.3
	Outlet	25.5	25.3	27.3	26.0
Conductivity(mS)	Input	1.0	0.9	1.3	1.1
	Study area	32.3	32.9	25.4	30.2
	Reference area	29.8	31.0	25.8	28.9
	Outlet	27.6	35	38.8	33.8
Salinity(ppt)	Input	0.5	0.5	1.5	0.8
	Study area	22.5	20.5	25.0	22.7
	Reference area	20.7	19.2	21.3	20.4
	Outlet	20.2	21.8	29.8	24.0

Reference: Sawangchat (2001)

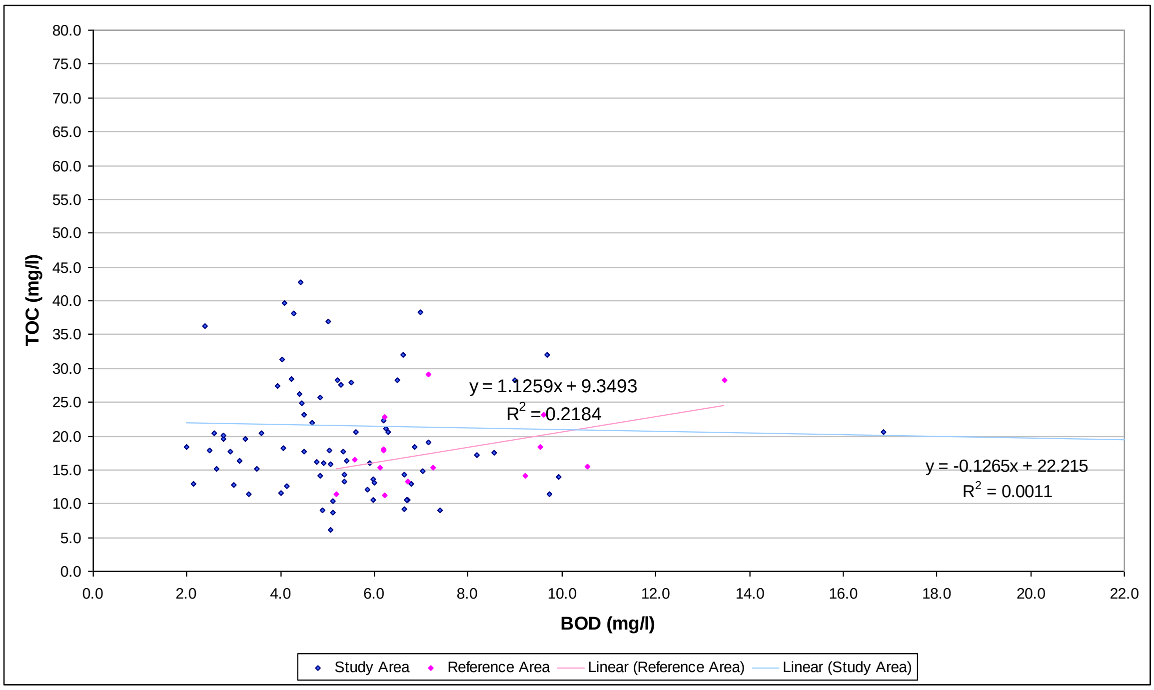

Figure B-1 Relationship between BOD and TOC by the linear model

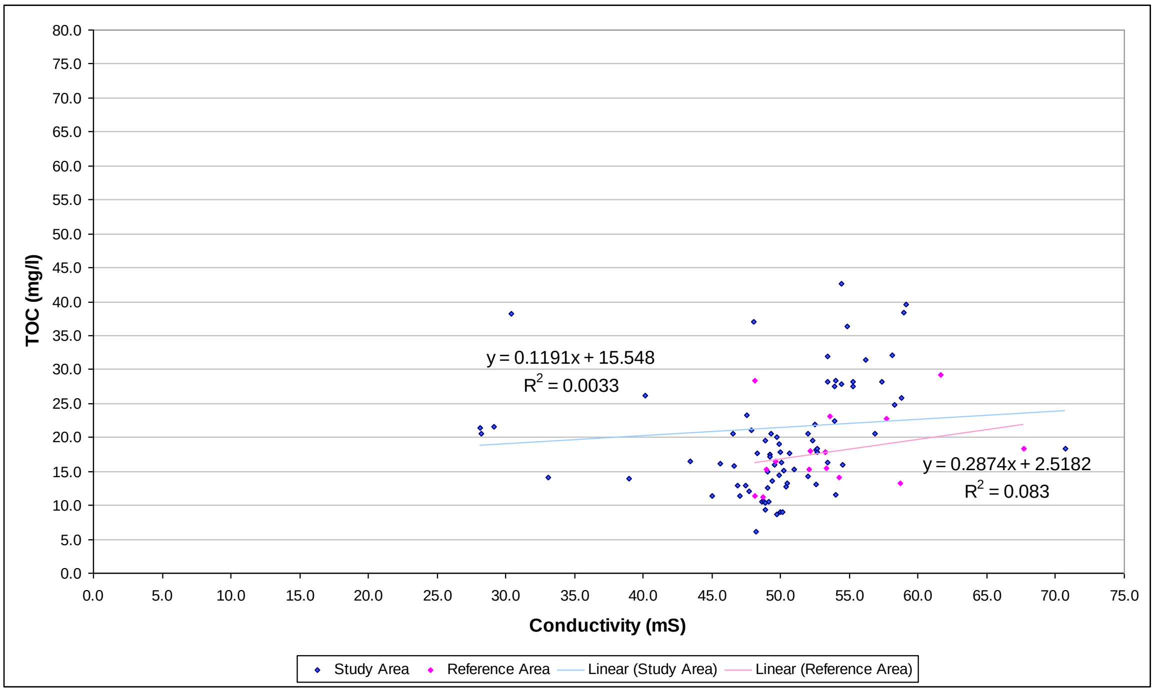

Figure B-2 Relationship between Conductivity and TOC by the linear model

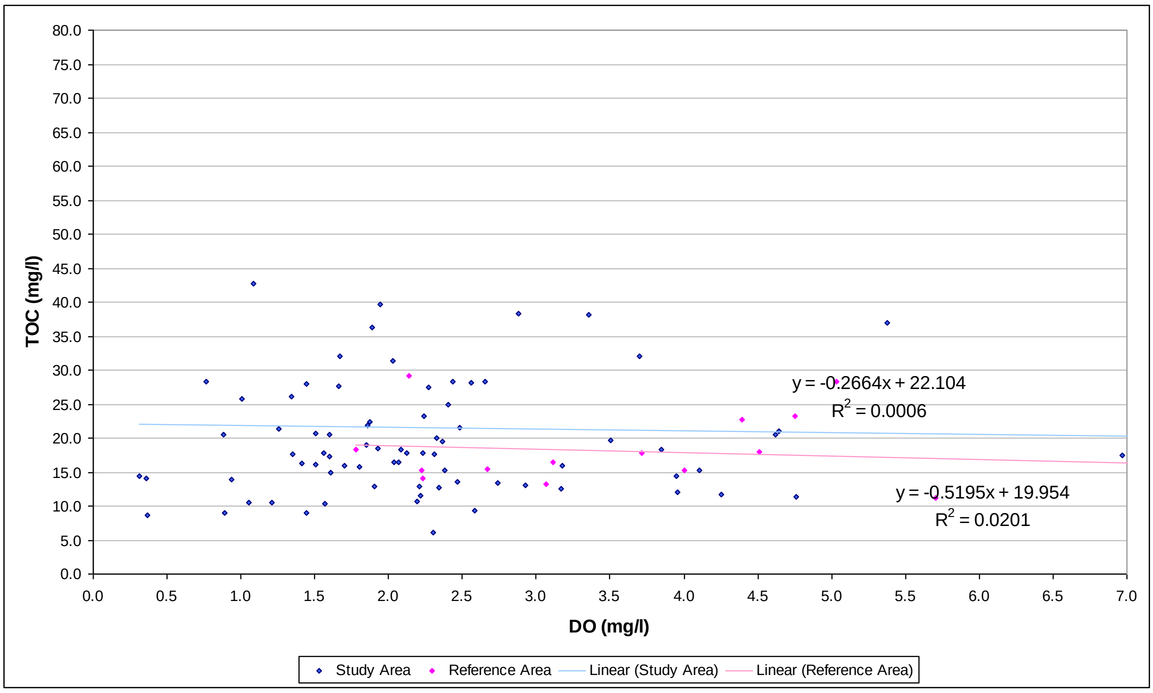

Figure B-3 Relationship between DO and TOC by the linear model

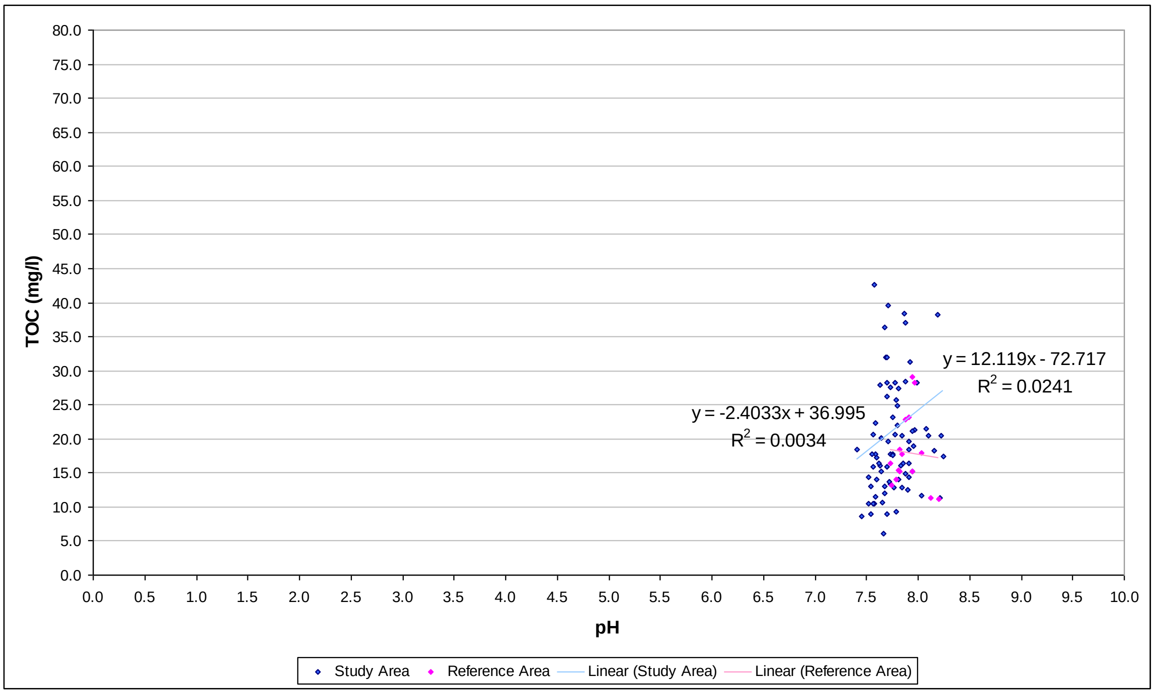

Figure B-4 Relationship between pH in water and TOC by the linear model

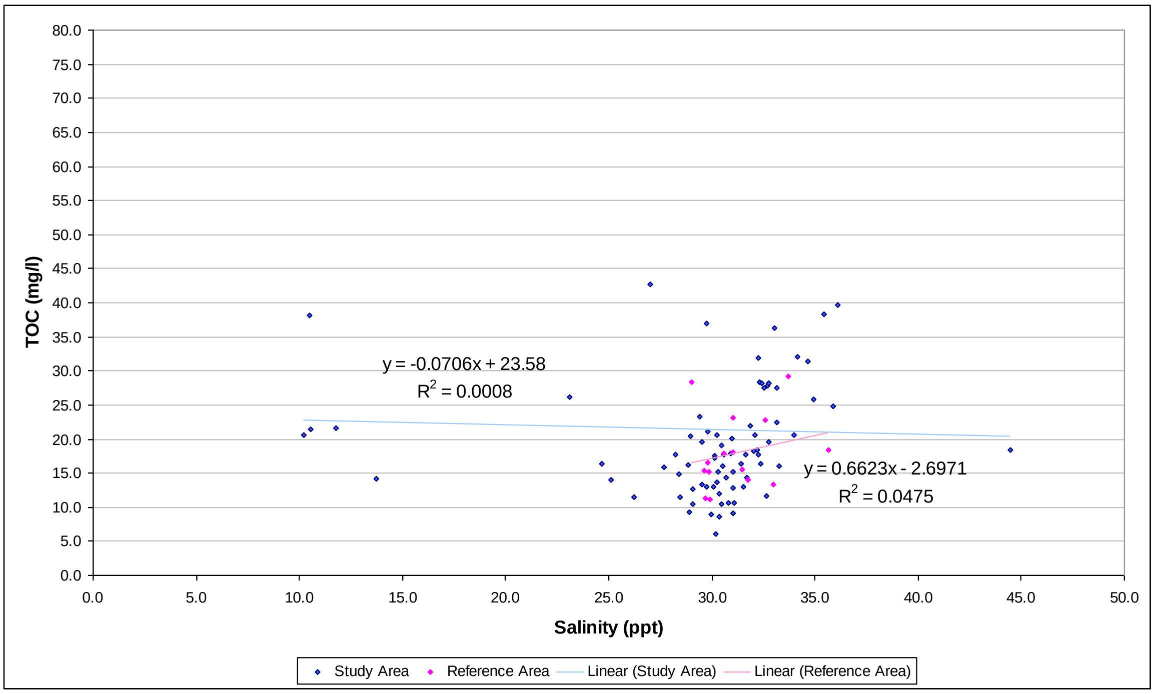

Figure B-5 Relationship between Salinity and TOC by the linear model

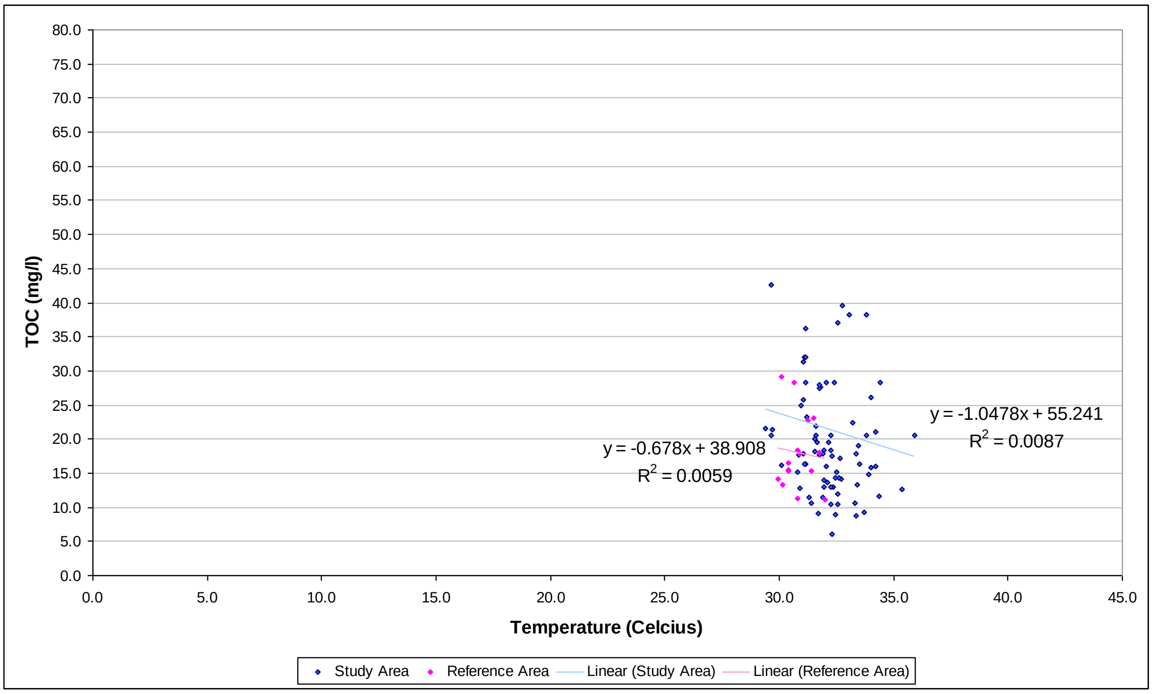

Figure B-6 Relationship between Temperature and TOC by the linear model

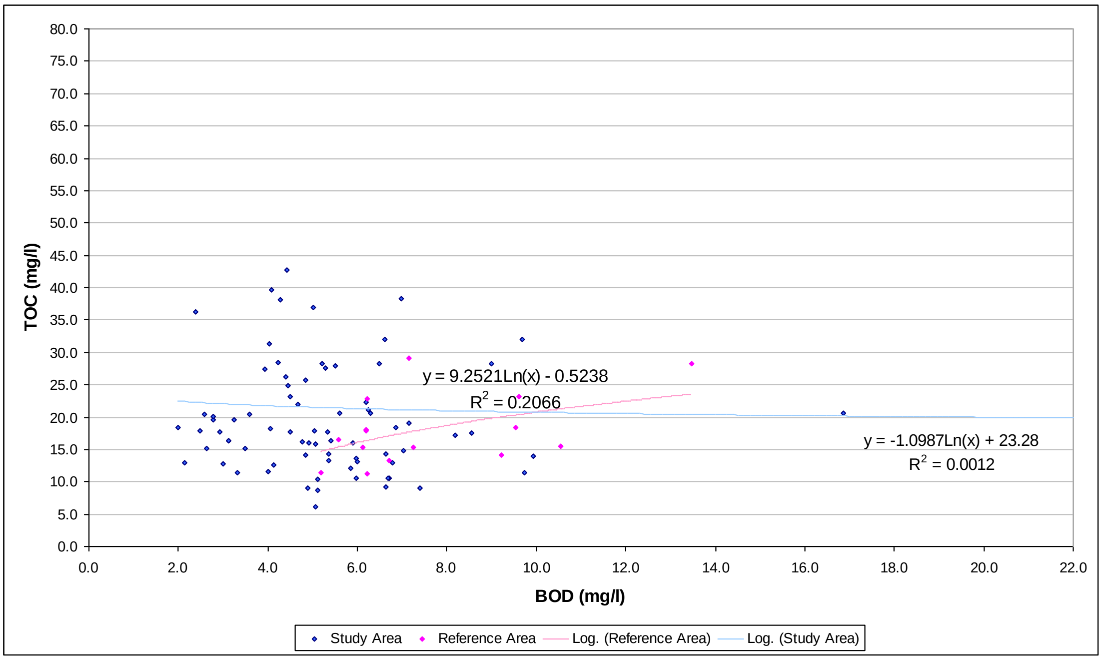

Figure B-7 Relationship between BOD and TOC by the Logarithmic model

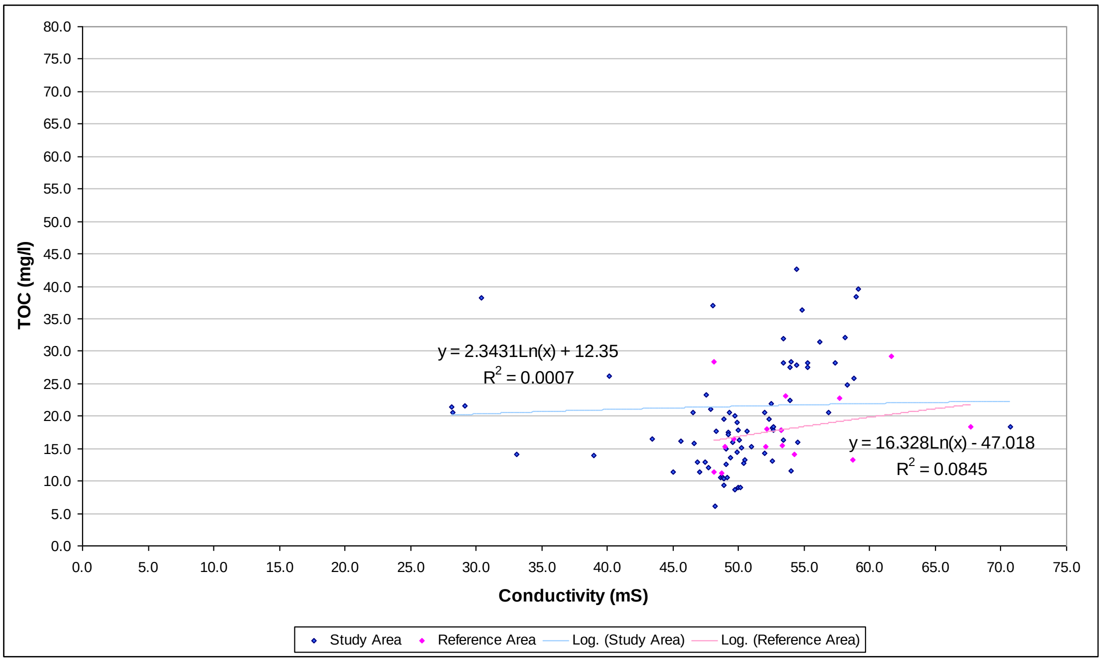

Figure B-8 Relationship between Conductivity and TOC by the Logarithmic model

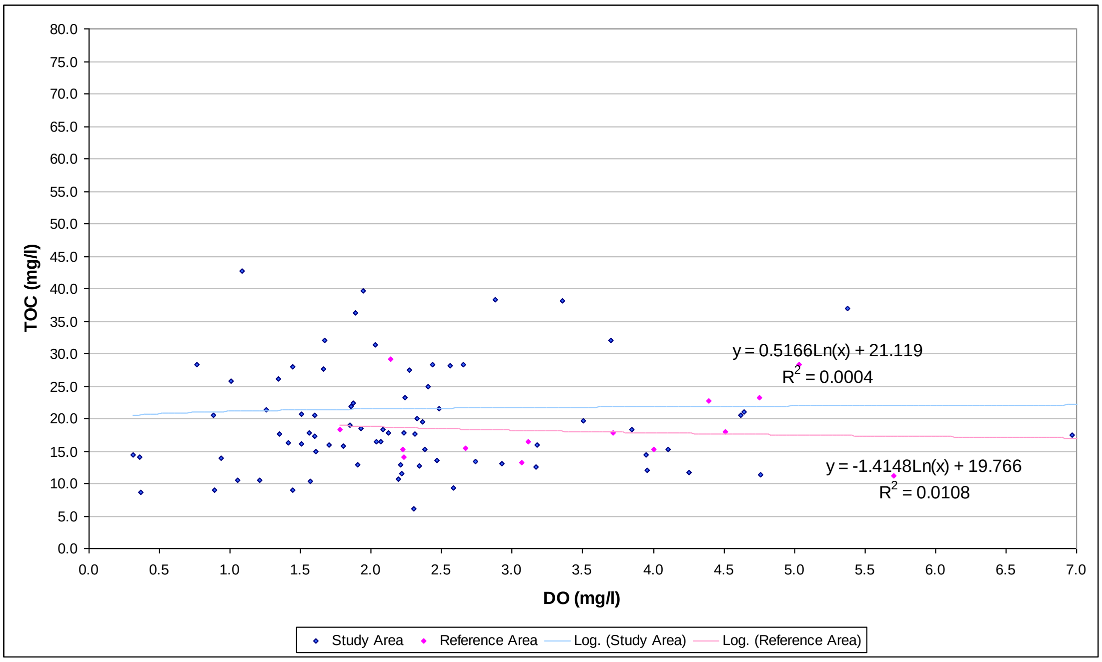

Figure B-9 Relationship between DO and TOC by the Logarithmic model

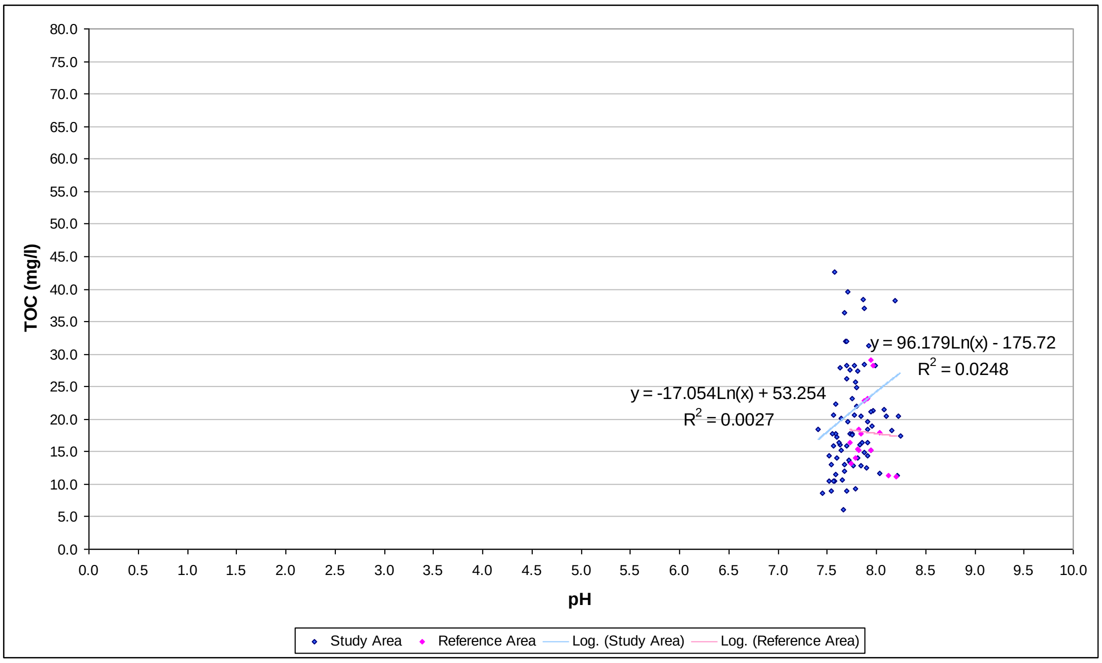

Figure B-10 Relationship between pH in water and TOC by the Logarithmic model

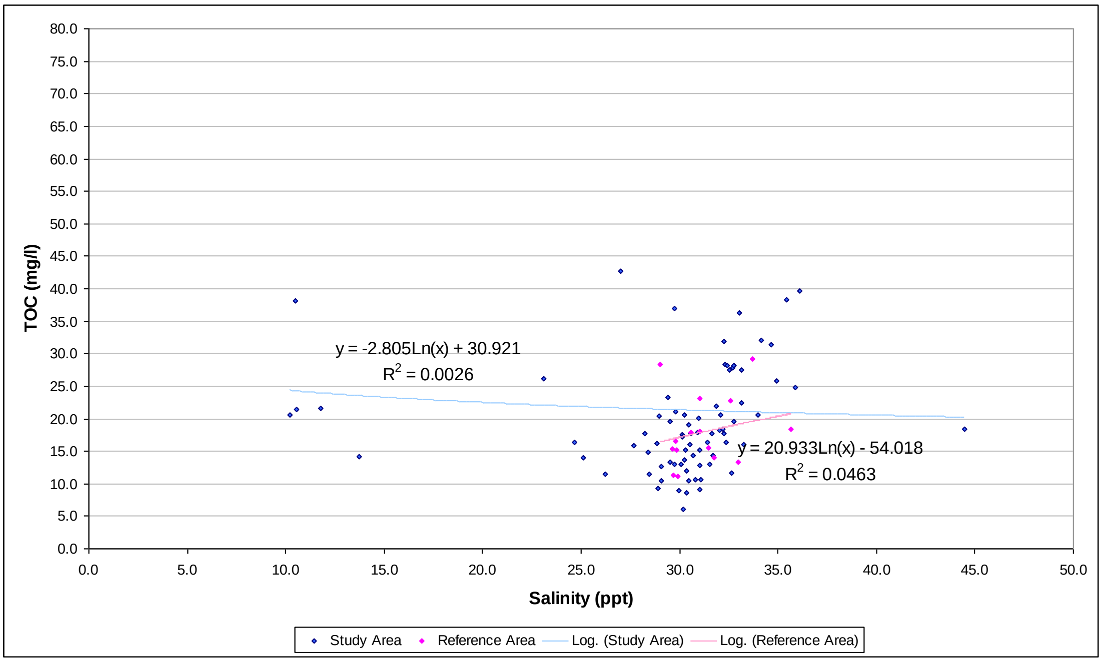

Figure B-11 Relationship between salinity in water and TOC by the Logarithmic model

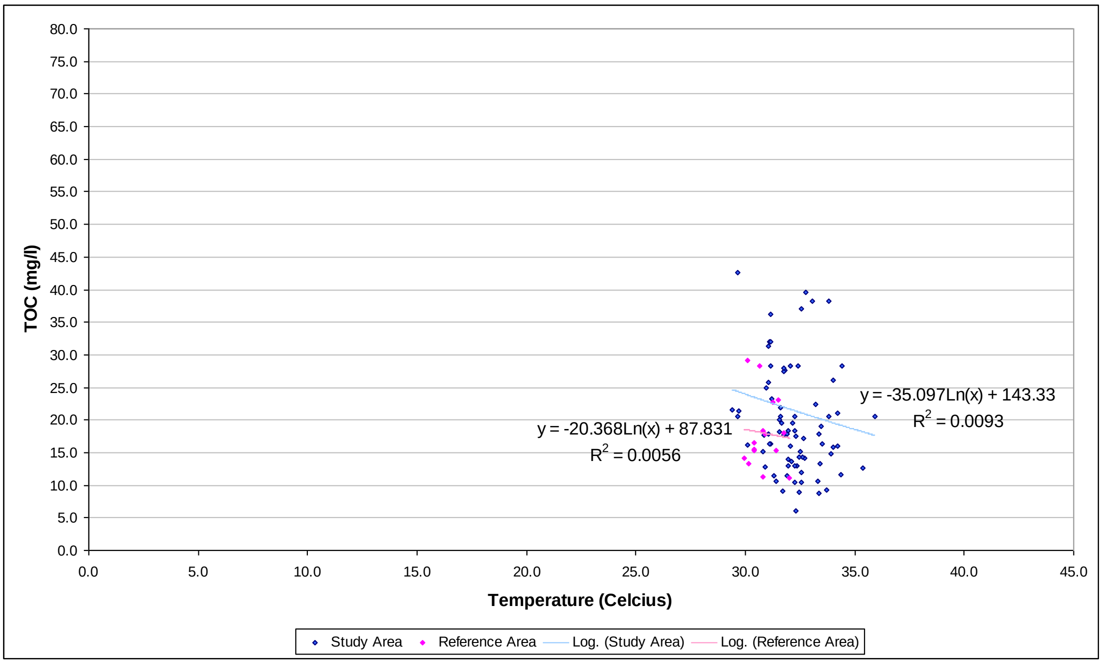

Figure B-12 Relationship between temperature and TOC by the Logarithmic model

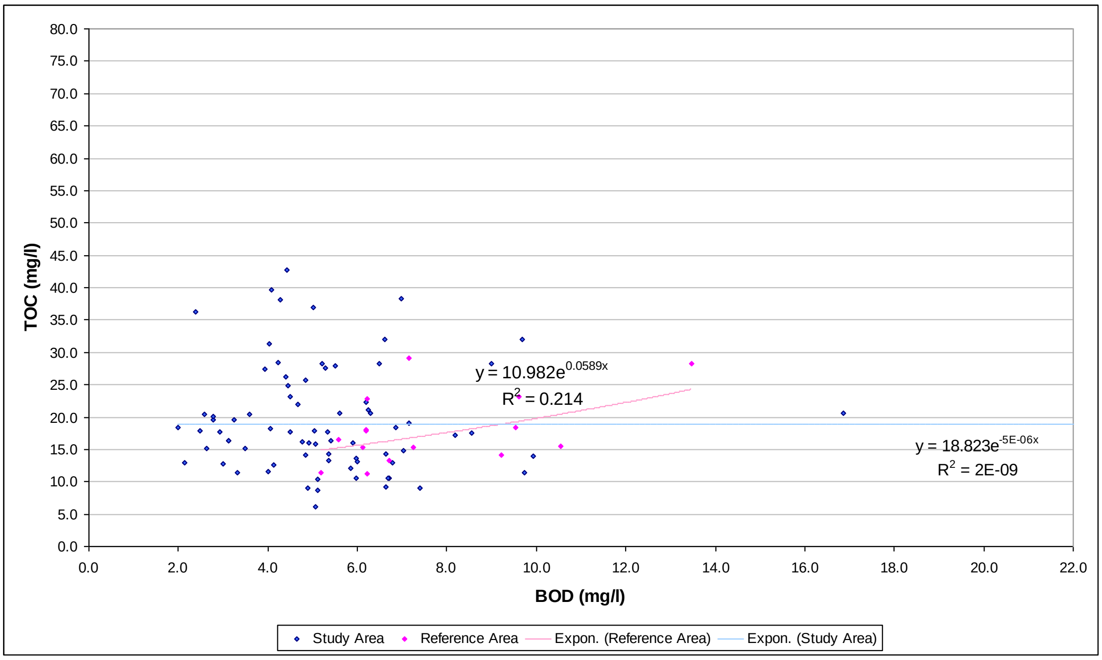

Figure B-13 Relationship between BOD and TOC by the Exponential model

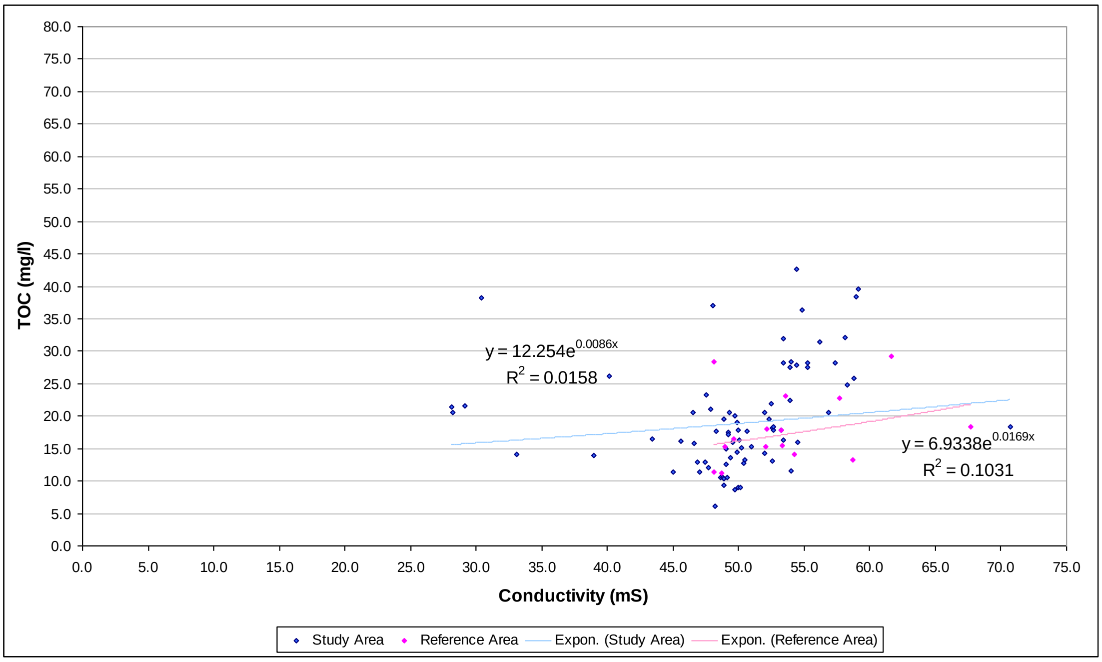

Figure B-14 Relationship between Conductivity and TOC by the Exponential model

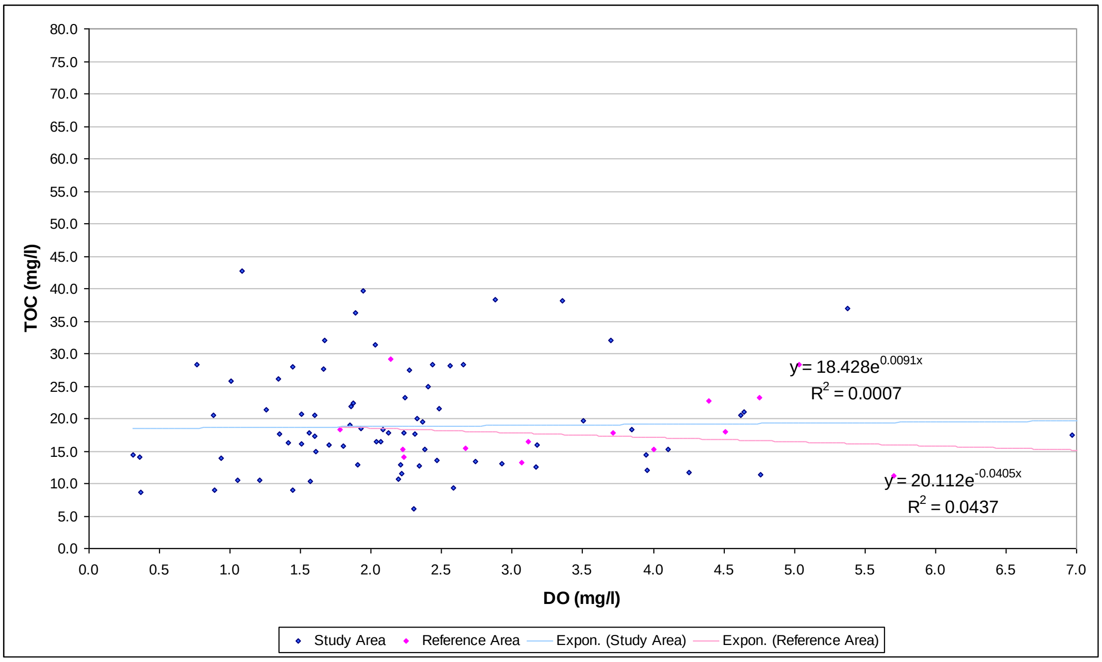

Figure B-15 Relationship between DO and TOC by the Exponential model

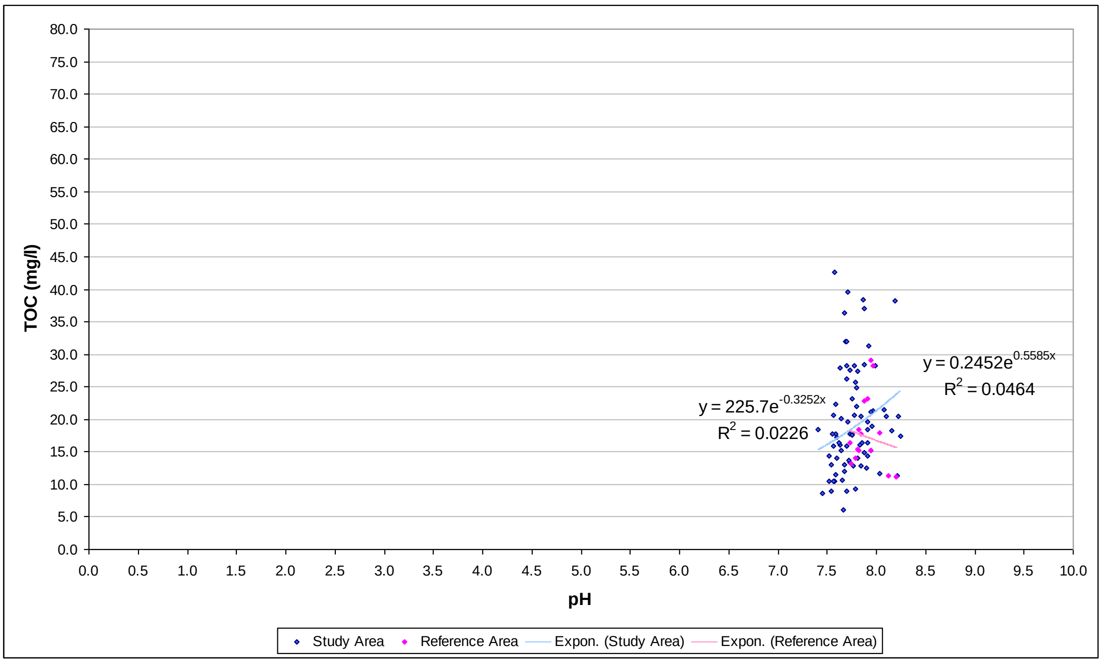

Figure B-16 Relationship between pH in water and TOC by the Exponential model

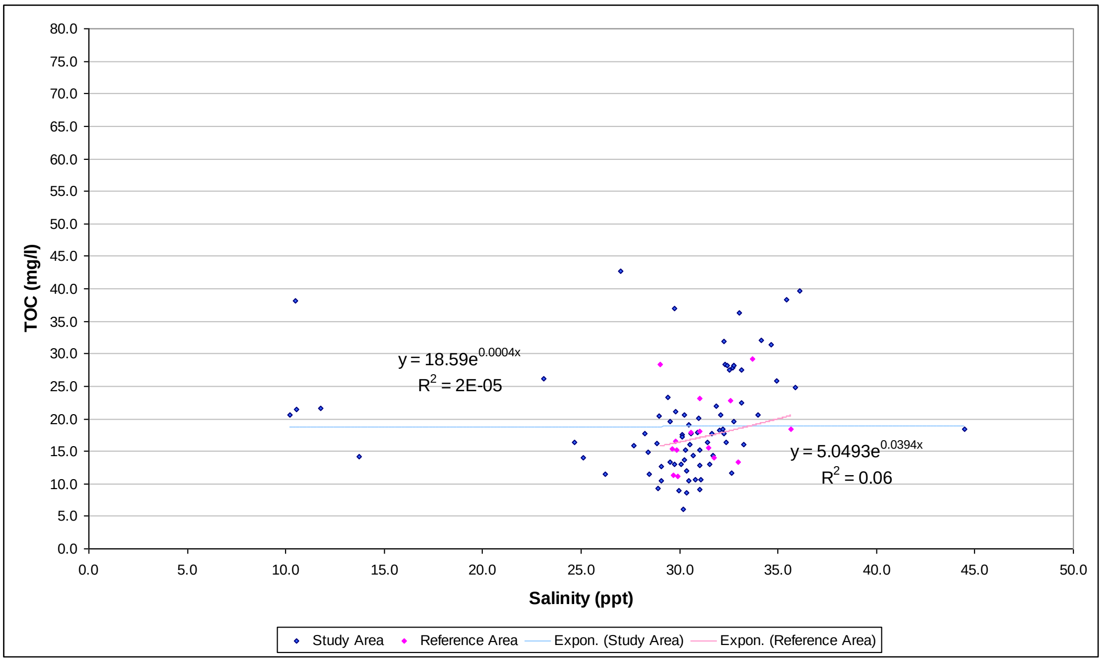

Figure B-17 Relationship between salinity in water and TOC by the Exponential model

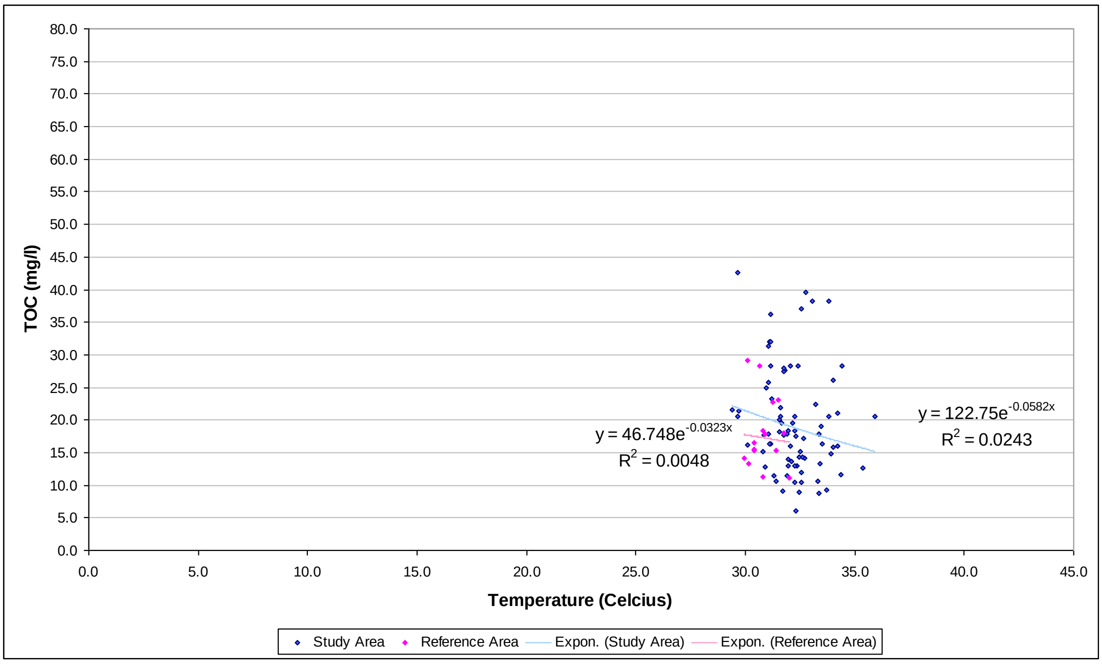

Figure B-18 Relationship between temperature in water and TOC by the Exponential model

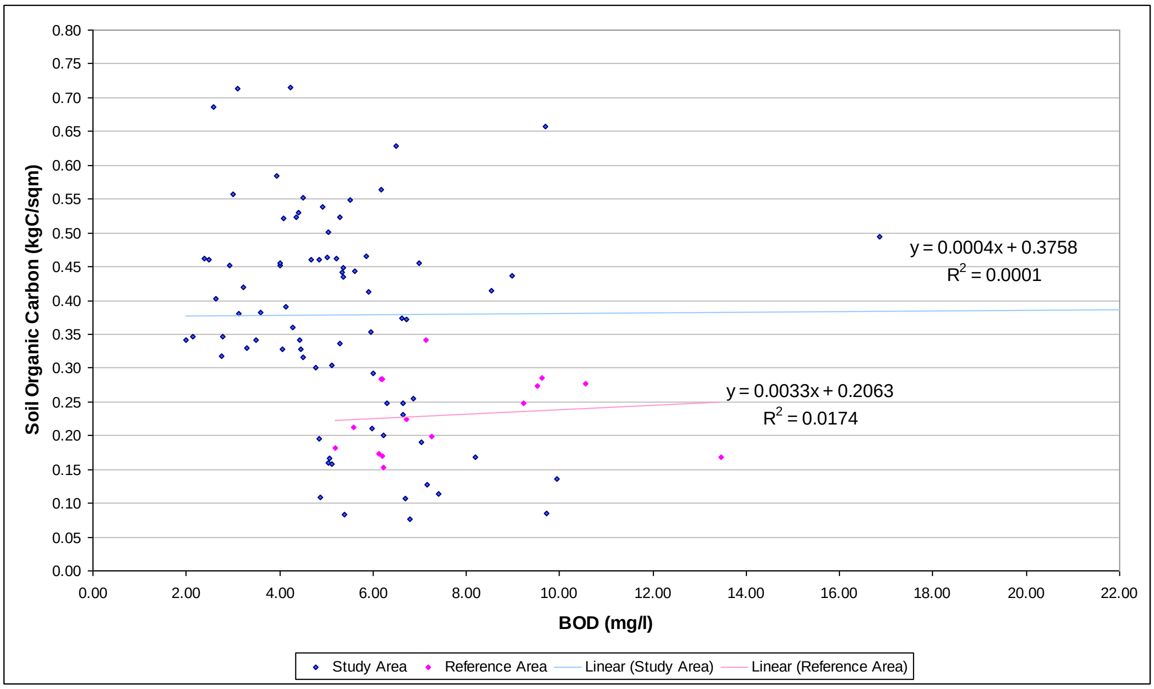

Figure B-19 Relationship between BOD and SOC by the linear model

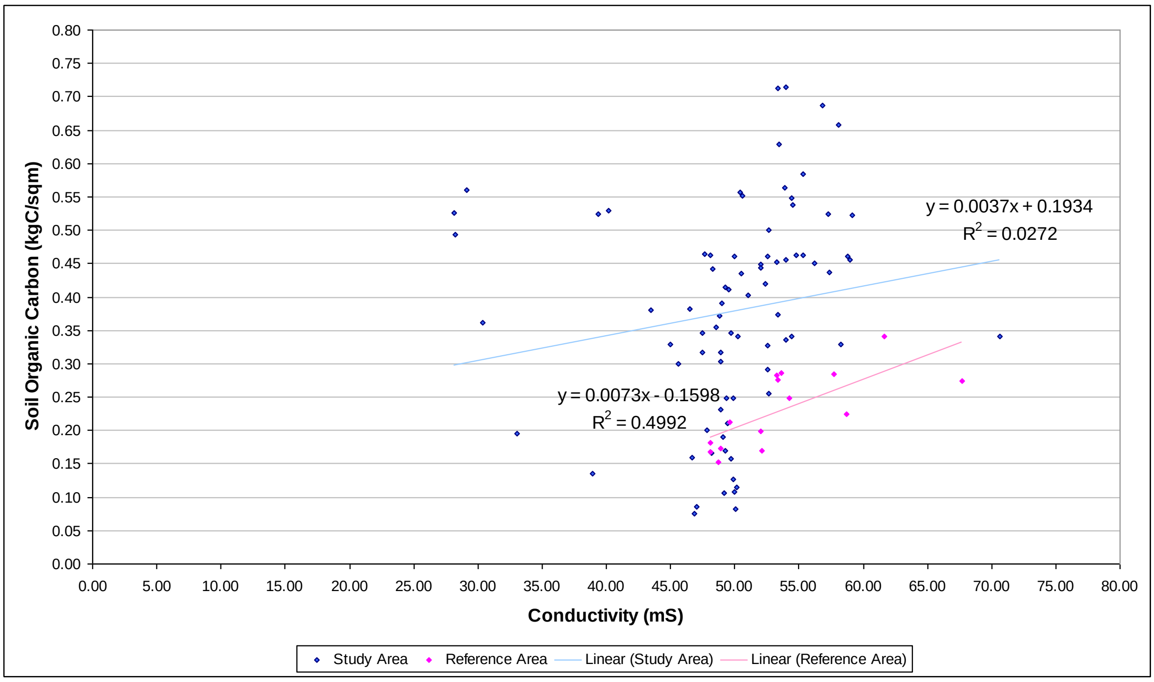

Figure B-20 Relationship between conductivity and SOC by the linear model

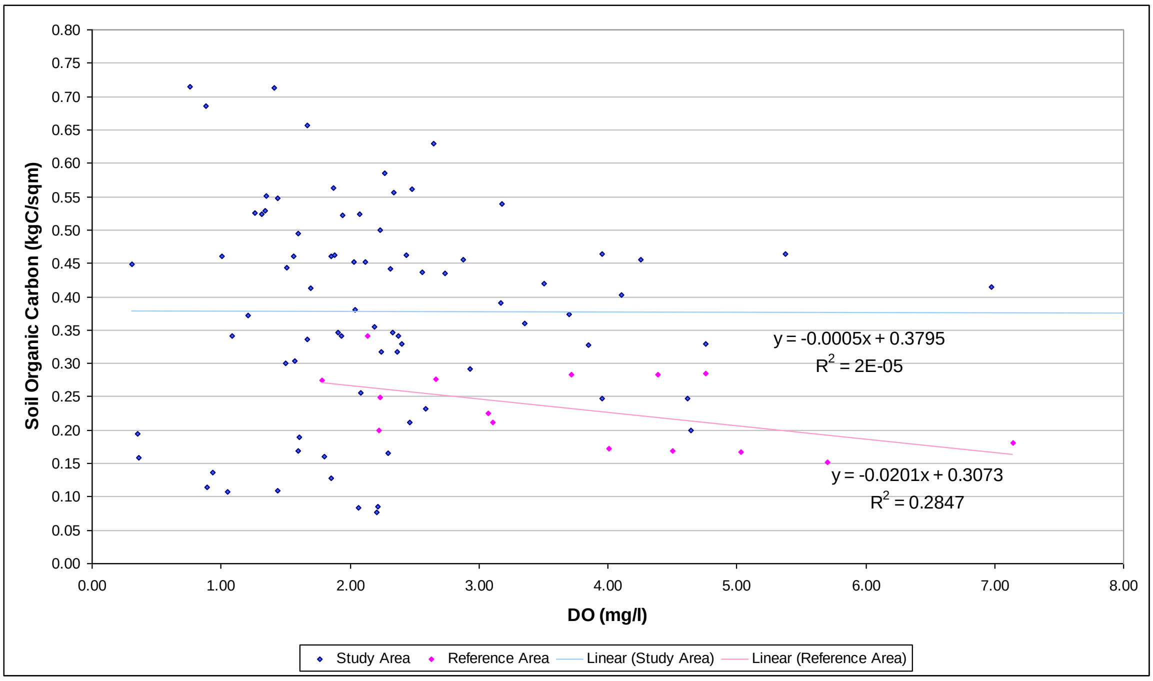

Figure B-21 Relationship between DO and SOC by the linear model

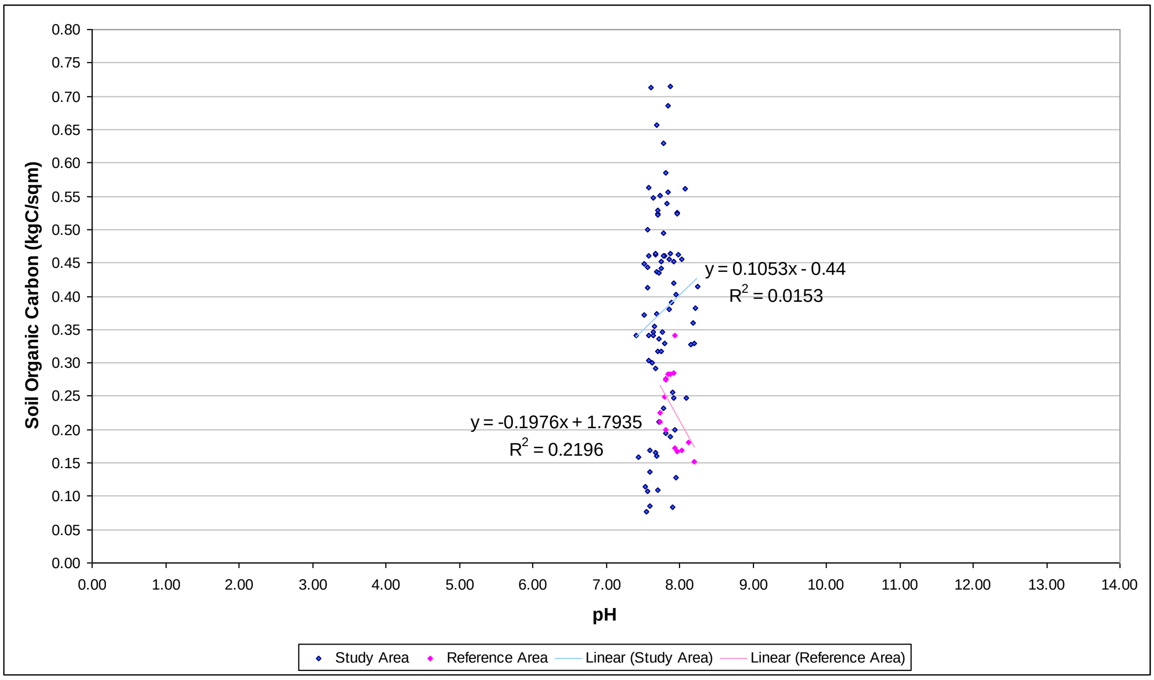

Figure B-22 Relationship between pH in water and SOC by the linear model

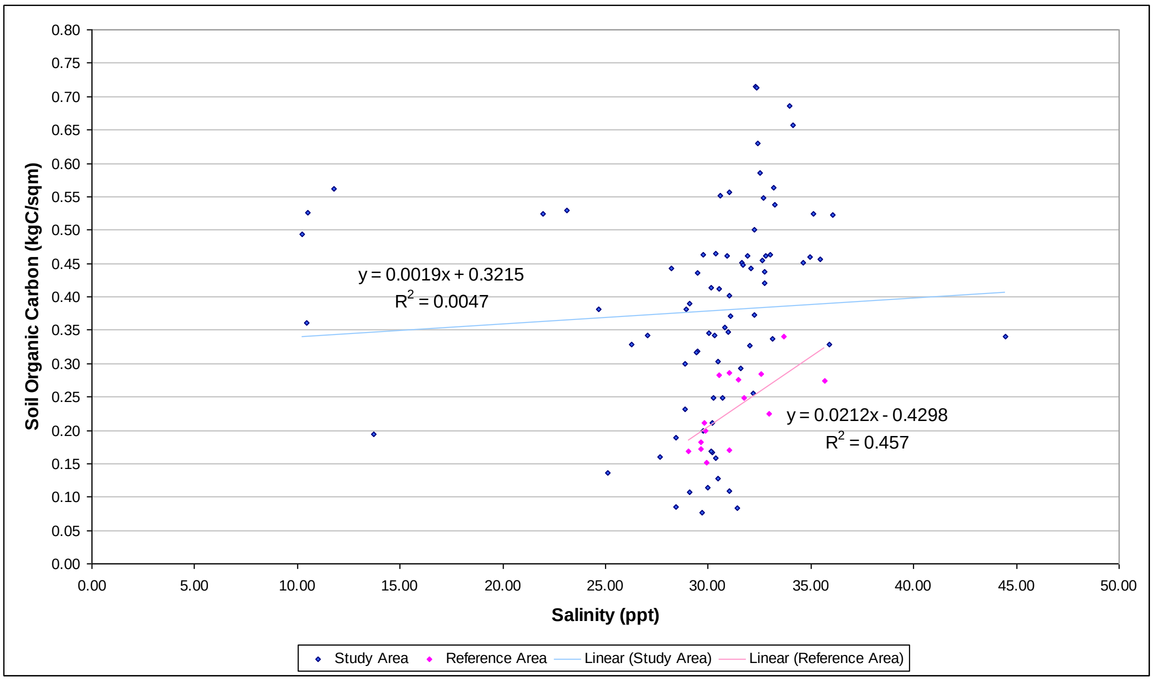

Figure B-23 Relationship between salinity in water and SOC by the linear model

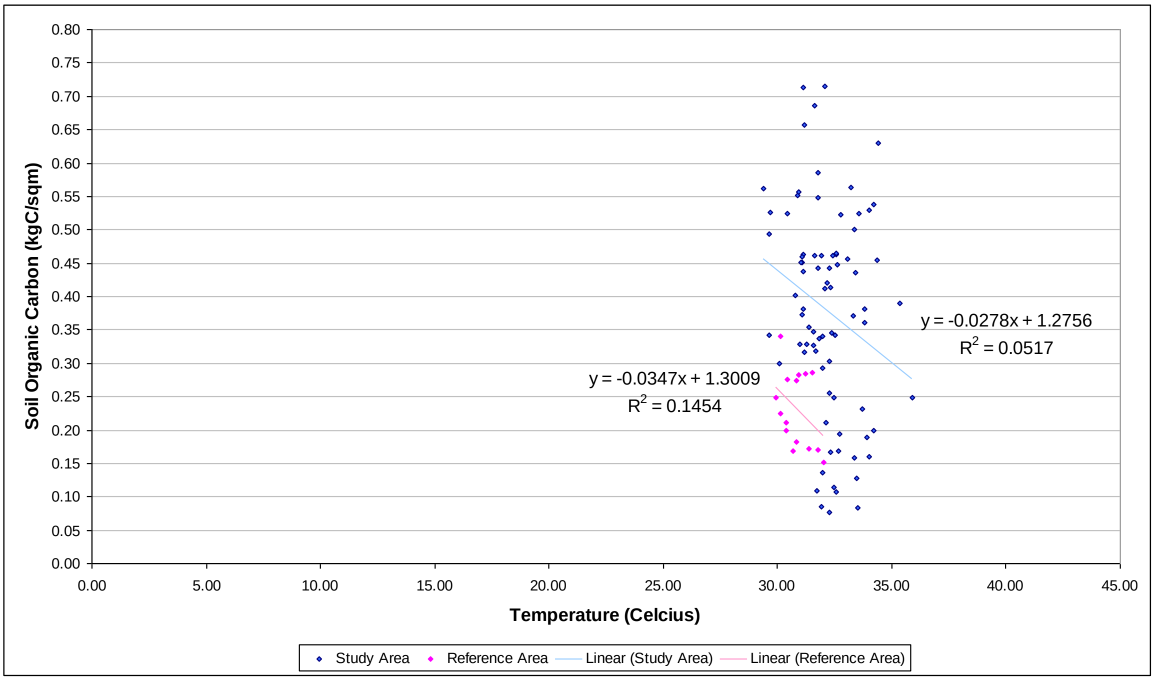

Figure B-24 Relationship between temperature in water and SOC by the linear model

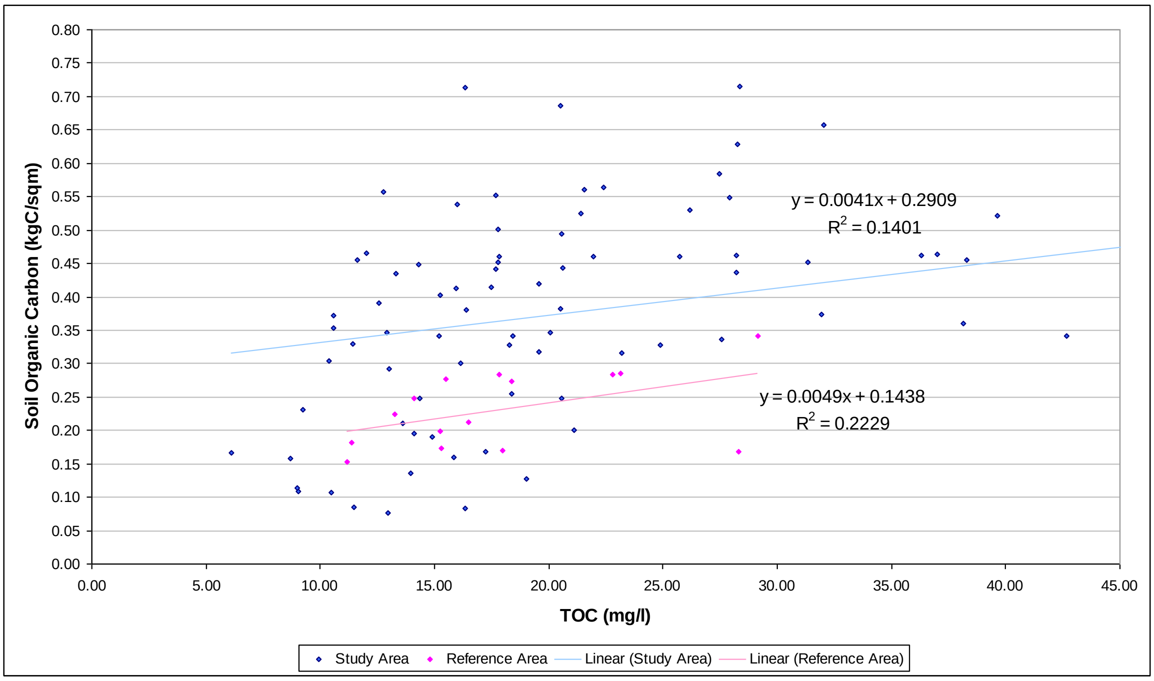

Figure B-25 Relationship between TOC and SOC by the linear model

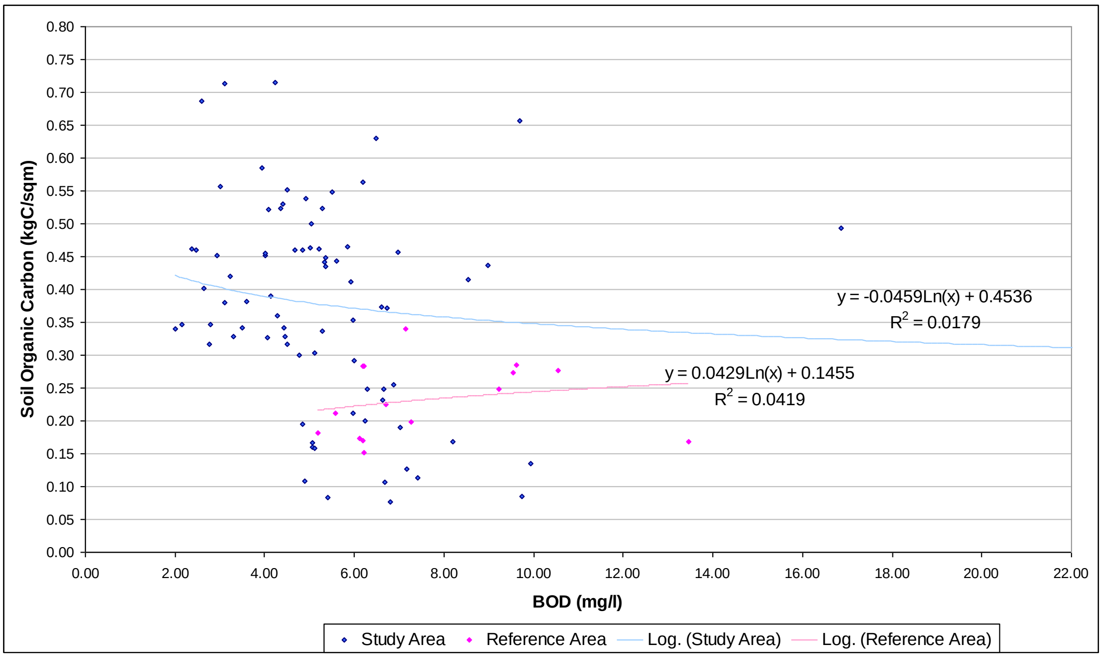

Figure B-26 Relationship between BOD and SOC by the Logarithmic model

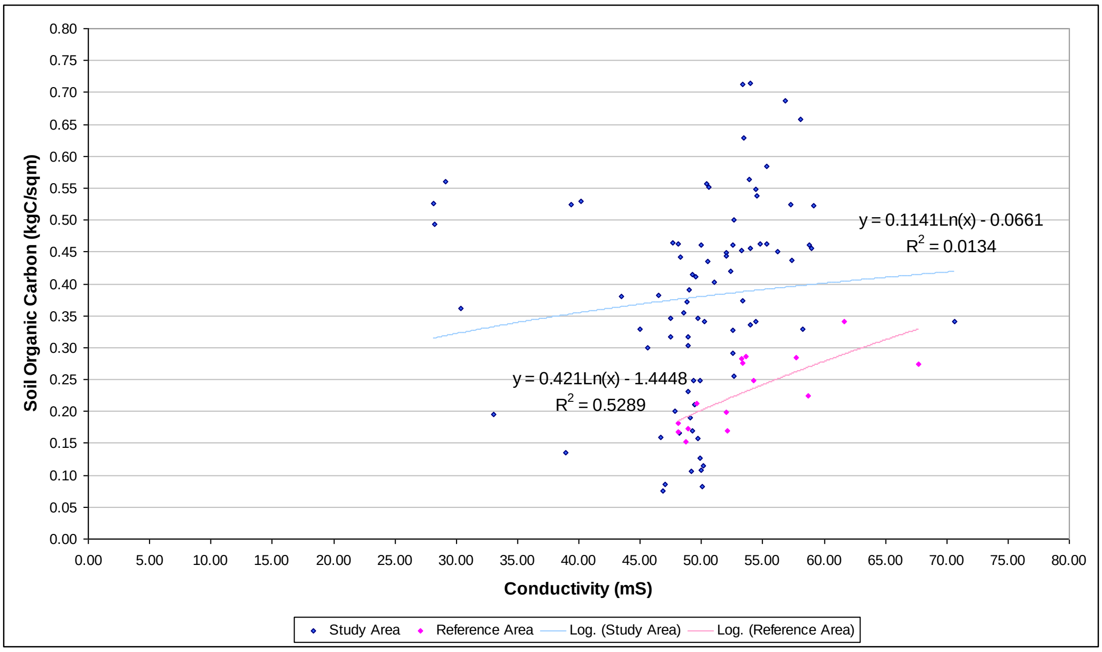

Figure B-27 Relationship between conductivity and SOC by the Logarithmic model

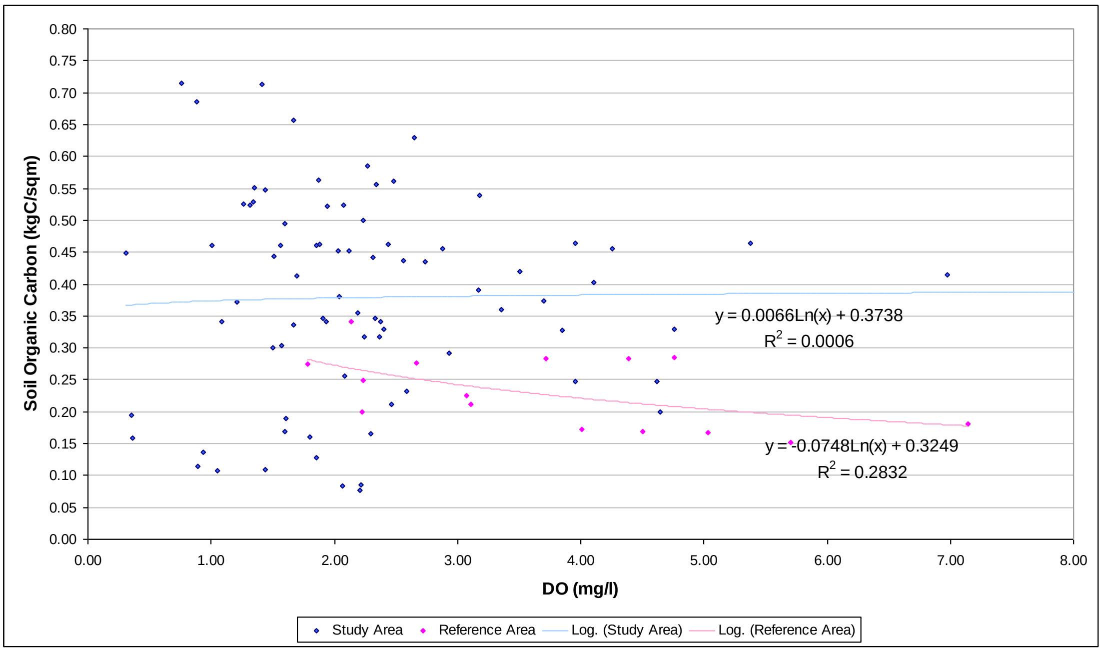

Figure B-28 Relationship between DO and SOC by the Logarithmic model

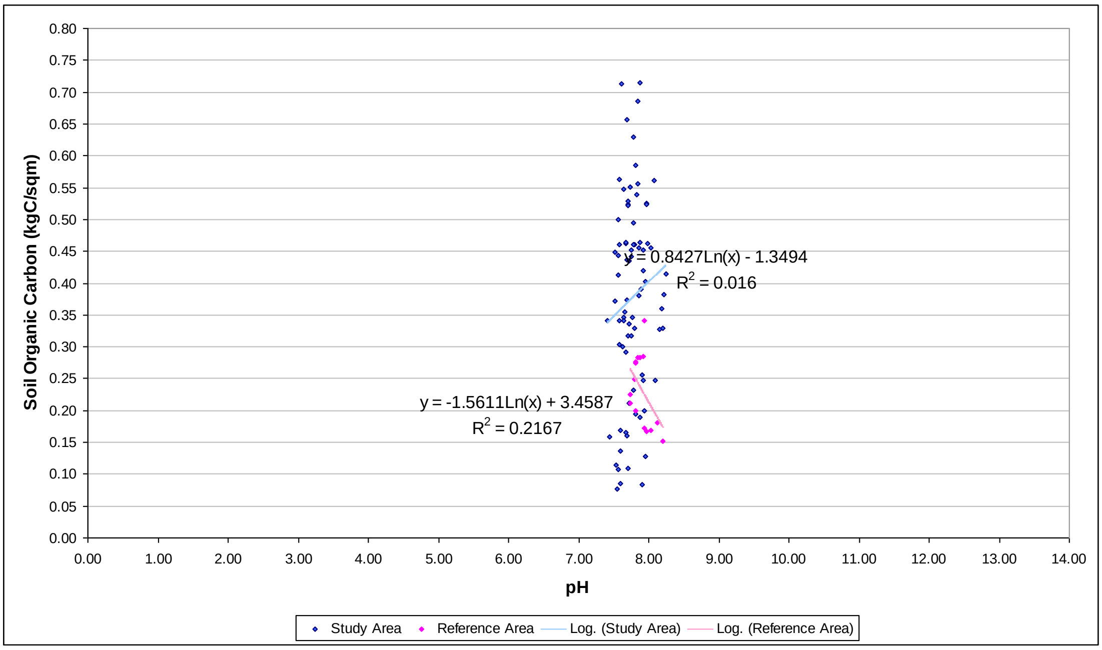

Figure B-29 Relationship between pH in water and SOC by the Logarithmic model

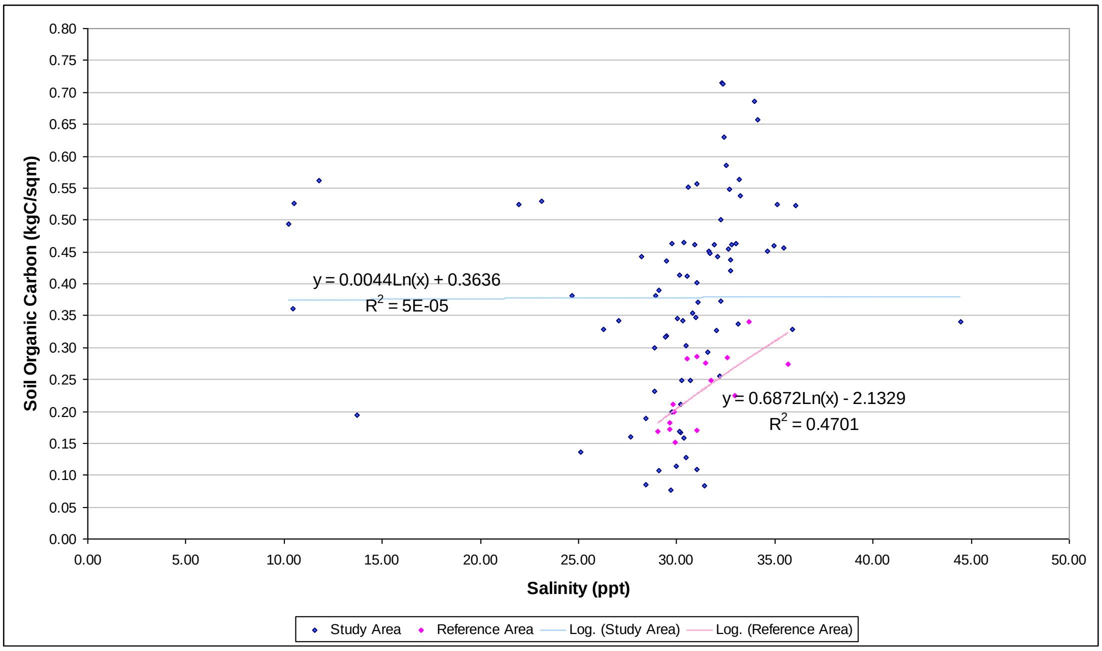

Figure B-30 Relationship between salinity in water and SOC by the Logarithmic model

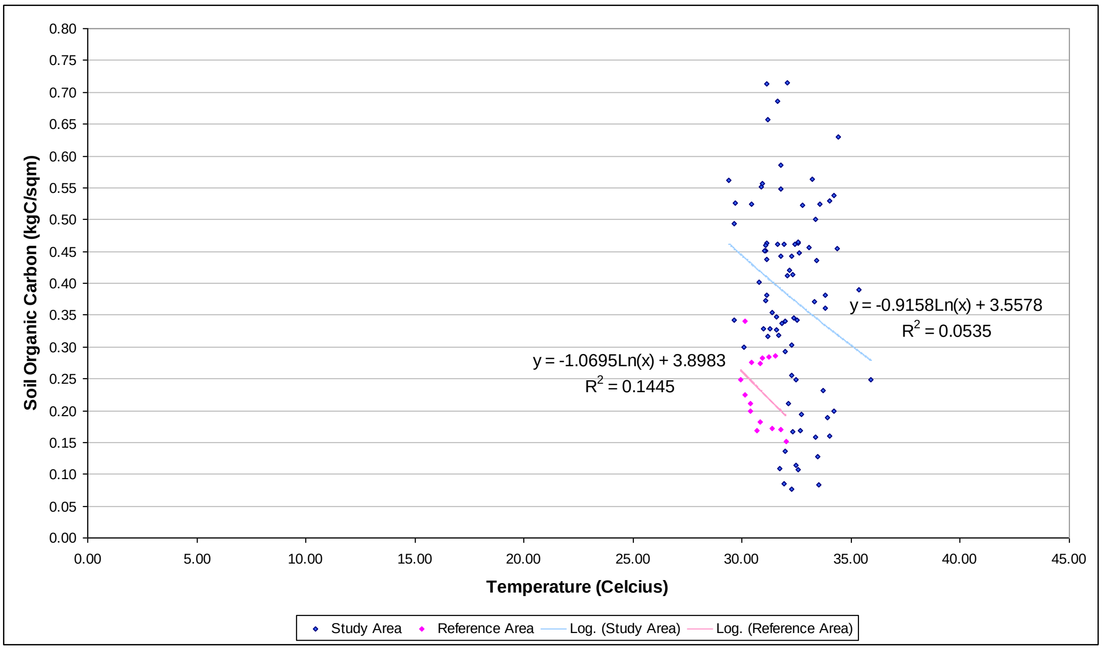

Figure B-31 Relationship between temperature in water and SOC by the Logarithmic model

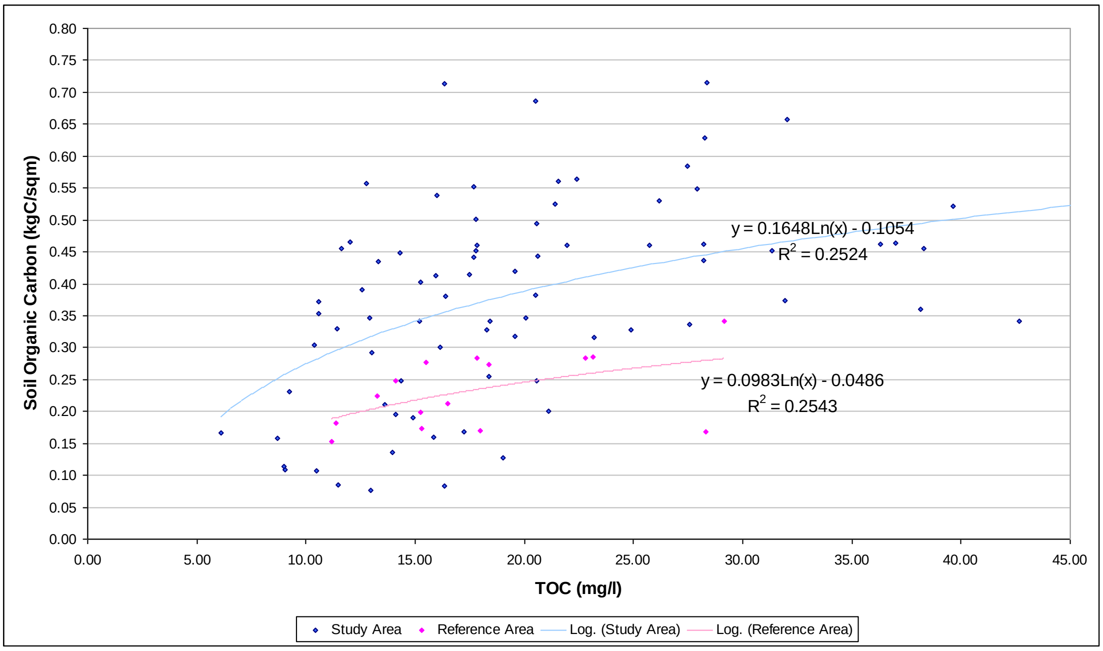

Figure B-32 Relationship between TOC and SOC by the Logarithmic model

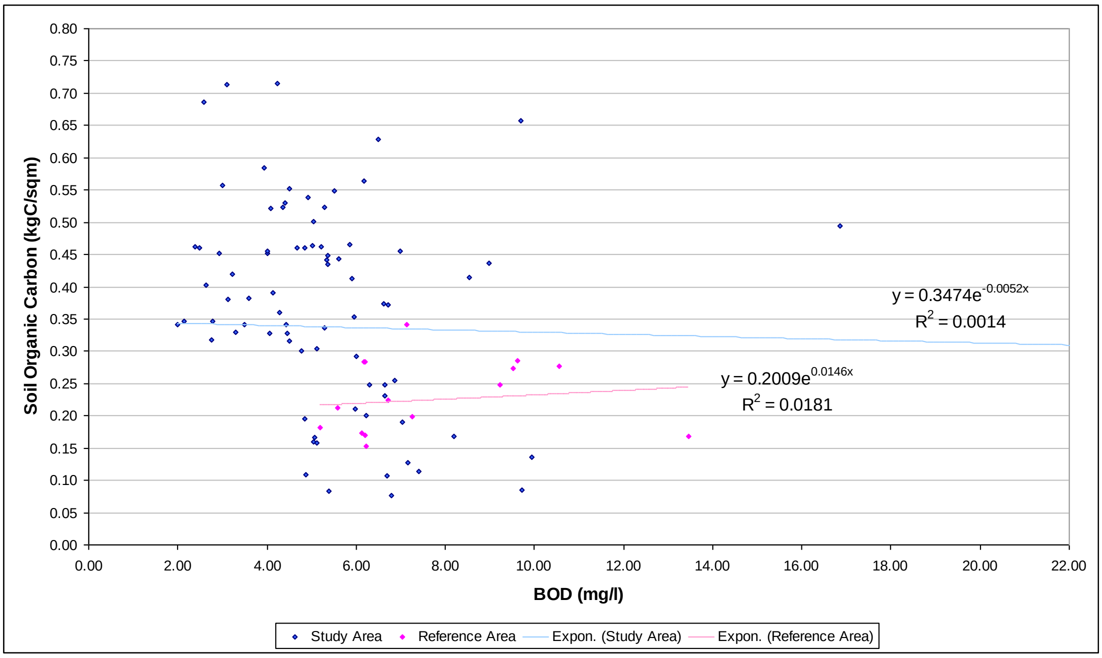

Figure B-33 Relationship between BOD and SOC by the Exponential model

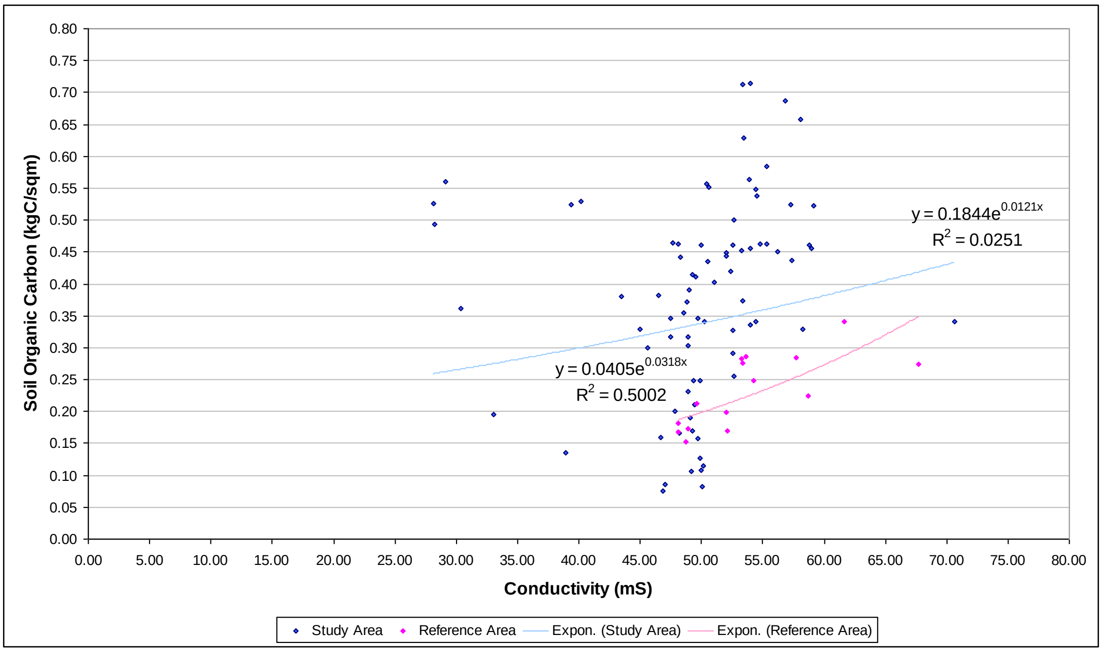

Figure B-34 Relationship between conductivity and SOC by the Exponential model

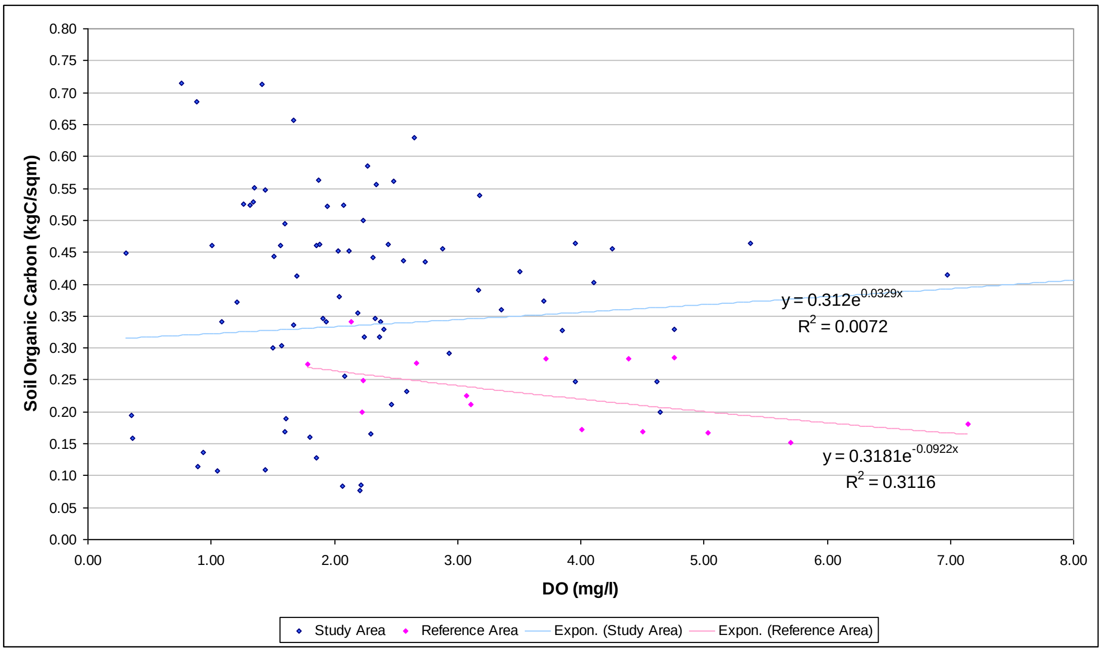

Figure B-35 Relationship between DO and SOC by the Exponential model

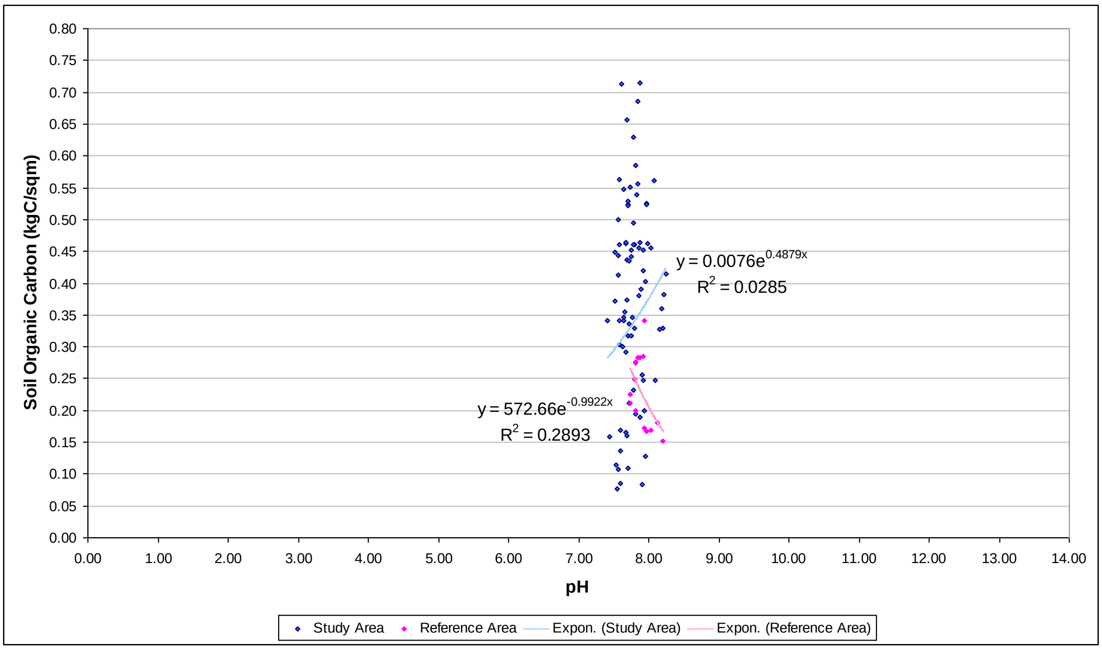

Figure B-36 Relationship between pH in water and SOC by the Exponential model

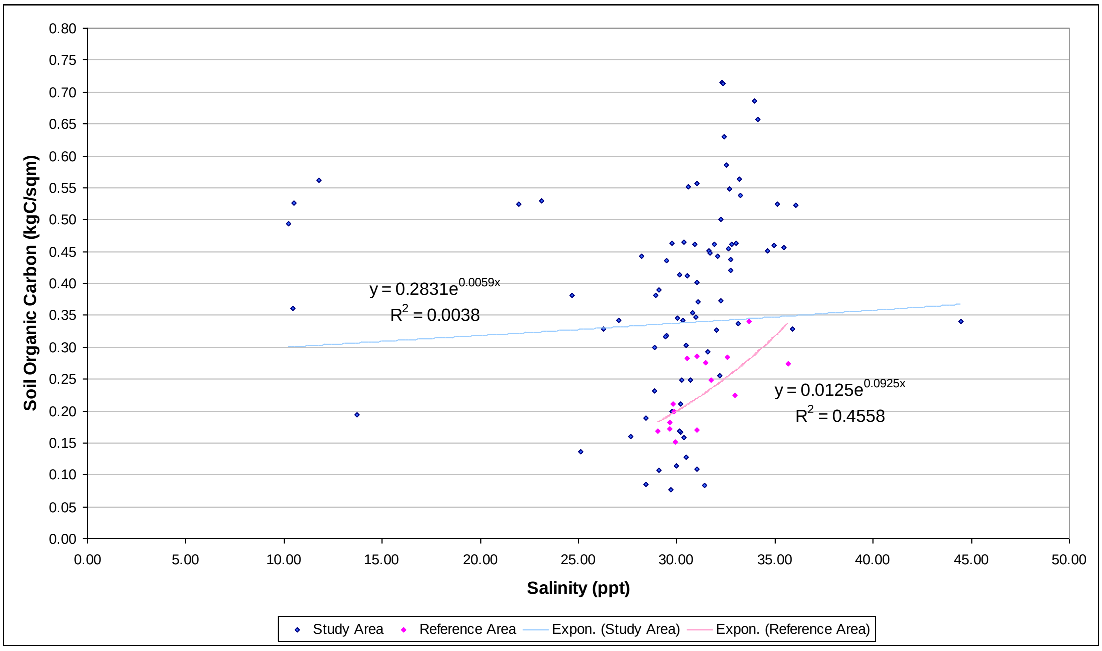

Figure B-37 Relationship between salinity in water and SOC by the Exponential model

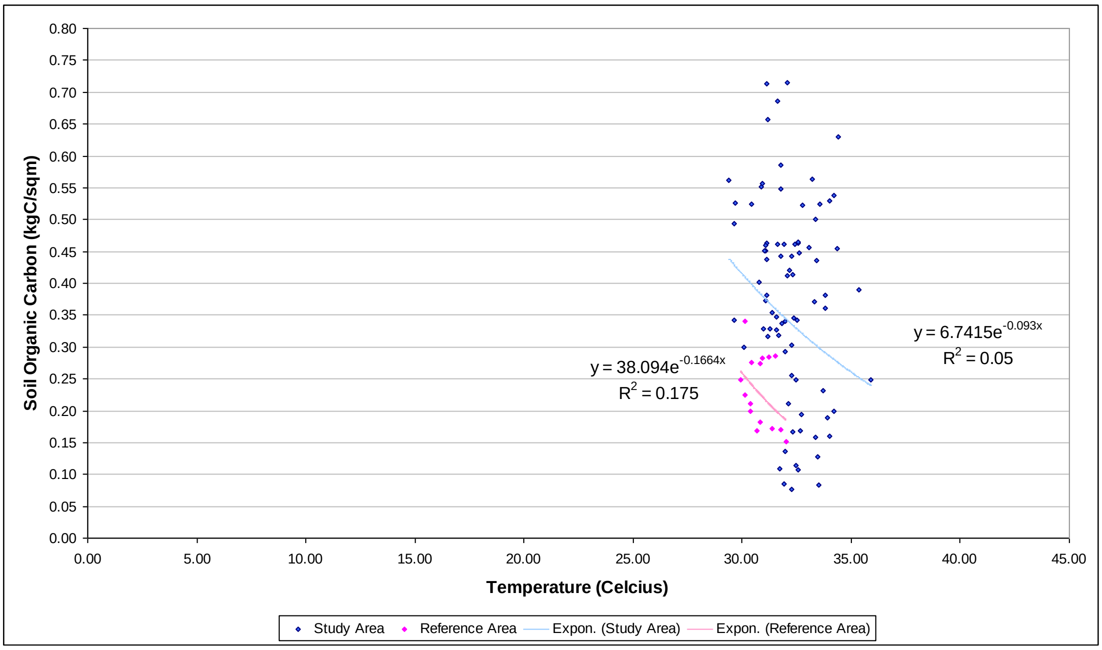

Figure B-38 Relationship between temperature in water and SOC by the Exponential model

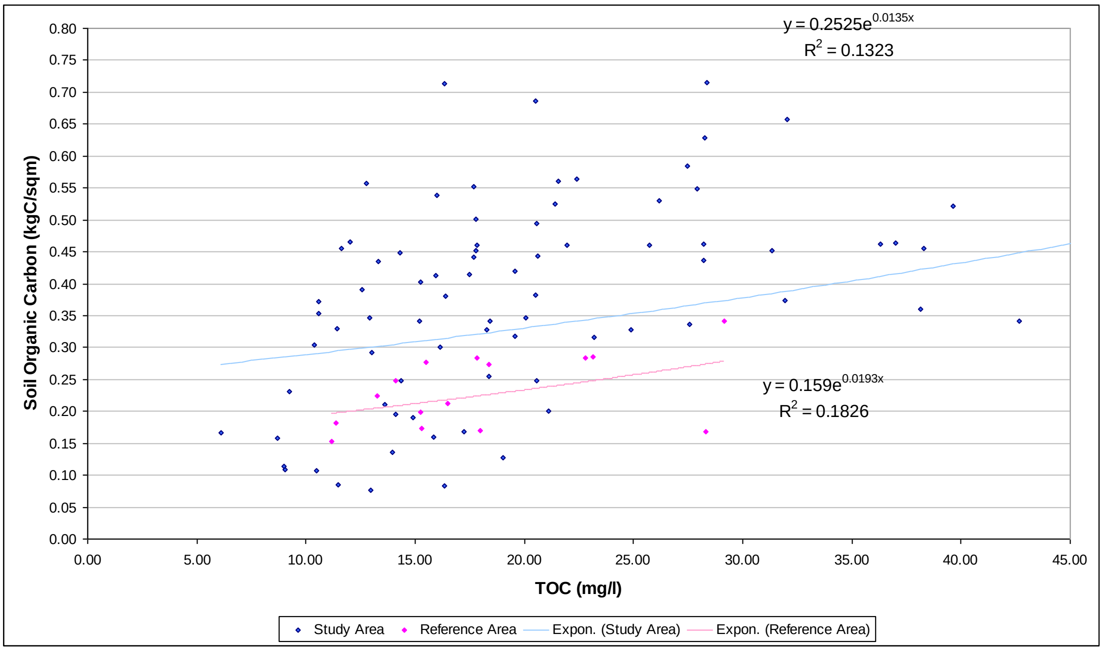

Figure B-39 Relationship between TOC and SOC by the Exponential model

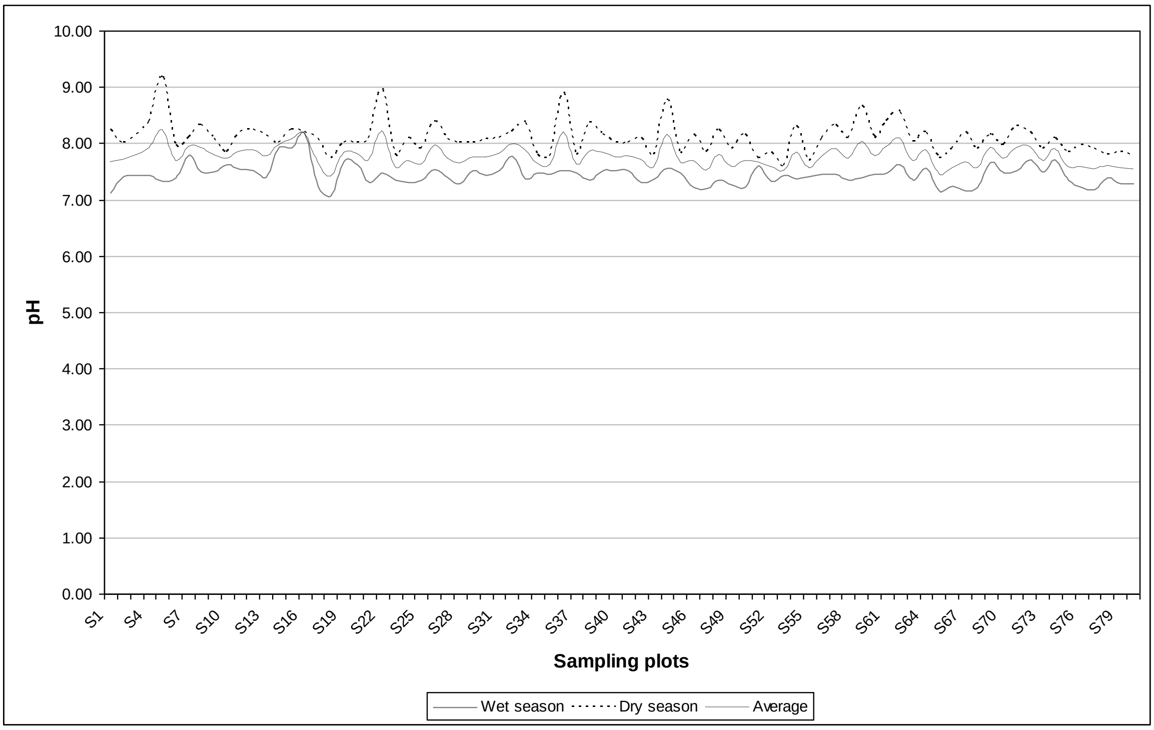

Figure B-40 The pattern of pH values in study area

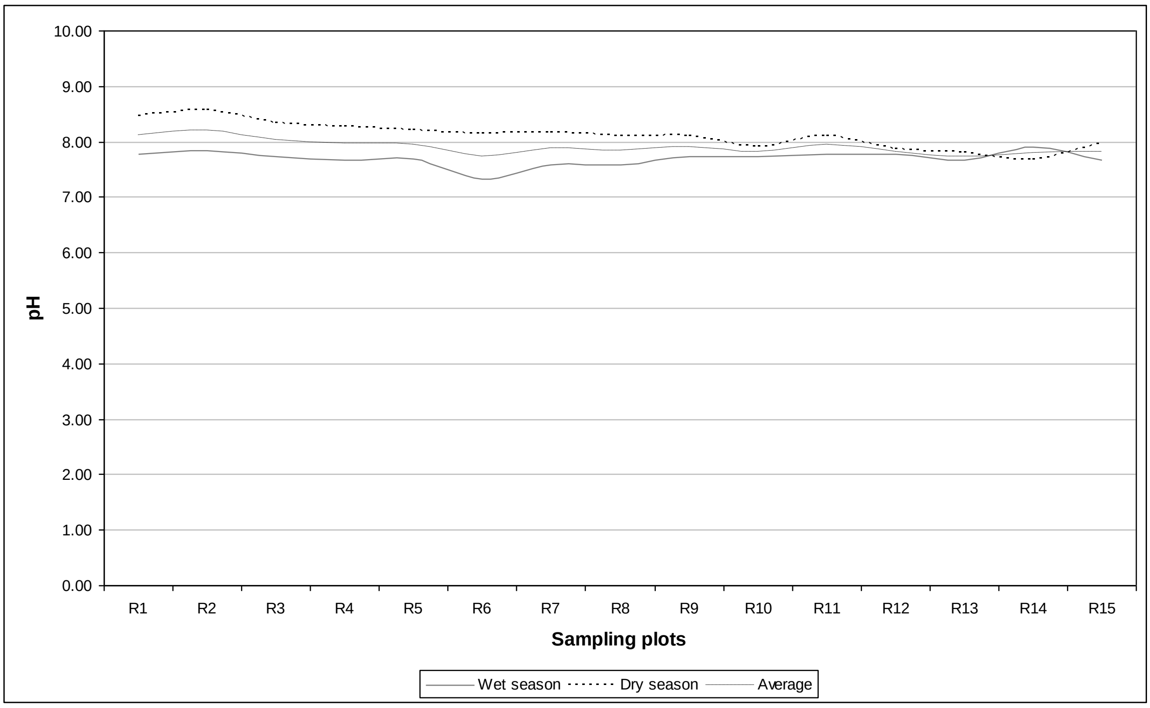

Figure B-41 The pattern of pH values in reference area

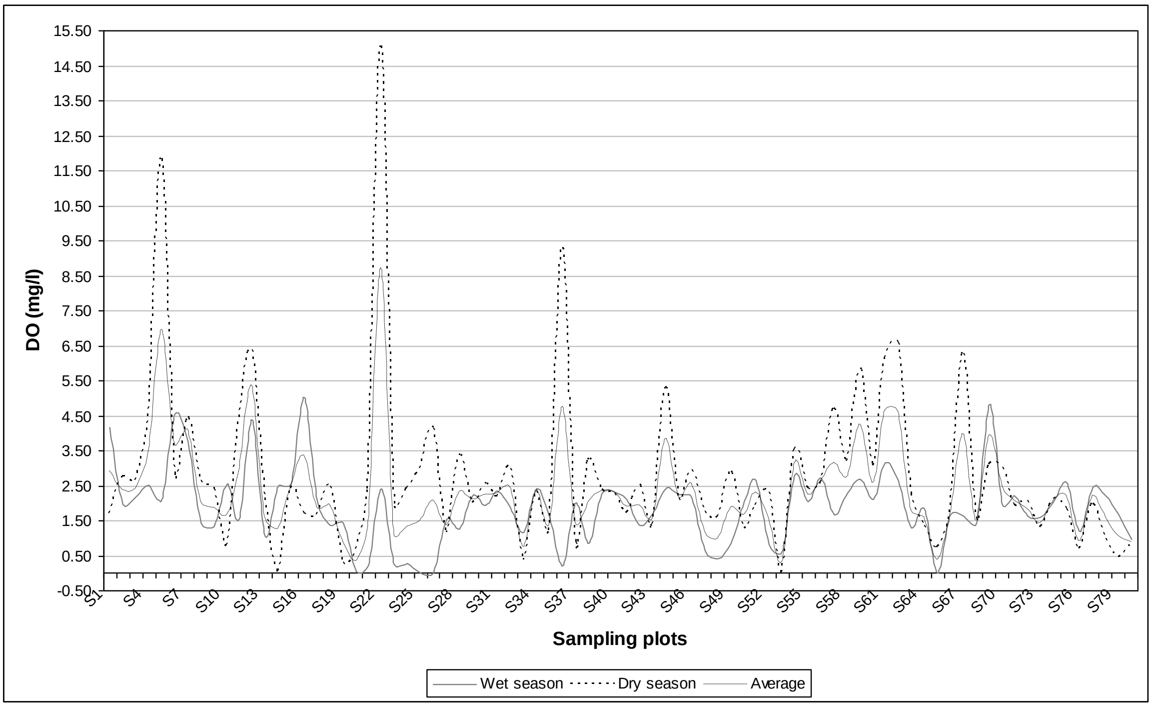

Figure B-42 The pattern of DO (mg/l) values in study area

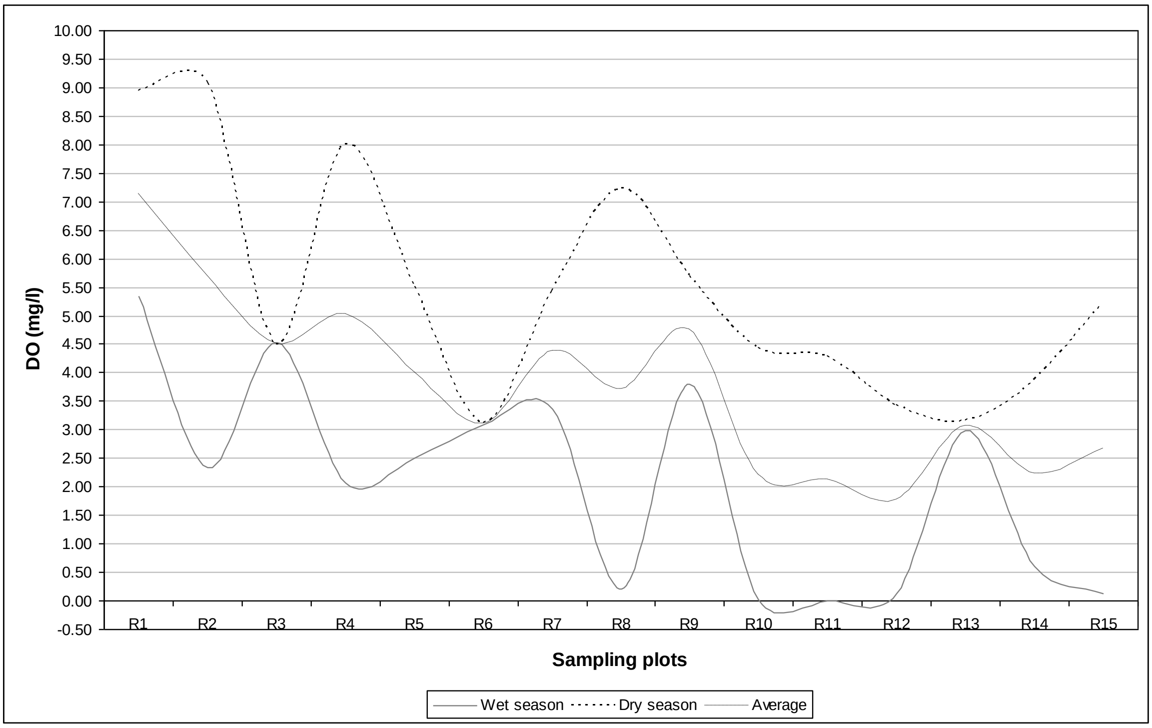

Figure B-43 The pattern of DO (mg/l) values in reference area

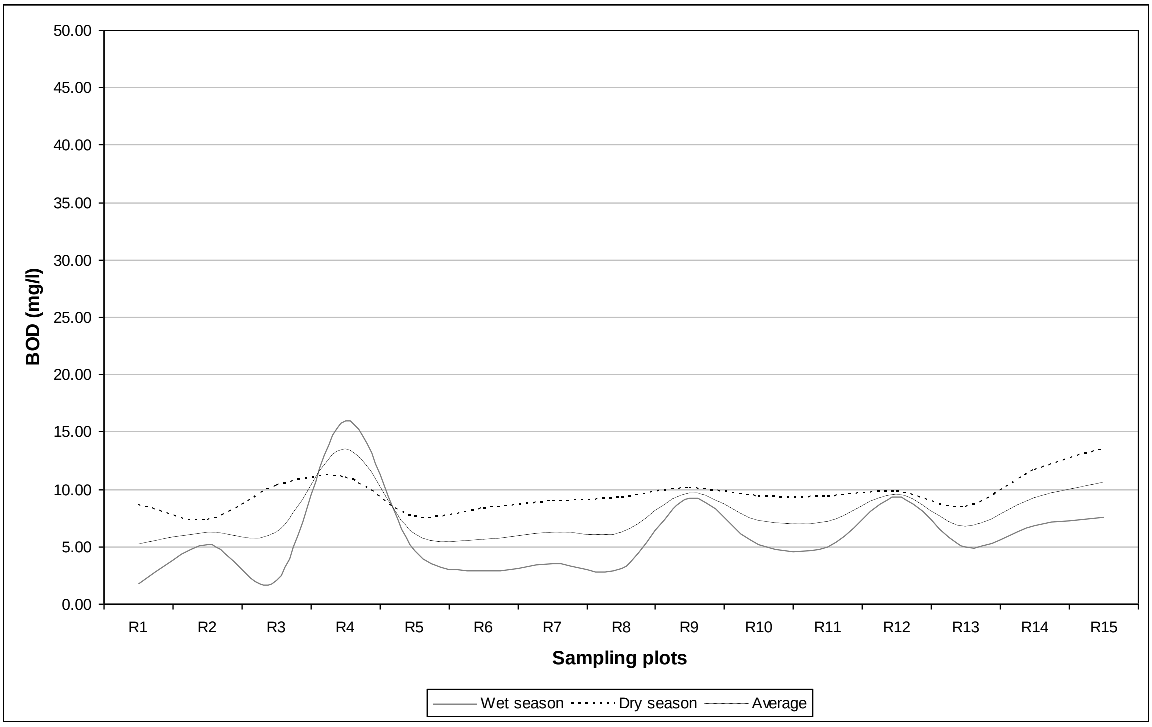

Figure B-44 The pattern of BDO (mg/l) values inreference area

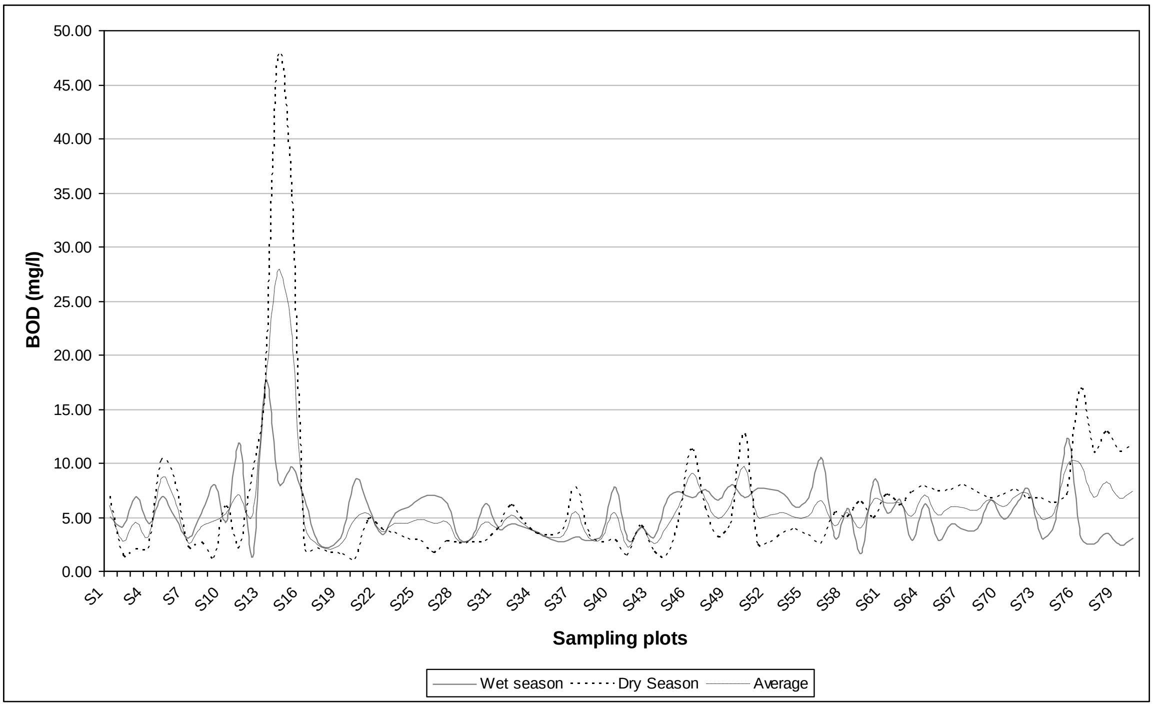

Figure B-45 The pattern of BDO (mg/l) values in study area

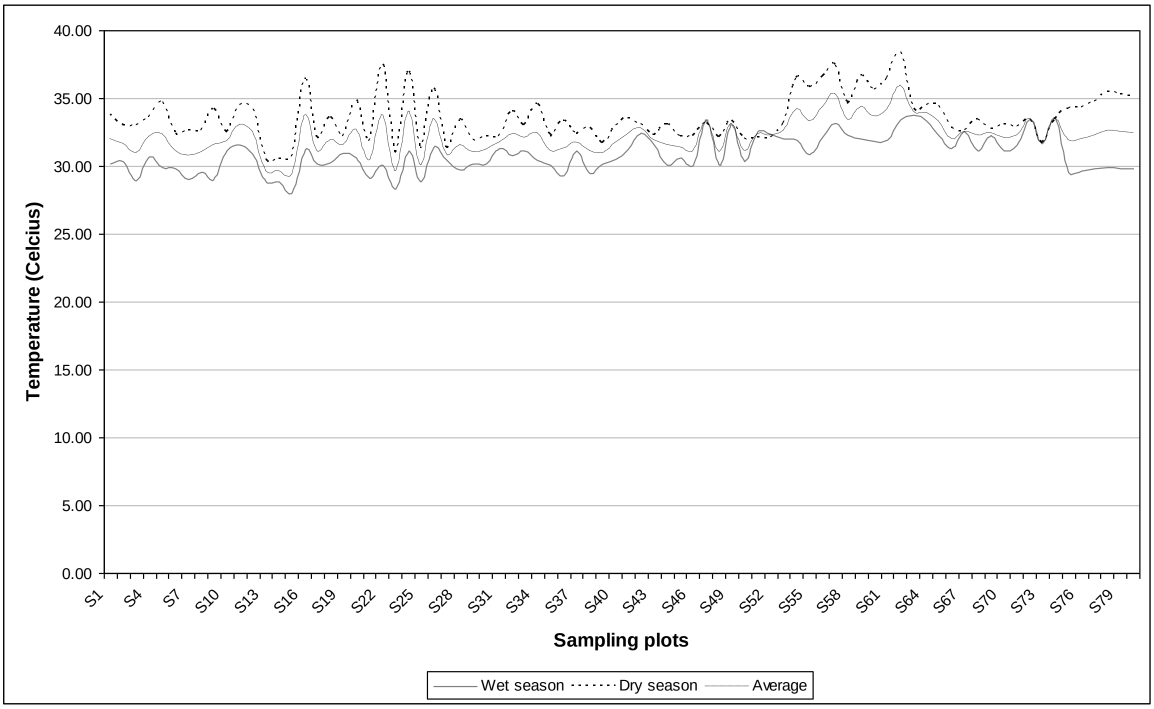

Figure B-46 The pattern of Temperature (Celsius) in study area

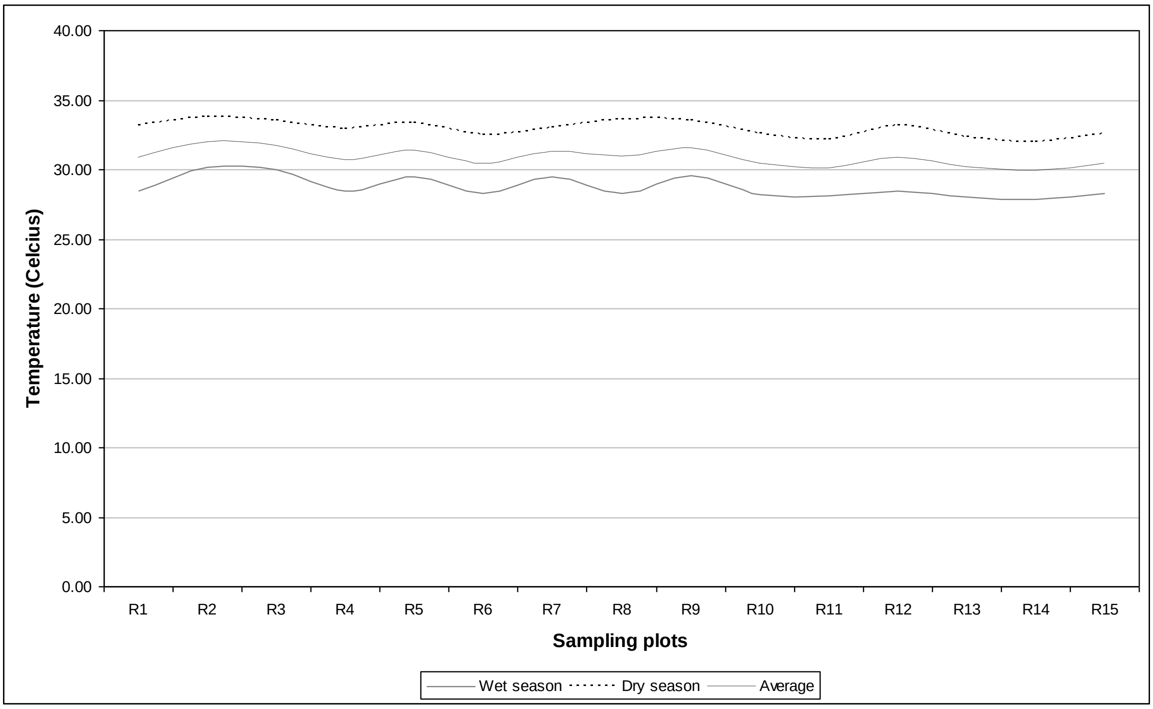

Figure B-47 The pattern of Temperature (Celsius) in reference area

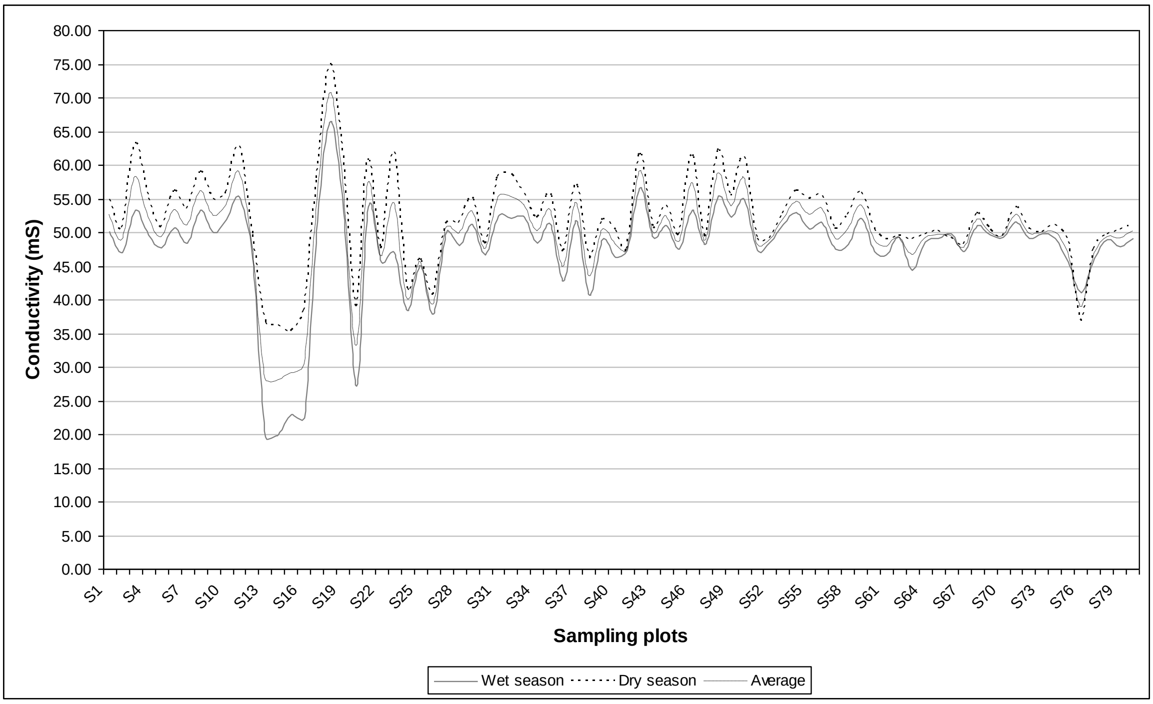

Figure B-48 The pattern of conductivity(mS) in study area

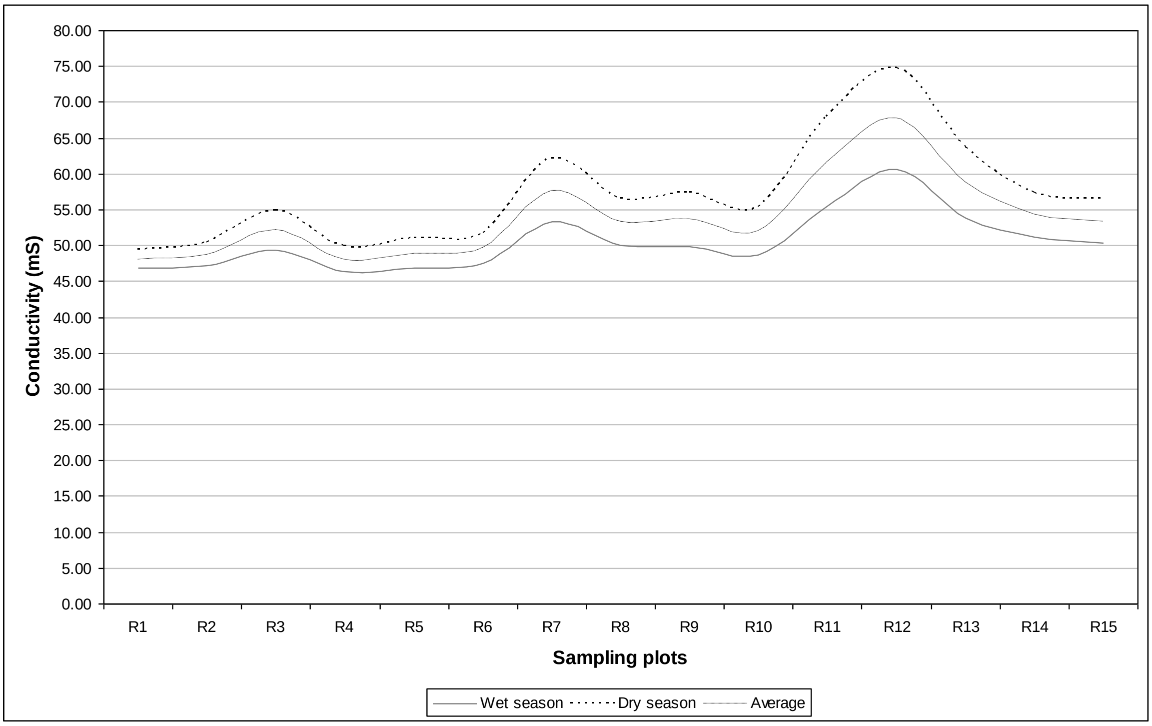

Figure B-49 The pattern of conductivity (mS) in reference area

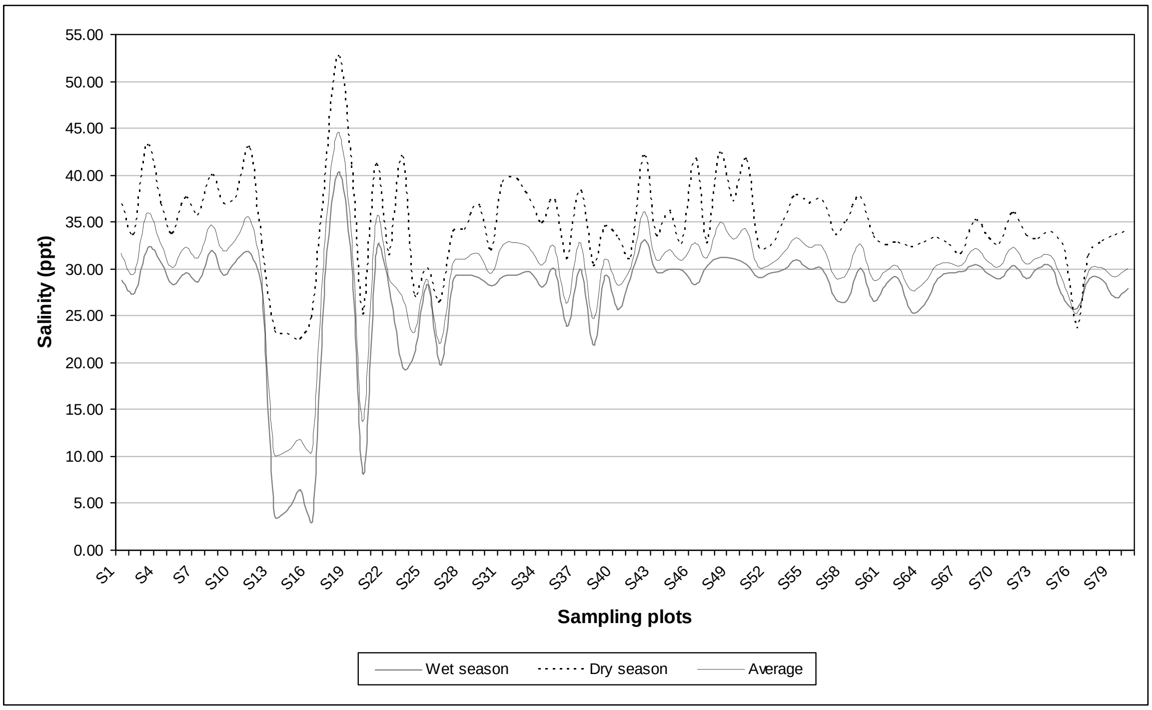

Figure B-50 The pattern of salinity (ppt) in study area

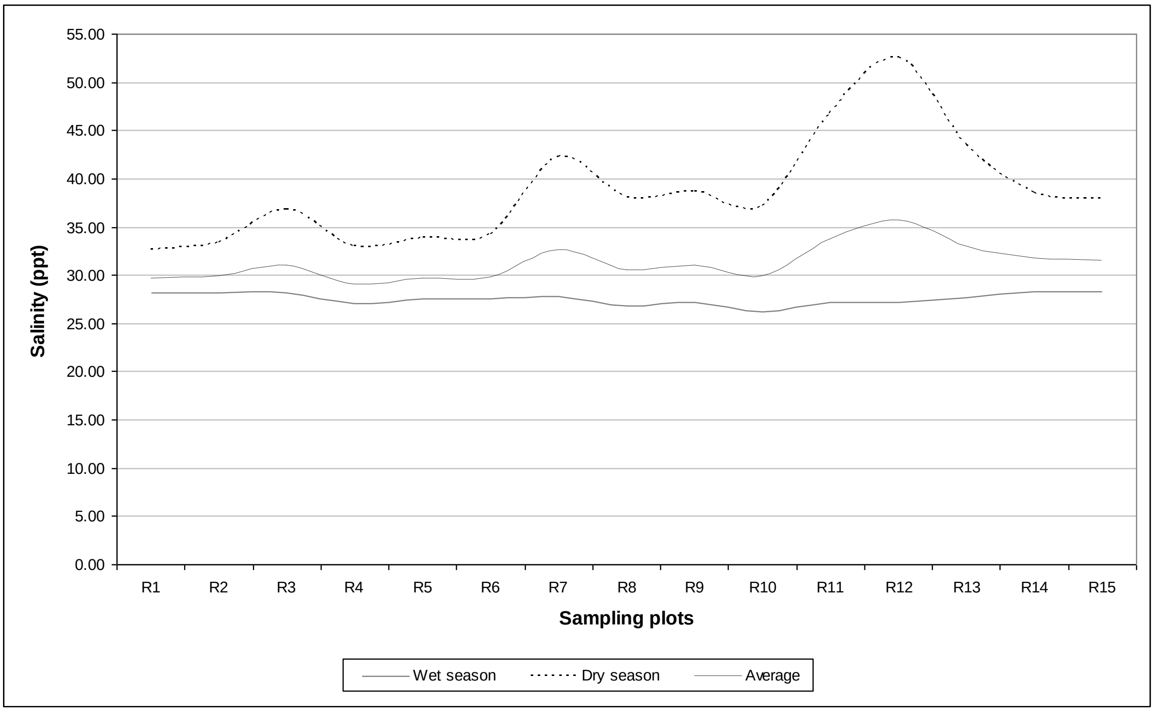

Figure B-51 The pattern of salinity (ppt) in reference area

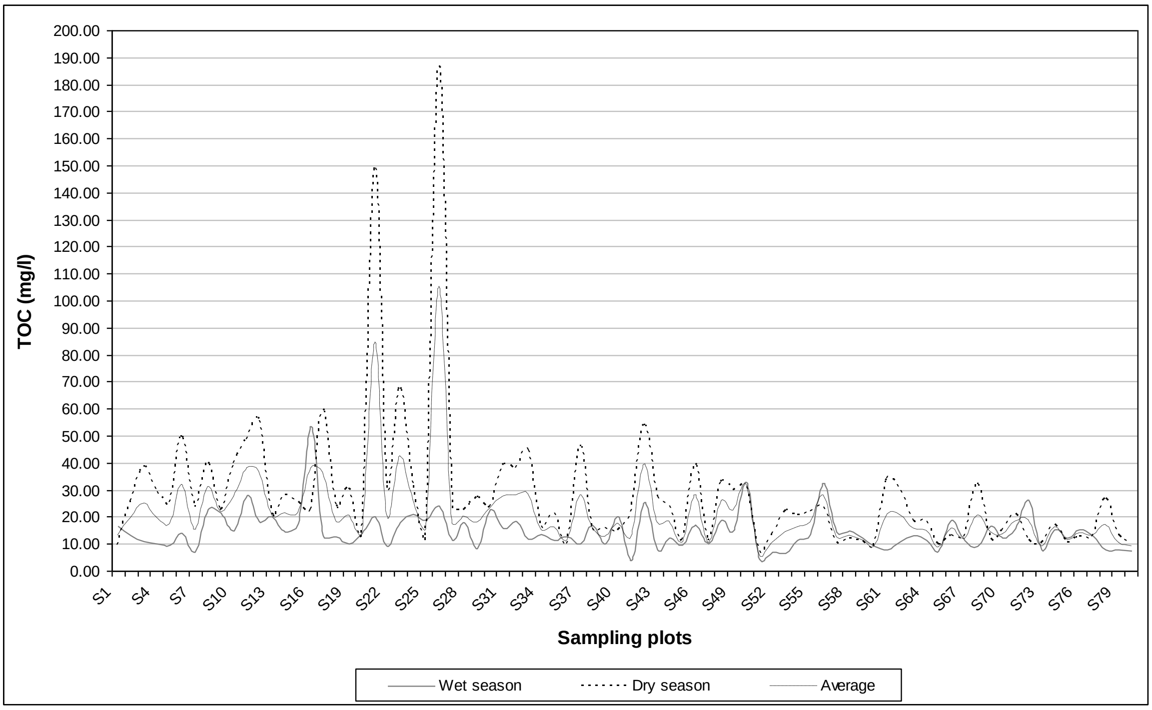

Figure B-52 The pattern of total organic carbon (mg/l) in study area

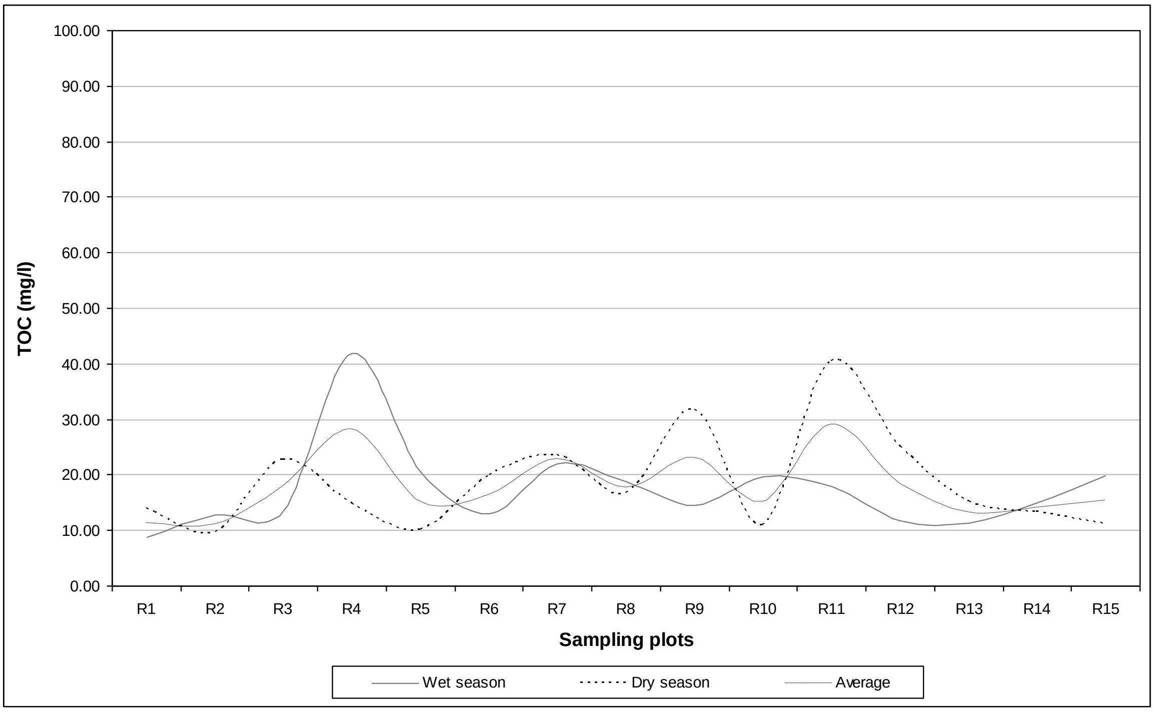

Figure B-53 The pattern of total organic carbon (mg/l) in reference area

APPENDIX C

Table C-1 D^2H and Total leaf area data of cutting-sampling tree

species	D^2H (sq.cm*m.)	Total Leaf area (sq.m)
Avicennia marina	30.12	3.00
Avicennia marina	78.50	4.96
Avicennia marina	43.00	3.65
Avicennia marina	20.86	2.53
Avicennia marina	13.52	1.01
Avicennia marina	17.07	1.45
Rhizophora mucronata	13.65	1.12
Rhizophora mucronata	7.84	0.78
Rhizophora mucronata	9.96	0.92
Rhizophora mucronata	12.79	1.00
Rhizophora mucronata	27.45	2.78
Rhizophora mucronata	11.86	0.96

Table C-2 D^2H and trunk dry weight data of cutting-sampling trees

species	D^2H (sq.m)	Weight of trunk(kg)
Avicennia marina	30.12	0.74
Avicennia marina	78.50	5.42
Avicennia marina	43.00	2.17
Avicennia marina	20.86	1.54
Avicennia marina	13.52	0.57
Avicennia marina	17.07	1.01
Rhizophora mucronata	13.65	0.55
Rhizophora mucronata	7.84	0.43
Rhizophora mucronata	9.96	0.49
Rhizophora mucronata	12.79	0.52
Rhizophora mucronata	27.45	0.70
Rhizophora mucronata	11.86	0.53

Table C-3 D^2H and leaf dry weight data of cutting-sampling trees

species	D^2H (sq.m)	Weight of leaf (kg)
Avicennia marina	30.12	0.61
Avicennia marina	78.50	1.11
Avicennia marina	43.00	0.74
Avicennia marina	20.86	0.30
Avicennia marina	13.52	0.22
Avicennia marina	17.07	0.34
Rhizophora mucronata	13.65	0.50
Rhizophora mucronata	7.84	0.19
Rhizophora mucronata	9.96	0.21
Rhizophora mucronata	12.79	0.30
Rhizophora mucronata	27.45	0.71
Rhizophora mucronata	11.86	0.30

Table C-4 D^2H and branch dry weight data of cutting-sampling trees

species	D^2H (sq.m)	Weight of branch(kg)
Avicennia marina	30.12	0.83
Avicennia marina	78.50	1.27
Avicennia marina	43.00	0.92
Avicennia marina	20.86	0.69
Avicennia marina	13.52	0.34
Avicennia marina	17.07	0.42
Rhizophora mucronata	13.65	0.36
Rhizophora mucronata	7.84	0.20
Rhizophora mucronata	9.96	0.23
Rhizophora mucronata	12.79	0.30
Rhizophora mucronata	27.45	0.53
Rhizophora mucronata	11.86	0.29

Table C-5 D^2H and prop root dry weight data of cutting-sampling trees

species	D^2H (sq.m)	Weight of root(kg)
Rhizophora mucronata	13.65	0.92
Rhizophora mucronata	7.84	0.51
Rhizophora mucronata	9.96	0.65
Rhizophora mucronata	12.79	0.80
Rhizophora mucronata	27.45	1.52
Rhizophora mucronata	11.86	0.75

Table C-6 Diameter at Breath Height (cm) of mangrove tree in study area

Sampling plots	Wet season	Dry season	Annual average
S1	10.30	12.15	6.08
S2	9.90	10.85	5.54
S3	9.90	10.95	5.82
S4	10.40	11.40	5.08
S5	11.00	11.75	4.70
S6	10.50	6.00	3.44
S7	0.00	0.00	0.00
S8	12.70	14.60	5.99
S9	11.30	11.95	5.81
S10	0.00	5.45	1.00
S11	10.80	10.80	4.36
S12	13.40	14.55	5.33
S13	11.50	11.65	5.33
S14	12.00	12.80	5.83
S15	11.60	12.00	5.30
S16	12.00	14.90	6.69
S17	10.20	10.25	4.88
S18	10.10	11.45	5.83
S19	10.40	11.75	4.84
S20	11.80	14.45	6.19
S21	12.00	13.90	5.59
S22	9.90	0.00	2.15
S23	12.00	12.75	5.86
S24	0.00	0.00	0.00
S25	13.10	13.60	5.20
S26	10.60	11.20	4.98
S27	11.80	11.85	4.68
S28	12.30	13.75	6.62
S29	10.80	0.00	2.50
S30	10.00	10.90	5.81

Table C-6 Diameter at Breath Height (cm) of mangrove tree in study area (Cont.)

Sampling plots	**Wet season**	**Dry season**	**Annual average**
S31	11.00	11.35	4.85
S32	10.00	10.15	5.78
S33	0.00	0.00	0.00
S34	11.20	12.55	6.13
S35	10.90	12.15	5.00
S36	9.90	10.15	6.35
S37	12.10	12.70	5.70
S38	9.60	10.55	4.86
S39	0.00	0.00	0.00
S40	11.10	12.70	6.75
S41	15.30	15.80	9.39
S42	0.00	0.00	0.00
S43	10.60	11.55	5.13
S44	0.00	0.00	0.00
S45	11.00	12.45	8.43
S46	0.00	0.00	0.00
S47	12.40	14.25	5.93
S48	0.00	0.00	0.00
S49	10.30	11.30	5.19
S50	11.10	12.50	4.80
S51	12.40	13.30	4.27
S52	10.70	12.45	4.95
S53	11.10	12.65	5.28
S54	12.80	12.45	3.91
S55	0.00	0.00	0.00
S56	11.10	11.85	5.27
S57	0.00	0.00	0.00
S58	0.00	0.00	0.00
S59	0.00	0.00	0.00
S60	0.00	0.00	0.00

Table C-6 Diameter at Breath Height (cm) of mangrove tree in study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S61	0.00	0.00	0.00
S62	0.00	0.00	0.00
S63	10.90	13.85	6.00
S64	10.20	12.05	6.81
S65	11.10	12.80	6.27
S66	11.70	11.65	6.77
S67	11.80	12.90	6.50
S68	10.20	11.55	6.08
S69	0.00	0.00	0.00
S70	0.00	0.00	0.00
S71	0.00	0.00	0.00
S72	11.20	12.55	7.23
S73	10.80	11.60	6.80
S74	10.60	13.60	6.22
S75	11.50	13.95	6.74
S76	12.70	15.20	6.51
S77	13.60	16.55	7.37
S78	11.90	15.50	7.21
S79	13.80	16.05	7.32
S80	11.20	13.35	6.77

Table C-7 Diameter at Breath Height (cm) of mangrove tree in reference area

Sampling plots	Wet season	Dry season	Annual average
R1	9.60	12.50	11.05
R2	0.00	0.00	0.00
R3	0.00	0.00	0.00
R4	0.00	0.00	0.00
R5	0.00	0.00	0.00
R6	0.00	0.00	0.00
R7	11.10	12.07	11.58
R8	0.00	0.00	0.00
R9	10.50	11.73	11.11
R10	10.50	11.75	11.13
R11	10.30	12.50	11.40
R12	10.60	11.79	11.19
R13	0.00	0.00	0.00
R14	9.50	11.27	10.39
R15	13.50	13.76	13.63

Table C-8 Height (m) of mangrove tree in study area

Sampling plots	Wet season	Dry season	Annual average
S1	6.20	5.95	6.08
S2	5.38	5.70	5.54
S3	5.267	6.37	5.82
S4	4.90	5.27	5.08
S5	4.40	5.00	4.70
S6	4.63	2.25	3.44
S7	0.00	0.00	0.00
S8	5.75	6.23	5.99
S9	6.11	5.51	5.81
S10	0.00	2.00	1.00
S11	4.00	4.73	4.36
S12	4.87	5.79	5.33
S13	5.05	5.62	5.33
S14	5.50	6.15	5.83
S15	4.95	5.66	5.30
S16	6.64	6.75	6.69
S17	5.00	4.75	4.88
S18	5.85	5.80	5.83
S19	4.48	5.21	4.84
S20	6.09	6.30	6.19
S21	5.32	5.86	5.59
S22	4.30	0.00	2.15
S23	5.32	6.40	5.86
S24	0.00	0.00	0.00
S25	5.00	5.40	5.20
S26	4.767	5.20	4.98
S27	4.2	5.15	4.68
S28	6.00	7.245	6.62
S29	5.00	0.00	2.50
S30	6.00	5.63	5.81

Table C-8 Height (m) of mangrove tree in study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S31	4.57	5.14	4.85
S32	6.00	5.55	5.78
S33	0.00	0.00	0.00
S34	5.92	6.33	6.13
S35	5.03	4.96	5.00
S36	5.80	6.9	6.35
S37	5.47	5.93	5.70
S38	4.71	5.00	4.86
S39	0.00	0.00	0.00
S40	6.39	7.12	6.75
S41	10.37	8.41	9.39
S42	0.00	0.00	0.00
S43	4.50	5.75	5.13
S44	0.00	0.00	0.00
S45	9.47	7.38	8.43
S46	0.00	0.00	0.00
S47	6.00	5.85	5.93
S48	0.00	0.00	0.00
S49	5.04	5.33	5.19
S50	4.50	5.10	4.80
S51	4.13	4.42	4.27
S52	4.90	5.00	4.95
S53	5.00	5.55	5.28
S54	3.60	4.23	3.91
S55	0.00	0.00	0.00
S56	5.13	5.42	5.27
S57	0.00	0.00	0.00
S58	0.00	0.00	0.00
S59	0.00	0.00	0.00
S60	0.00	0.00	0.00

Table C-8 Height (m) of mangrove tree in study area (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S61	0.00	0.00	0.00
S62	0.00	0.00	0.00
S63	5.75	6.25	6.00
S64	6.88	6.75	6.81
S65	6.24	6.3	6.27
S66	6.58	6.95	6.77
S67	5.75	7.25	6.50
S68	5.75	6.42	6.08
S69	0.00	0.00	0.00
S70	0.00	0.00	0.00
S71	0.00	0.00	0.00
S72	6.75	7.72	7.23
S73	6.36	7.23	6.80
S74	6.27	6.17	6.22
S75	6.71	6.77	6.74
S76	5.97	7.05	6.51
S77	7.30	7.43	7.37
S78	7.01	7.42	7.21
S79	7.06	7.58	7.32
S80	6.37	7.17	6.77

Table C-9 Height (m) of mangrove tree in reference area

Sampling plots	Wet season	Dry season	Annual average
R1	7.00	7.00	7.00
R2	0.00	0.00	0.00
R3	0.00	0.00	0.00
R4	0.00	0.00	0.00
R5	0.00	0.00	0.00
R6	0.00	0.00	0.00
R7	3.30	3.30	3.30
R8	0.00	0.00	0.00
R9	5.16	5.16	5.16
R10	3.50	3.50	3.50
R11	5.00	5.00	5.00
R12	6.23	6.23	6.23
R13	0.00	0.00	0.00
R14	4.00	4.00	4.00
R15	4.50	4.50	4.50

Table C-10 LAI of mangrove tree in study site

Sampling plots	Wet season	Dry season	Annual average
S1	18.35	34.71	26.53
S2	1.94	2.90	2.42
S3	1.87	3.60	2.73
S4	1.96	3.00	2.48
S5	11.52	20.41	15.97
S6	10.47	0.18	5.33
S7	0.00	0.00	0.00
S8	39.12	86.15	62.64
S9	26.77	27.24	27.01
S10	0.00	0.09	0.05
S11	8.61	12.43	10.52
S12	34.32	72.33	53.33
S13	18.98	25.40	22.19
S14	27.63	46.97	37.30
S15	18.87	29.42	24.14
S16	41.82	112.63	77.22
S17	10.94	9.99	10.47
S18	14.81	25.26	20.04
S19	9.34	22.34	15.84
S20	32.06	84.44	58.25
S21	25.68	60.78	43.23
S22	6.88	0.00	3.44
S23	25.68	50.40	38.04
S24	0.00	0.00	0.00
S25	32.97	46.07	39.52
S26	11.67	18.02	14.84
S27	14.16	22.62	18.39
S28	37.32	92.39	64.86
S29	2.29	0.00	1.15
S30	14.99	19.01	17.00

Table C-10 LAI of mangrove tree in study site (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S31	12.53	18.61	15.57
S32	14.99	13.48	14.23
S33	0.00	0.00	0.00
S34	23.95	45.93	34.94
S35	14.85	23.26	19.06
S36	13.31	21.78	17.54
S37	28.28	41.86	35.07
S38	7.34	12.70	10.02
S39	0.00	0.00	0.00
S40	27.26	62.59	44.93
S41	24.78	19.46	22.12
S42	0.00	0.00	0.00
S43	1.81	3.62	2.72
S44	0.00	0.00	0.00
S45	7.09	7.07	7.08
S46	0.00	0.00	0.00
S47	4.93	7.52	6.23
S48	0.00	0.00	0.00
S49	11.63	19.81	15.72
S50	12.59	28.01	20.30
S51	2.65	3.74	3.19
S52	2.15	3.69	2.92
S53	15.89	35.57	25.73
S54	14.43	18.18	16.30
S55	0.00	0.00	0.00
S56	16.83	25.28	21.05
S57	0.00	0.00	0.00
S58	0.00	0.00	0.00
S59	0.00	0.00	0.00
S60	0.00	0.00	0.00

Table C-10 LAI of mangrove tree in study site (Cont.)

Sampling plots	Wet season	Dry season	Annual average
S61	0.00	0.00	0.00
S62	0.00	0.00	0.00
S63	19.95	68.89	44.42
S64	22.08	44.19	33.13
S65	25.88	49.53	37.71
S66	36.72	40.61	38.67
S67	28.30	69.85	49.08
S68	14.89	32.79	23.84
S69	0.00	0.00	0.00
S70	0.00	0.00	0.00
S71	0.00	0.00	0.00
S72	4.28	7.81	6.04
S73	3.43	5.39	4.41
S74	3.14	7.03	5.09
S75	4.62	8.93	6.77
S76	5.29	12.74	9.02
S77	9.31	18.49	13.90
S78	5.57	14.80	10.18
S79	9.25	17.25	13.25
S80	3.88	8.49	6.18

Table C-11 LAI of mangrove tree in reference site

Sampling plots	Wet season	Dry season	Annual average
R1	17.58	0.77	9.18
R2	0.00	0.00	0.00
R3	0.00	0.00	0.00
R4	0.00	0.00	0.00
R5	0.00	0.00	0.00
R6	0.00	0.00	0.00
R7	6.36	0.66	3.51
R8	0.00	0.00	0.00
R9	13.31	0.58	6.95
R10	5.67	0.59	3.13
R11	11.42	0.77	6.10
R12	21.01	0.60	10.81
R13	0.00	0.00	0.00
R14	4.89	0.49	2.69
R15	29.84	1.18	15.51

Table C-12 Above Ground Biomass (t/ha) of study site in Wet season

Sampling plots	**Wet Season**				
	$\mathbf{W_L}$	$\mathbf{W_B}$	$\mathbf{W_S}$	$\mathbf{W_R}$	$\mathbf{W_T}$
S1	0.10	0.12	170.89	0.00	171.11
S2	0.08	0.04	0.04	0.58	0.74
S3	0.08	0.04	0.04	0.57	0.73
S4	0.09	0.04	0.04	0.58	0.75
S5	0.09	0.11	101.77	0.00	101.96
S6	0.09	0.11	91.55	0.00	91.74
S7	0.00	0.00	0.00	0.00	0.00
S8	0.12	0.14	396.73	0.00	396.98
S9	0.11	0.13	260.10	0.00	260.34
S10	0.00	0.00	0.00	0.00	0.00
S11	0.08	0.10	73.63	0.00	73.81
S12	0.11	0.14	342.95	0.00	343.20
S13	0.10	0.12	177.40	0.00	177.62
S14	0.11	0.13	269.43	0.00	269.67
S15	0.10	0.12	176.23	0.00	176.45
S16	0.12	0.15	427.23	0.00	427.49
S17	0.09	0.11	96.15	0.00	96.34
S18	0.09	0.11	134.62	0.00	134.83
S19	0.08	0.10	80.57	0.00	80.76
S20	0.11	0.14	317.89	0.00	318.13
S21	0.11	0.13	248.33	0.00	248.56
S22	0.08	0.10	57.38	0.00	57.56
S23	0.11	0.13	248.33	0.00	248.56
S24	0.00	0.00	0.00	0.00	0.00
S25	0.11	0.14	327.89	0.00	328.14
S26	0.09	0.11	103.28	0.00	103.48
S27	0.09	0.11	128.11	0.00	128.31
S28	0.11	0.14	376.41	0.00	376.66
S29	0.09	0.04	0.04	0.63	0.80

Table C-12 Above Ground Biomass (t/ha) of study site in Wet season (Cont.)

Sampling plots	Wet Season				
	W_L	W_B	W_S	W_R	W_T
S30	0.09	0.11	136.42	0.00	136.63
S31	0.09	0.11	111.74	0.00	111.94
S32	0.09	0.11	136.42	0.00	136.63
S33	0.00	0.00	0.00	0.00	0.00
S34	0.10	0.13	229.80	0.00	230.03
S35	0.09	0.11	135.03	0.00	135.23
S36	0.09	0.11	119.50	0.00	119.70
S37	0.11	0.13	276.51	0.00	276.75
S38	0.08	0.10	61.69	0.00	61.87
S39	0.00	0.00	0.00	0.00	0.00
S40	0.11	0.13	265.44	0.00	265.67
S41	0.17	0.06	0.06	0.30	0.59
S42	0.00	0.00	0.00	0.00	0.00
S43	0.08	0.04	0.04	0.56	0.72
S44	0.00	0.00	0.00	0.00	0.00
S45	0.12	0.05	0.05	1.10	1.32
S46	0.00	0.00	0.00	0.00	0.00
S47	0.11	0.05	0.05	0.92	1.12
S48	0.00	0.00	0.00	0.00	0.00
S49	0.09	0.11	102.85	0.00	103.04
S50	0.09	0.11	112.41	0.00	112.61
S51	0.09	0.04	0.04	0.67	0.85
S52	0.09	0.04	0.04	0.61	0.78
S53	0.09	0.12	145.54	0.00	145.75
S54	0.09	0.11	130.82	0.00	131.02
S55	0.00	0.00	0.00	0.00	0.00
S56	0.10	0.12	155.21	0.00	155.42
S57	0.00	0.00	0.00	0.00	0.00
S58	0.00	0.00	0.00	0.00	0.00

Table C-12 Above Ground Biomass (t/ha) of study site in Wet season (Cont.)

Sampling plots	**Wet Season**				
	W_L	W_B	W_S	W_R	W_T
S59	0.00	0.00	0.00	0.00	0.00
S60	0.00	0.00	0.00	0.00	0.00
S61	0.00	0.00	0.00	0.00	0.00
S62	0.00	0.00	0.00	0.00	0.00
S63	0.10	0.12	187.52	0.00	187.75
S64	0.10	0.13	209.88	0.00	210.10
S65	0.11	0.13	250.52	0.00	250.75
S66	0.11	0.14	369.74	0.00	370.00
S67	0.11	0.13	276.68	0.00	276.92
S68	0.09	0.11	135.43	0.00	135.64
S69	0.00	0.00	0.00	0.00	0.00
S70	0.00	0.00	0.00	0.00	0.00
S71	0.00	0.00	0.00	0.00	0.00
S72	0.11	0.05	0.05	0.85	1.05
S73	0.10	0.05	0.05	0.76	0.96
S74	0.10	0.05	0.04	0.73	0.92
S75	0.11	0.05	0.05	0.89	1.09
S76	0.11	0.05	0.05	0.95	1.16
S77	0.13	0.06	0.05	1.26	1.49
S78	0.11	0.05	0.05	0.97	1.19
S79	0.13	0.06	0.05	1.25	1.49
S80	0.10	0.05	0.05	0.81	1.01

Table C-13 Above Ground Biomass (t/ha) of reference site in Wet season

Sampling plots	Wet Season				
	W_L	W_B	W_S	W_R	W_T
R1	0.10	0.12	162.95	0.00	163.17
R2	0.00	0.00	0.00	0.00	0.00
R3	0.00	0.00	0.00	0.00	0.00
R4	0.00	0.00	0.00	0.00	0.00
R5	0.00	0.00	0.00	0.00	0.00
R6	0.00	0.00	0.00	0.00	0.00
R7	0.08	0.09	52.55	0.00	52.72
R8	0.00	0.00	0.00	0.00	0.00
R9	0.09	0.11	119.56	0.00	119.76
R10	0.07	0.09	46.23	0.00	46.40
R11	0.09	0.11	100.86	0.00	101.05
R12	0.10	0.12	198.67	0.00	198.90
R13	0.00	0.00	0.00	0.00	0.00
R14	0.07	0.09	39.26	0.00	39.42
R15	0.11	0.13	293.49	0.00	293.74

Table C-14 Above Ground Biomass (t/ha) of study site in Dry season

Sampling plots	**Dry Season**				
	W_L	**W_B**	**W_S**	**W_R**	**W_T**
S1	0.11	0.14	347.23	0.00	347.49
S2	0.09	0.05	0.04	0.35	0.54
S3	0.10	0.05	0.05	0.39	0.58
S4	0.10	0.05	0.04	0.36	0.54
S5	0.10	0.12	192.37	0.00	192.60
S6	0.03	0.04	1.01	0.00	1.08
S7	0.00	0.00	0.00	0.00	0.00
S8	0.14	0.17	954.67	0.00	954.98
S9	0.11	0.13	265.21	0.00	265.45
S10	0.03	0.03	0.47	0.00	0.53
S11	0.09	0.11	110.77	0.00	110.97
S12	0.13	0.17	786.01	0.00	786.31
S13	0.10	0.13	245.32	0.00	245.56
S14	0.12	0.15	486.17	0.00	486.44
S15	0.11	0.13	288.86	0.00	289.11
S16	0.15	0.18	1286.36	0.00	1286.70
S17	0.08	0.10	86.84	0.00	87.03
S18	0.10	0.13	243.83	0.00	244.07
S19	0.10	0.13	212.64	0.00	212.87
S20	0.14	0.17	933.67	0.00	933.98
S21	0.13	0.16	647.68	0.00	647.97
S22	0.00	0.00	0.00	0.00	0.00
S23	0.12	0.15	525.87	0.00	526.14
S24	0.00	0.00	0.00	0.00	0.00
S25	0.12	0.15	475.79	0.00	476.06
S26	0.10	0.12	167.43	0.00	167.64
S27	0.10	0.13	215.61	0.00	215.83
S28	0.14	0.18	1032.00	0.00	1032.32
S29	0.00	0.00	0.04	0.00	0.04

Table C-14 Above Ground Biomass (t/ha) of study site in Dry season (Cont.)

Sampling plots	Dry Season				
	W_L	W_B	W_S	W_R	W_T
S30	0.10	0.12	177.69	0.00	177.91
S31	0.10	0.12	173.53	0.00	173.75
S32	0.09	0.11	121.22	0.00	121.42
S33	0.00	0.00	0.00	0.00	0.00
S34	0.12	0.15	474.25	0.00	474.52
S35	0.10	0.13	222.49	0.00	222.72
S36	0.10	0.13	206.71	0.00	206.94
S37	0.12	0.15	427.69	0.00	427.95
S38	0.09	0.11	113.44	0.00	113.64
S39	0.00	0.00	0.00	0.00	0.00
S40	0.13	0.16	669.09	0.00	669.38
S41	0.16	0.06	0.06	0.13	0.41
S42	0.00	0.00	0.00	0.00	0.00
S43	0.10	0.05	0.05	0.39	0.59
S44	0.00	0.00	0.00	0.00	0.00
S45	0.12	0.05	0.05	0.55	0.77
S46	0.00	0.00	0.00	0.00	0.00
S47	0.12	0.05	0.05	0.57	0.79
S48	0.00	0.00	0.00	0.00	0.00
S49	0.10	0.12	186.10	0.00	186.32
S50	0.11	0.13	273.51	0.00	273.75
S51	0.10	0.05	0.05	0.40	0.59
S52	0.10	0.05	0.05	0.40	0.59
S53	0.11	0.14	356.78	0.00	357.03
S54	0.10	0.12	169.07	0.00	169.28
S55	0.00	0.00	0.00	0.00	0.00
S56	0.10	0.13	243.99	0.00	244.23
S57	0.00	0.00	0.00	0.00	0.00
S58	0.00	0.00	0.00	0.00	0.00

Table C-14 Above Ground Biomass (t/ha) of study site in Dry season (Cont.)

Sampling plots	Dry Season				
	W_L	W_B	W_S	W_R	W_T
S59	0.00	0.00	0.00	0.00	0.00
S60	0.00	0.00	0.00	0.00	0.00
S61	0.00	0.00	0.00	0.00	0.00
S62	0.00	0.00	0.00	0.00	0.00
S63	0.13	0.16	744.44	0.00	744.74
S64	0.12	0.15	454.29	0.00	454.55
S65	0.12	0.15	515.76	0.00	516.03
S66	0.12	0.14	413.56	0.00	413.82
S67	0.13	0.16	756.04	0.00	756.33
S68	0.11	0.14	325.95	0.00	326.20
S69	0.00	0.00	0.00	0.00	0.00
S70	0.00	0.00	0.00	0.00	0.00
S71	0.00	0.00	0.00	0.00	0.00
S72	0.12	0.05	0.05	0.58	0.80
S73	0.11	0.05	0.05	0.48	0.69
S74	0.12	0.05	0.05	0.55	0.77
S75	0.13	0.05	0.05	0.62	0.85
S76	0.14	0.06	0.05	0.73	0.99
S77	0.16	0.06	0.06	0.13	0.40
S78	0.15	0.06	0.05	0.79	1.05
S79	0.15	0.06	0.06	0.85	1.12
S80	0.13	0.05	0.05	0.60	0.83

Table C-15 Above Ground Biomass (t/ha) of reference site in Dry season

Sampling plots	Dry Season				
	W_L	W_B	W_S	W_R	W_T
R1	0.05	0.06	5.04	0.00	5.14
R2	0.00	0.00	0.00	0.00	0.00
R3	0.00	0.00	0.00	0.00	0.00
R4	0.00	0.00	0.00	0.00	0.00
R5	0.00	0.00	0.00	0.00	0.00
R6	0.00	0.00	0.00	0.00	0.00
R7	0.04	0.05	4.24	0.00	4.34
R8	0.00	0.00	0.00	0.00	0.00
R9	0.04	0.05	3.69	0.00	3.79
R10	0.04	0.05	3.72	0.00	3.82
R11	0.05	0.06	5.04	0.00	5.14
R12	0.04	0.05	3.78	0.00	3.88
R13	0.00	0.00	0.00	0.00	0.00
R14	0.04	0.05	3.04	0.00	3.13
R15	0.05	0.06	8.07	0.00	8.19

Table C-16 Above Ground Carbon (t/ha) of study site in Wet season

Sampling plots	Wet Season				
	AGC_L	AGC_B	AGC_S	AGC_R	AGC_T
S1	0.05	0.06	85.45	0.00	85.55
S2	0.04	0.02	0.02	0.29	0.37
S3	0.04	0.02	0.02	0.28	0.37
S4	0.04	0.02	0.02	0.29	0.37
S5	0.04	0.05	50.88	0.00	50.98
S6	0.04	0.05	45.77	0.00	45.87
S7	0.00	0.00	0.00	0.00	0.00
S8	0.06	0.07	198.36	0.00	198.49
S9	0.05	0.07	130.05	0.00	130.17
S10	0.00	0.00	0.00	0.00	0.00
S11	0.04	0.05	36.82	0.00	36.91
S12	0.06	0.07	171.48	0.00	171.60
S13	0.05	0.06	88.70	0.00	88.81
S14	0.05	0.07	134.72	0.00	134.83
S15	0.05	0.06	88.12	0.00	88.23
S16	0.06	0.07	213.62	0.00	213.75
S17	0.04	0.05	48.07	0.00	48.17
S18	0.05	0.06	67.31	0.00	67.41
S19	0.04	0.05	40.29	0.00	40.38
S20	0.06	0.07	158.94	0.00	159.07
S21	0.05	0.07	124.16	0.00	124.28
S22	0.04	0.05	28.69	0.00	28.78
S23	0.05	0.07	124.16	0.00	124.28
S24	0.00	0.00	0.00	0.00	0.00
S25	0.06	0.07	163.94	0.00	164.07
S26	0.04	0.05	51.64	0.00	51.74
S27	0.05	0.06	64.05	0.00	64.16
S28	0.06	0.07	188.20	0.00	188.33
S29	0.04	0.02	0.02	0.31	0.40

Table C-16 Above Ground Carbon (t/ha) of study site in Wet season (Cont.)

Sampling plots	Wet Season				
	AGC_L	AGC_B	AGC_S	AGC_R	AGC_T
S30	0.05	0.06	68.21	0.00	68.31
S31	0.04	0.05	55.87	0.00	55.97
S32	0.05	0.06	68.21	0.00	68.31
S33	0.00	0.00	0.00	0.00	0.00
S34	0.05	0.06	114.90	0.00	115.01
S35	0.05	0.06	67.51	0.00	67.62
S36	0.05	0.06	59.75	0.00	59.85
S37	0.05	0.07	138.25	0.00	138.37
S38	0.04	0.05	30.85	0.00	30.93
S39	0.00	0.00	0.00	0.00	0.00
S40	0.05	0.07	132.72	0.00	132.84
S41	0.08	0.03	0.03	0.15	0.30
S42	0.00	0.00	0.00	0.00	0.00
S43	0.04	0.02	0.02	0.28	0.36
S44	0.00	0.00	0.00	0.00	0.00
S45	0.06	0.03	0.02	0.55	0.66
S46	0.00	0.00	0.00	0.00	0.00
S47	0.05	0.02	0.02	0.46	0.56
S48	0.00	0.00	0.00	0.00	0.00
S49	0.04	0.05	51.42	0.00	51.52
S50	0.04	0.05	56.21	0.00	56.30
S51	0.05	0.02	0.02	0.34	0.43
S52	0.04	0.02	0.02	0.30	0.39
S53	0.05	0.06	72.77	0.00	72.87
S54	0.05	0.06	65.41	0.00	65.51
S55	0.00	0.00	0.00	0.00	0.00
S56	0.05	0.06	77.61	0.00	77.71
S57	0.00	0.00	0.00	0.00	0.00
S58	0.00	0.00	0.00	0.00	0.00

Table C-16 Above Ground Carbon (t/ha) of study site in Wet season (Cont.)

Sampling plots	Wet Season				
	AGC_L	**AGC_B**	**AGC_S**	**AGC_R**	**AGC_T**
S59	0.00	0.00	0.00	0.00	0.00
S60	0.00	0.00	0.00	0.00	0.00
S61	0.00	0.00	0.00	0.00	0.00
S62	0.00	0.00	0.00	0.00	0.00
S63	0.05	0.06	93.76	0.00	93.87
S64	0.05	0.06	104.94	0.00	105.05
S65	0.05	0.07	125.26	0.00	125.38
S66	0.06	0.07	184.87	0.00	185.00
S67	0.05	0.07	138.34	0.00	138.46
S68	0.05	0.06	67.72	0.00	67.82
S69	0.00	0.00	0.00	0.00	0.00
S70	0.00	0.00	0.00	0.00	0.00
S71	0.00	0.00	0.00	0.00	0.00
S72	0.05	0.02	0.02	0.43	0.53
S73	0.05	0.02	0.02	0.38	0.48
S74	0.05	0.02	0.02	0.37	0.46
S75	0.05	0.02	0.02	0.44	0.55
S76	0.06	0.03	0.02	0.47	0.58
S77	0.06	0.03	0.03	0.63	0.75
S78	0.06	0.03	0.02	0.49	0.59
S79	0.06	0.03	0.03	0.63	0.74
S80	0.05	0.02	0.02	0.41	0.50

Table C-17 Above Ground Carbon (t/ha) of reference site in Wet season

Sampling plots	Wet Season				
	AGC_L	**AGC_B**	**AGC_S**	**AGC_R**	**AGC_T**
R1	0.05	0.06	81.48	0.00	81.58
R2	0.00	0.00	0.00	0.00	0.00
R3	0.00	0.00	0.00	0.00	0.00
R4	0.00	0.00	0.00	0.00	0.00
R5	0.00	0.00	0.00	0.00	0.00
R6	0.00	0.00	0.00	0.00	0.00
R7	0.04	0.05	26.28	0.00	26.36
R8	0.00	0.00	0.00	0.00	0.00
R9	0.05	0.06	59.78	0.00	59.88
R10	0.04	0.05	23.12	0.00	23.20
R11	0.04	0.05	50.43	0.00	50.53
R12	0.05	0.06	99.34	0.00	99.45
R13	0.00	0.00	0.00	0.00	0.00
R14	0.04	0.04	19.63	0.00	19.71
R15	0.05	0.07	146.75	0.00	146.87

Table C-18 Above Ground Carbon (t/ha) of study site in Dry season

Sampling plots	Dry Season				
	AGC_L	AGC_B	AGC_S	AGC_R	AGC_T
S1	0.00	0.07	173.62	0.00	173.69
S2	0.00	0.02	0.02	0.02	0.06
S3	0.00	0.02	0.02	0.02	0.07
S4	0.00	0.02	0.02	0.02	0.06
S5	0.00	0.06	96.19	0.00	96.25
S6	0.00	0.02	0.50	0.00	0.52
S7	0.00	0.00	0.00	0.00	0.00
S8	0.00	0.09	477.34	0.00	477.42
S9	0.00	0.07	132.60	0.00	132.67
S10	0.00	0.02	0.24	0.00	0.25
S11	0.00	0.05	55.38	0.00	55.44
S12	0.00	0.08	393.00	0.00	393.09
S13	0.00	0.06	122.66	0.00	122.73
S14	0.00	0.07	243.09	0.00	243.16
S15	0.00	0.07	144.43	0.00	144.50
S16	0.00	0.09	643.18	0.00	643.28
S17	0.00	0.05	43.42	0.00	43.47
S18	0.00	0.06	121.92	0.00	121.98
S19	0.00	0.06	106.32	0.00	106.38
S20	0.00	0.09	466.83	0.00	466.92
S21	0.00	0.08	323.84	0.00	323.92
S22	0.00	0.00	0.00	0.00	0.00
S23	0.00	0.08	262.93	0.00	263.01
S24	0.00	0.00	0.00	0.00	0.00
S25	0.00	0.07	237.90	0.00	237.97
S26	0.00	0.06	83.71	0.00	83.77
S27	0.00	0.06	107.80	0.00	107.87
S28	0.00	0.09	516.00	0.00	516.09
S29	0.00	0.00	0.02	0.00	0.02

Table C-18 Above Ground Carbon (t/ha) of study site in Dry season (Cont.)

Sampling plots	Dry Season				
	AGC_L	AGC_B	AGC_S	AGC_R	AGC_T
S30	0.00	0.06	88.84	0.00	88.91
S31	0.00	0.06	86.77	0.00	86.83
S32	0.00	0.06	60.61	0.00	60.67
S33	0.00	0.00	0.00	0.00	0.00
S34	0.00	0.07	237.12	0.00	237.20
S35	0.00	0.06	111.24	0.00	111.31
S36	0.00	0.06	103.36	0.00	103.42
S37	0.00	0.07	213.84	0.00	213.92
S38	0.00	0.06	56.72	0.00	56.78
S39	0.00	0.00	0.00	0.00	0.00
S40	0.00	0.08	334.55	0.00	334.63
S41	0.01	0.03	0.03	0.01	0.07
S42	0.00	0.00	0.00	0.00	0.00
S43	0.00	0.02	0.02	0.02	0.07
S44	0.00	0.00	0.00	0.00	0.00
S45	0.00	0.03	0.02	0.03	0.08
S46	0.00	0.00	0.00	0.00	0.00
S47	0.00	0.03	0.03	0.03	0.09
S48	0.00	0.00	0.00	0.00	0.00
S49	0.00	0.06	93.05	0.00	93.11
S50	0.00	0.07	136.76	0.00	136.82
S51	0.00	0.02	0.02	0.02	0.07
S52	0.00	0.02	0.02	0.02	0.07
S53	0.00	0.07	178.39	0.00	178.46
S54	0.00	0.06	84.53	0.00	84.59
S55	0.00	0.00	0.00	0.00	0.00
S56	0.00	0.06	122.00	0.00	122.06
S57	0.00	0.00	0.00	0.00	0.00
S58	0.00	0.00	0.00	0.00	0.00

Table C-18 Above Ground Carbon (t/ha) of study site in Dry season (Cont.)

Sampling plots	Dry Season				
	AGC_L	AGC_B	AGC_S	AGC_R	AGC_T
S59	0.00	0.00	0.00	0.00	0.00
S60	0.00	0.00	0.00	0.00	0.00
S61	0.00	0.00	0.00	0.00	0.00
S62	0.00	0.00	0.00	0.00	0.00
S63	0.00	0.08	372.22	0.00	372.31
S64	0.00	0.07	227.14	0.00	227.22
S65	0.00	0.08	257.88	0.00	257.96
S66	0.00	0.07	206.78	0.00	206.85
S67	0.00	0.08	378.02	0.00	378.10
S68	0.00	0.07	162.97	0.00	163.04
S69	0.00	0.00	0.00	0.00	0.00
S70	0.00	0.00	0.00	0.00	0.00
S71	0.00	0.00	0.00	0.00	0.00
S72	0.00	0.03	0.03	0.03	0.09
S73	0.00	0.03	0.02	0.02	0.08
S74	0.00	0.03	0.02	0.03	0.08
S75	0.00	0.03	0.03	0.03	0.09
S76	0.00	0.03	0.03	0.04	0.10
S77	0.01	0.03	0.03	0.01	0.07
S78	0.01	0.03	0.03	0.05	0.11
S79	0.01	0.03	0.03	0.05	0.11
S80	0.00	0.03	0.03	0.03	0.09

Table C-19 Above Ground Carbon (t/ha) of reference site in Dry season

Sampling plots	**Dry Season**				
	AGC_L	**AGC_B**	**AGC_S**	**AGC_R**	**AGC_T**
R1	0.00	0.03	2.52	0.00	2.55
R2	0.00	0.00	0.00	0.00	0.00
R3	0.00	0.00	0.00	0.00	0.00
R4	0.00	0.00	0.00	0.00	0.00
R5	0.00	0.00	0.00	0.00	0.00
R6	0.00	0.00	0.00	0.00	0.00
R7	0.00	0.03	2.12	0.00	2.15
R8	0.00	0.00	0.00	0.00	0.00
R9	0.00	0.03	1.84	0.00	1.87
R10	0.00	0.03	1.86	0.00	1.89
R11	0.00	0.03	2.52	0.00	2.55
R12	0.00	0.03	1.89	0.00	1.92
R13	0.00	0.00	0.00	0.00	0.00
R14	0.00	0.03	1.52	0.00	1.54
R15	0.00	0.03	4.04	0.00	4.07

Table C-20 Average of carbon content (%) of *Rhizophora mucronata*

parts of tree	Average of carbon content (%) of *Rhizophora mucronata*	
	Study site	**Reference site**
roots	45.35	46.51
stems	45.99	44.04
branches	45.87	43.73
leaves	43.19	48.23

Remark: N=6

Table C-21 Average of carbon content (%) of *Avicennia marina*

parts of tree	Average of carbon content (%) of *Avicennia marina*	
	Study site	Reference site
trunks	44.55	44.18
branches	43.45	42.92
leaves	42.8	44.42

Remark: N=6

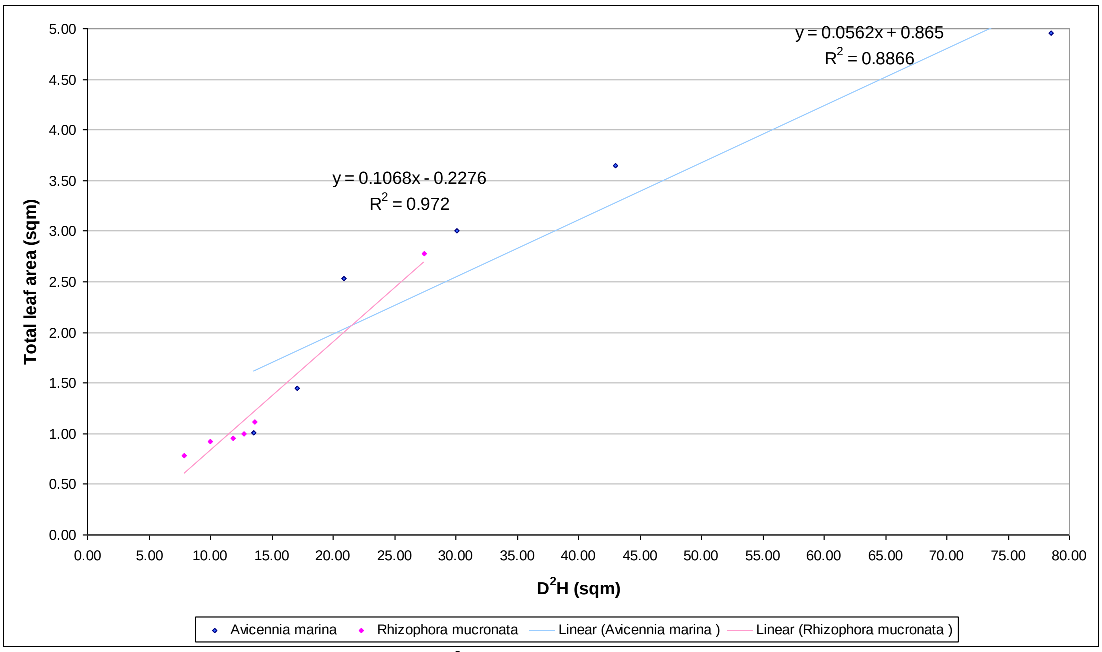

Figure C-1 Relationship between D^2H and LAI by the linear model

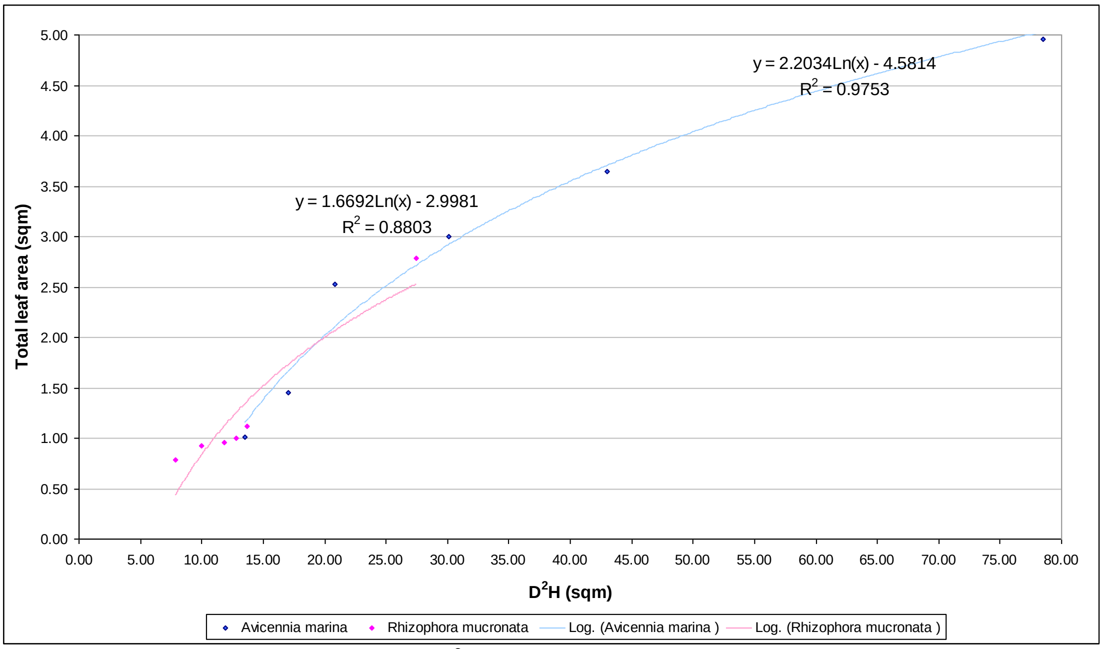

Figure C-2 Relationship between D^2H and LAI by the logarithmic model

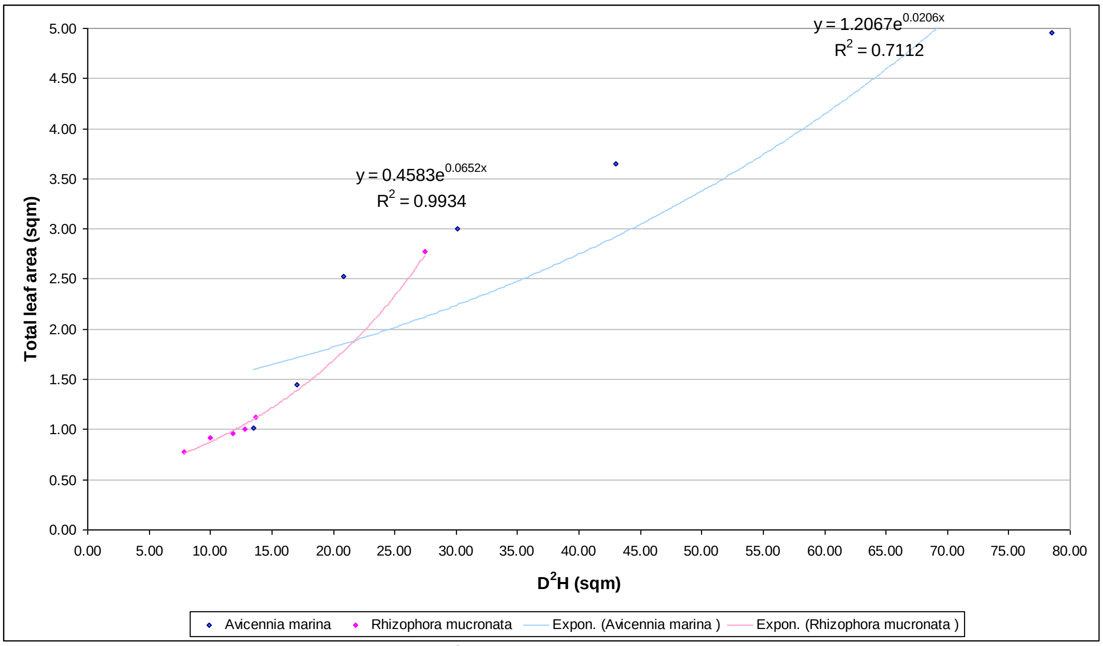

Figure C-3 Relationship between D^2H and LAI by the Exponential model

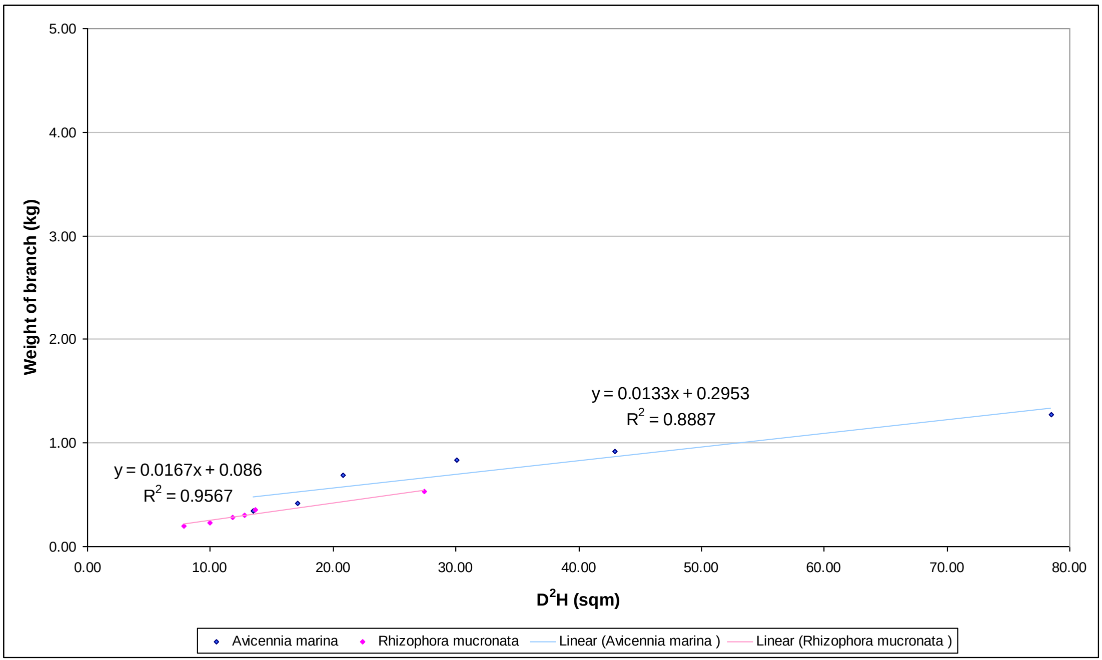

Figure C-4 Relationship between D^2H and branch dry weight by the linear model

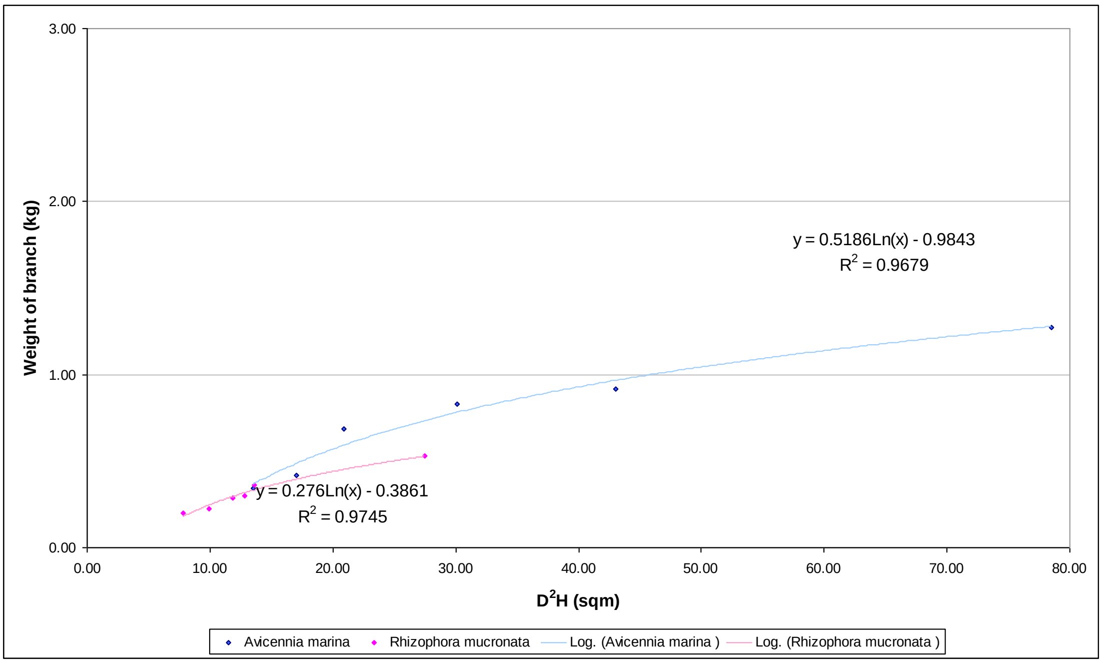

Figure C-5 Relationship between D^2H and branch dry weight by the logarithmic model

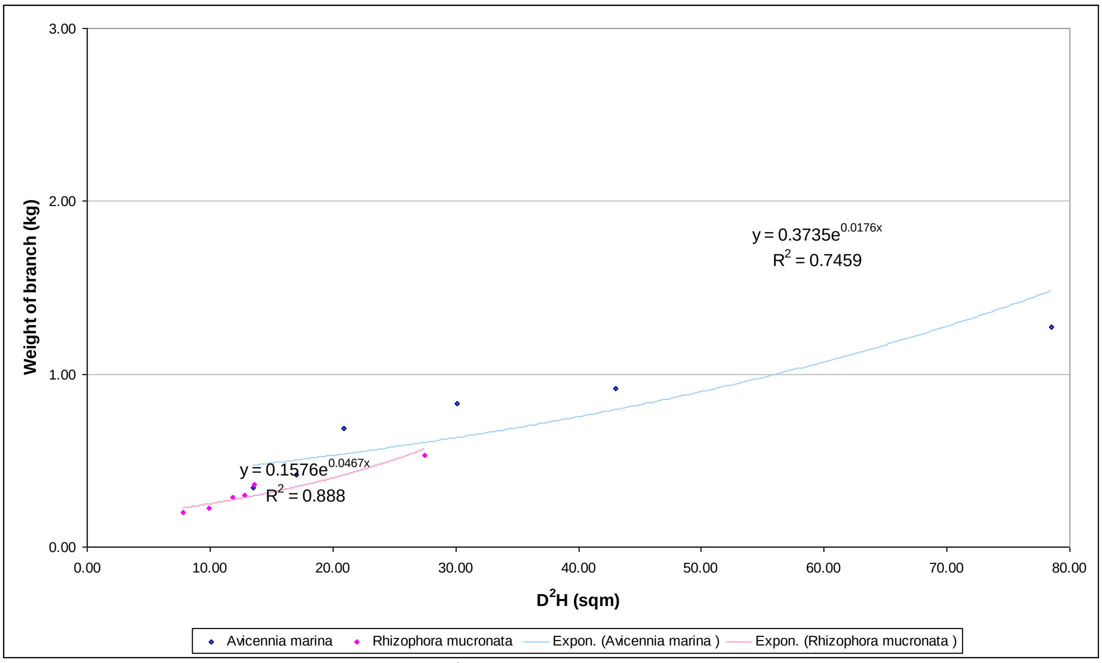

Figure C-6 Relationship between D^2H and branch dry weight by the Exponential model

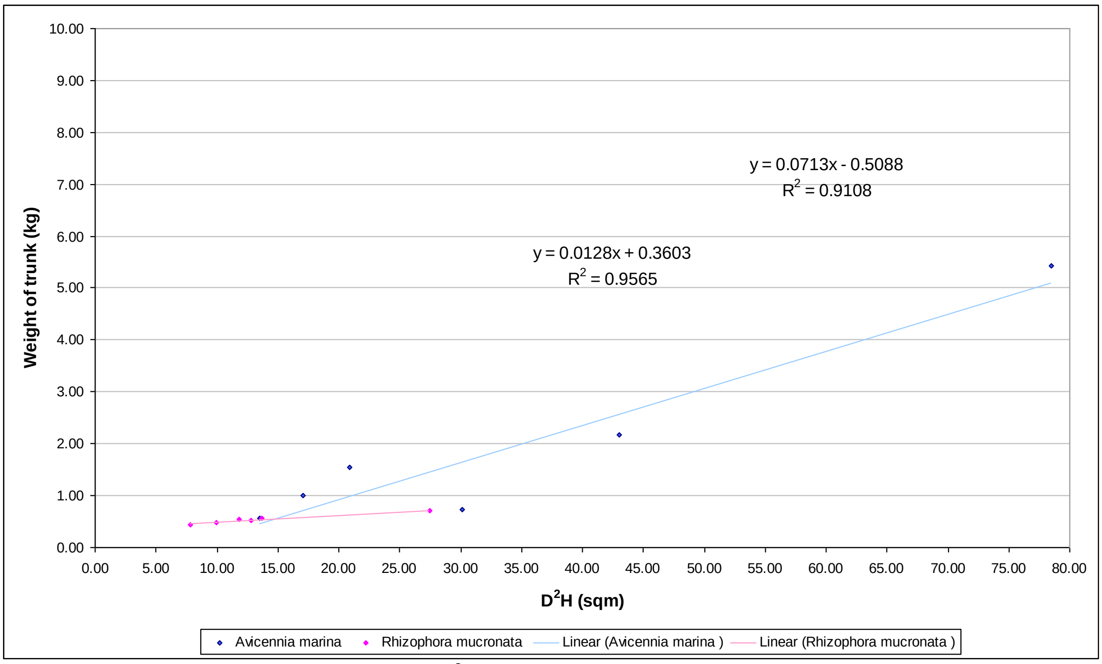

Figure C-7 Relationship between D^2H and trunk dry weight by the linear model

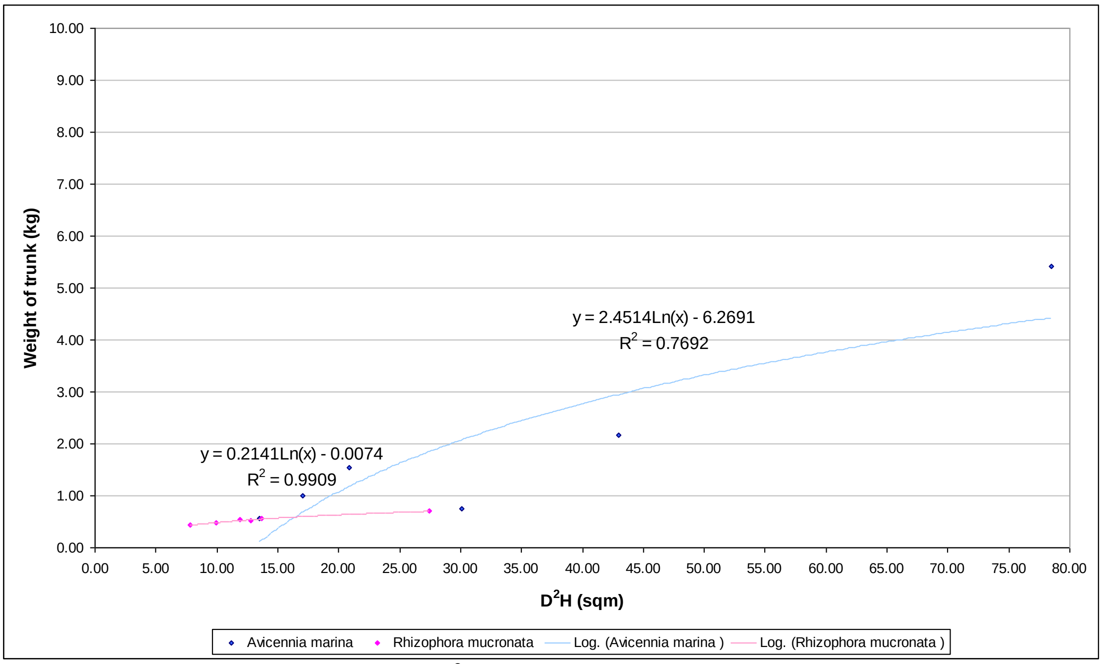

Figure C-8 Relationship between D^2H and trunk dry weight by the logarithmic model

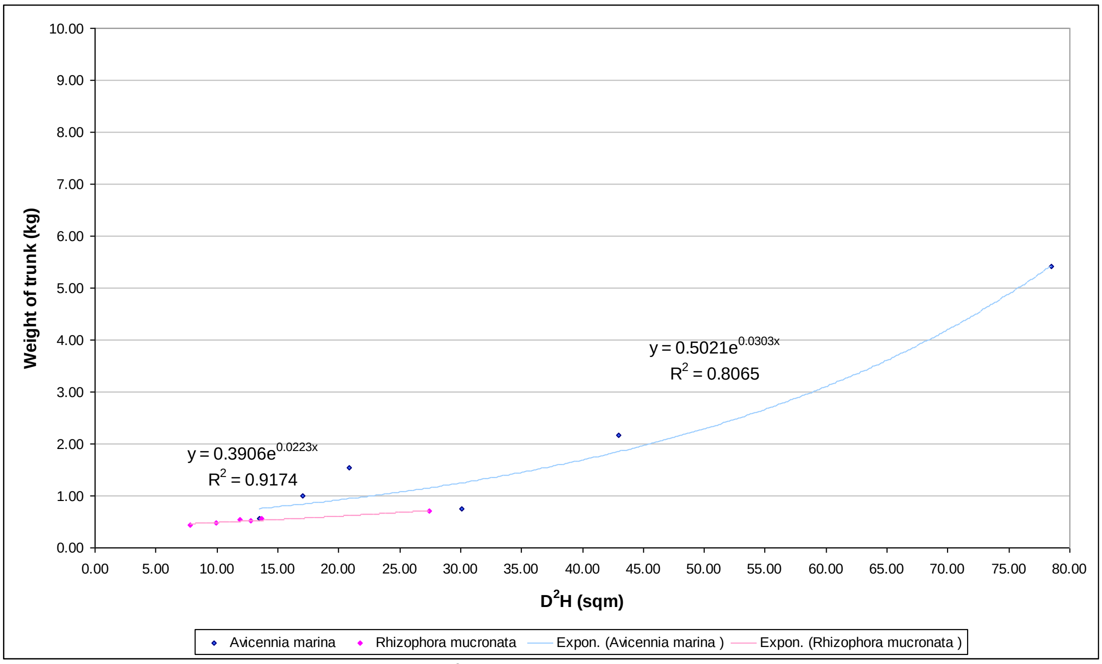

Figure C-9 Relationship between D^2H and trunk dry weight by the Exponential model

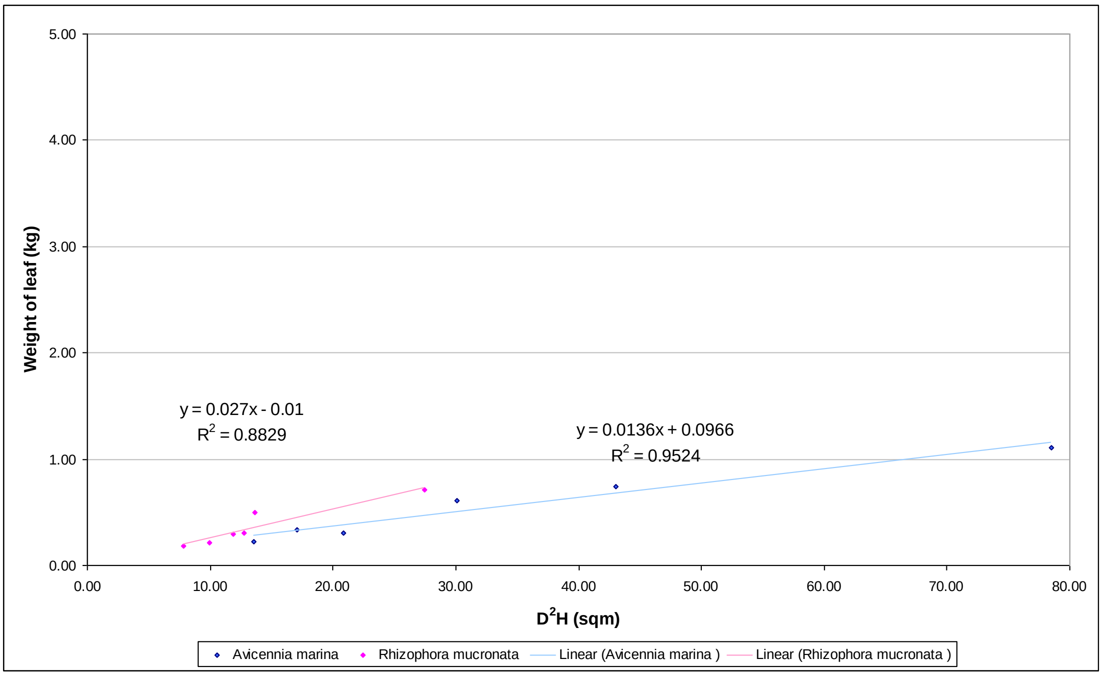

Figure C-10 Relationship between D^2H and leaf dry weight by the linear model

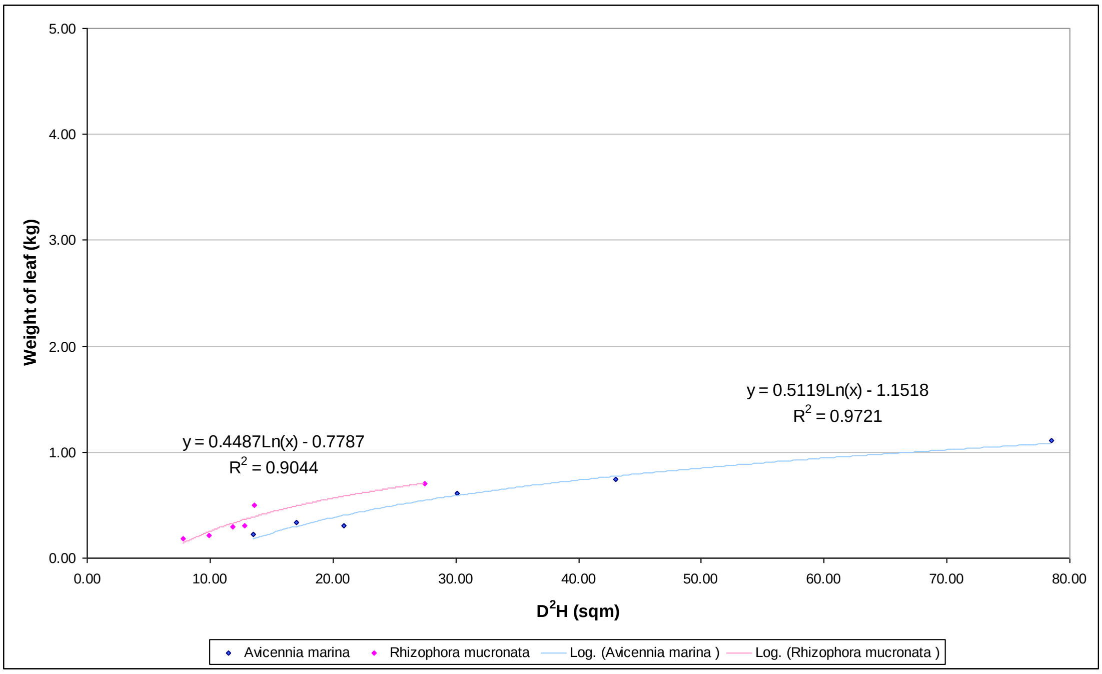

Figure C-11 Relationship between D^2H and leaf dry weight by the logarithmic model

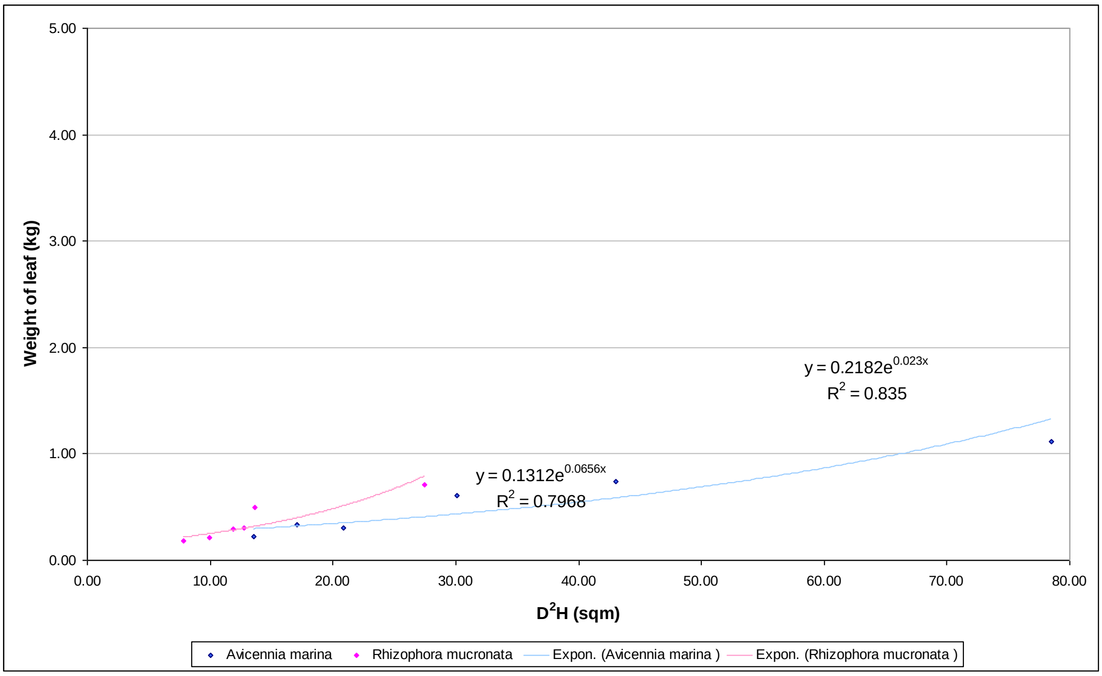

Figure C-12 Relationship between D^2H and leaf dry weight by the Exponential model

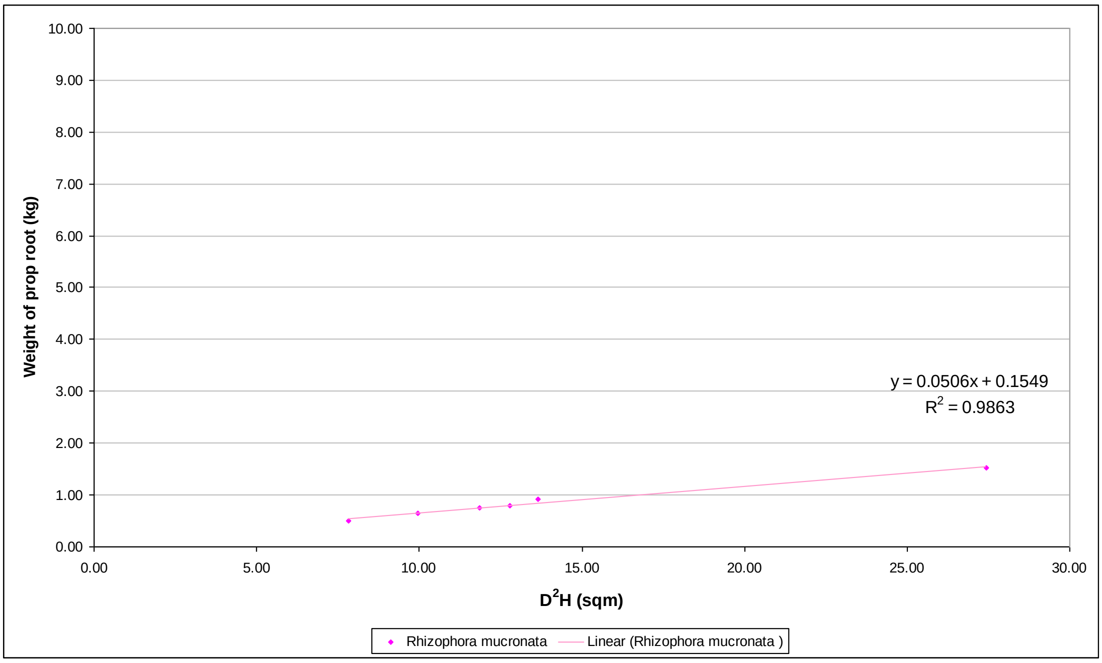

Figure C-13 Relationship between D^2H and root dry weight by the linear model

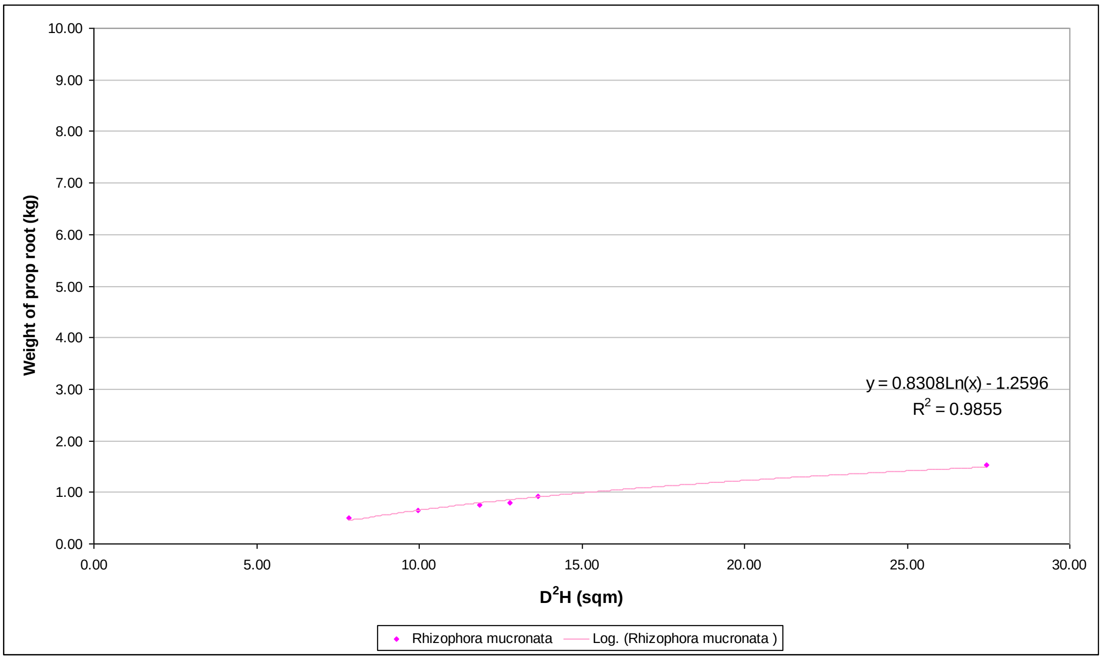

Figure C-14 Relationship between D^2H and prop root dry weight by the logarithmic model

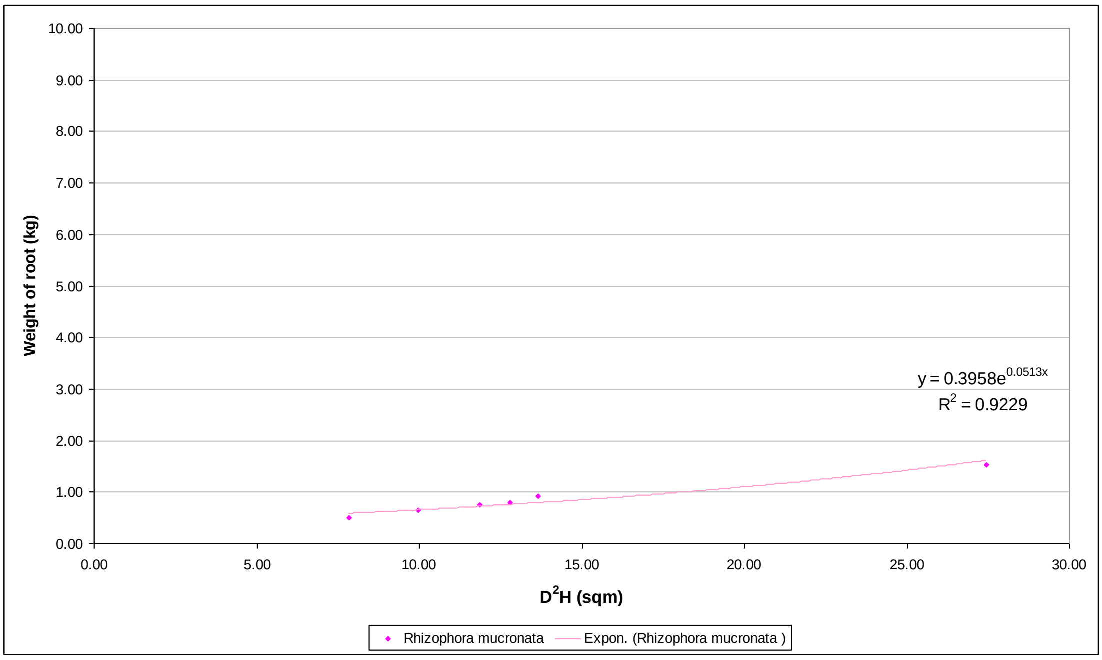

Figure C-15 Relationship between D^2H and prop root dry weight by the Exponential model

APPENDIX D

Table D-1 Vegetation Indexes values using by LANDSAT 5-TM in the study site

Sampling plots	UTM Coordination		Vegetation Indexes		
	E	N	NDVI	RVI	DVI
S1	618338	1443464	0.491	2.931	56.000
S2	618374	1443464	0.556	3.500	65.000
S3	618398	1443451	0.621	4.273	72.000
S4	618207	1443463	0.583	3.800	70.000
S5	618225	1443441	0.590	3.875	69.000
S6	618249	1443430	0.613	4.174	73.000
S7	618180	1443375	0.586	3.833	68.000
S8	618210	1443380	0.629	4.391	78.000
S9	618232	1443389	0.629	4.391	78.000
S10	618247	1443345	0.631	4.417	82.000
S11	618255	1443328	0.649	4.696	85.000
S12	618273	1443303	0.630	4.409	75.000
S13	618107	1443150	0.684	5.333	104.000
S14	618137	1443155	0.701	5.692	122.000
S15	618181	1443167	0.726	6.304	122.000
S16	618013	1443272	0.675	5.148	112.000
S17	618525	1443084	0.636	4.500	98.000
S18	617986	1443337	0.650	4.714	104.000
S19	618421	1443037	0.632	4.440	86.000
S20	618038	1443218	0.634	4.467	104.000
S21	618185	1442950	0.560	3.543	89.000
S22	618135	1443366	0.593	3.917	70.000
S23	618181	1442994	0.557	3.515	83.000
S24	618149	1443327	0.622	4.292	79.000
S25	618169	1443029	0.602	4.031	78.000
S26	618171	1443281	0.657	4.826	88.000
S27	618317	1442953	0.558	3.529	86.000
S28	618310	1443449	0.481	2.857	52.000

Table D-1 Vegetation Indexes values using by LANDSAT 5-TM in the study site (Cont.)

Sampling plots	UTM Coordination		Vegetation Indexes		
	E	N	NDVI	RVI	DVI
S29	618333	1442911	0.500	3.000	76.000
S30	618346	1443402	0.586	3.833	68.000
S31	618301	1443004	0.647	4.667	99.000
S32	618373	1443371	0.565	3.600	65.000
S33	618600	1442949	0.630	4.407	92.000
S34	618431	1443424	0.569	3.640	66.000
S35	618633	1442968	0.571	3.667	72.000
S36	618458	1443357	0.554	3.481	67.000
S37	618676	1442989	0.565	3.600	78.000
S38	618438	1443336	0.669	5.045	89.000
S39	618435	1443008	0.627	4.357	94.000
S40	618499	1443387	0.519	3.160	54.000
S41	618376	1442793	0.641	4.565	82.000
S42	618628	1443110	0.590	3.880	72.000
S43	618575	1442864	0.760	7.350	127.000
S44	618573	1443145	0.638	4.520	88.000
S45	618836	1442955	0.728	6.364	118.000
S46	618539	1443134	0.651	4.731	97.000
S47	618830	1442999	0.592	3.900	87.000
S48	618533	1443045	0.612	4.154	82.000
S49	618812	1443046	0.544	3.387	74.000
S50	618545	1442998	0.615	4.192	83.000
S51	618982	1443083	0.529	3.242	74.000
S52	618952	1443119	0.594	3.931	85.000
S53	618931	1443155	0.546	3.407	65.000
S54	618664	1443158	0.589	3.864	63.000
S55	618698	1443173	0.538	3.333	56.000
S56	618755	1443187	0.592	3.905	61.000

Table D-1 Vegetation Indexes values using by LANDSAT 5-TM in the study site (Cont.)

Sampling plots	UTM Coordination		Vegetation Indexes		
	E	N	NDVI	RVI	DVI
S57	618595	1443371	0.319	1.935	29.000
S58	618633	1443336	0.233	1.575	23.000
S59	618674	1443302	0.458	2.690	49.000
S60	618626	1443525	0.424	2.472	53.000
S61	618667	1443502	0.327	1.974	37.000
S62	618698	1443470	0.410	2.389	45.000
S63	618646	1443595	0.627	4.360	84.000
S64	618681	1443595	0.684	5.333	91.000
S65	618714	1443601	0.729	6.389	97.000
S66	618949	1443332	0.597	3.963	80.000
S67	618910	1443326	0.571	3.667	72.000
S68	618861	1443319	0.556	3.500	65.000
S69	618892	1443498	0.424	2.471	50.000
S70	618851	1443495	0.466	2.742	54.000
S71	618799	1443494	0.375	2.200	48.000
S72	618880	1443613	0.681	5.273	94.000
S73	618838	1443616	0.674	5.136	91.000
S74	618788	1443626	0.676	5.167	100.000
S75	618604	1443674	0.707	5.818	106.000
S76	618578	1443682	0.714	6.000	105.000
S77	618521	1443685	0.657	4.826	88.000
S78	618399	1443707	0.591	3.893	103.000
S79	618362	1443727	0.690	5.458	107.000
S80	618316	1443727	0.662	4.923	102.000

Table D-2 Vegetation Indexes values using by LANDSAT 5-TM in the reference site

Sampling plots	**UTM Coordination**		**Vegetation Indexes**		
	E	**N**	**NDVI**	**RVI**	**DVI**
R1	617964	1443828	0.327	1.972	35.000
R2	617990	1443807	0.276	1.763	29.000
R3	618023	1443782	0.276	1.763	29.000
R4	617919	1443782	0.431	2.515	50.000
R5	617950	1443755	0.274	1.756	31.000
R6	617978	1443725	0.274	1.756	31.000
R7	617856	1443724	0.457	2.686	59.000
R8	617885	1443696	0.557	3.519	68.000
R9	617902	1443657	0.613	4.167	76.000
R10	617819	1443698	0.580	3.767	83.000
R11	617852	1443659	0.646	4.652	84.000
R12	617871	1443624	0.642	4.583	86.000
R13	617746	1443628	0.705	5.773	105.000
R14	617766	1443603	0.711	5.909	108.000
R15	617790	1443560	0.650	4.720	93.000

Table D-3 Vegetation Indexes values using by THEOSE in the study site

Sampling plots	UTM Coordination		Vegetation Indexes		
	E	N	NDVI	RVI	DVI
S1	618338	1443464	0.110	1.246	16.000
S2	618374	1443464	0.085	1.185	12.000
S3	618398	1443451	0.077	1.167	11.000
S4	618207	1443463	0.208	1.524	33.000
S5	618225	1443441	0.163	1.391	25.000
S6	618249	1443430	0.203	1.277	32.000
S7	618180	1443375	0.152	1.359	23.000
S8	618210	1443380	0.156	1.369	24.000
S9	618232	1443389	0.110	1.246	16.000
S10	618247	1443345	0.266	1.484	31.000
S11	618255	1443328	0.203	1.476	32.000
S12	618273	1443303	0.266	1.726	45.000
S13	618107	1443150	0.304	1.873	55.000
S14	618137	1443155	0.208	1.524	33.000
S15	618181	1443167	0.222	1.571	36.000
S16	618013	1443272	0.234	1.609	39.000
S17	618525	1443084	0.284	1.794	50.000
S18	617986	1443337	0.248	1.661	41.000
S19	618421	1443037	0.217	1.556	35.000
S20	618038	1443218	0.247	2.097	68.000
S21	618185	1442950	0.259	1.698	44.000
S22	618135	1443366	0.129	1.297	19.000
S23	618181	1442994	0.239	1.629	39.000
S24	618149	1443327	0.250	1.667	42.000
S25	618169	1443029	0.303	1.869	53.000
S26	618171	1443281	0.790	1.806	50.000
S27	618317	1442953	0.291	1.823	51.000
S28	618310	1443449	0.158	1.375	24.000

Table D-3 Vegetation Indexes values using by THEOSE in the study site (Cont.)

Sampling plots	UTM Coordination		Vegetation Indexes		
	E	N	NDVI	RVI	DVI
S29	618333	1442911	0.266	1.726	45.000
S30	618346	1443402	0.203	1.508	32.000
S31	618301	1443004	0.280	1.778	49.000
S32	618373	1443371	0.077	1.167	11.000
S33	618600	1442949	0.303	1.871	54.000
S34	618431	1443424	-0.015	0.971	-2.000
S35	618633	1442968	0.271	1.742	46.000
S36	618458	1443357	-0.030	0.942	-4.000
S37	618676	1442989	0.236	1.742	46.000
S38	618438	1443336	0.015	1.030	2.000
S39	618435	1443008	0.188	1.462	30.000
S40	618499	1443387	-0.102	0.814	1.000
S41	618376	1442793	0.267	1.750	45.000
S42	618628	1443110	0.239	1.629	39.000
S43	618575	1442864	0.264	1.719	46.000
S44	618573	1443145	0.176	1.429	27.000
S45	618836	1442955	0.022	1.045	3.000
S46	618539	1443134	0.200	1.500	32.000
S47	618830	1442999	-0.246	0.606	-28.000
S48	618533	1443045	0.241	1.635	40.000
S49	618812	1443046	-0.071	0.868	-9.000
S50	618545	1442998	0.220	1.563	36.000
S51	618982	1443083	0.108	1.242	16.000
S52	618952	1443119	0.640	1.719	46.000
S53	618931	1443155	0.277	1.766	51.000
S54	618664	1443158	0.205	1.516	33.000
S55	618698	1443173	0.210	1.531	34.000
S56	618755	1443187	0.203	1.508	32.000

Table D-3 Vegetation Indexes values using by THEOSE in the study site (Cont.)

Sampling plots	**UTM Coordination**		**Vegetation Indexes**		
	E	**N**	**NDVI**	**RVI**	**DVI**
S57	618595	1443371	0.114	1.258	17.000
S58	618633	1443336	0.000	1.000	0.000
S59	618674	1443302	0.152	1.359	23.000
S60	618626	1443525	0.150	1.149	10.000
S61	618667	1443502	0.062	1.292	19.000
S62	618698	1443470	0.083	1.182	12.000
S63	618646	1443595	0.133	1.308	20.000
S64	618681	1443595	0.152	1.359	23.000
S65	618714	1443601	0.139	1.323	21.000
S66	618949	1443332	0.224	1.578	37.000
S67	618910	1443326	0.120	1.273	18.000
S68	618861	1443319	-0.279	0.563	-31.000
S69	618892	1443498	-0.104	0.812	-13.000
S70	618851	1443495	0.091	1.200	13.000
S71	618799	1443494	-0.047	0.910	-6.000
S72	618880	1443613	0.246	1.651	41.000
S73	618838	1443616	0.224	1.578	37.000
S74	618788	1443626	0.182	1.444	28.000
S75	618604	1443674	0.276	1.762	48.000
S76	618578	1443682	0.279	1.774	48.000
S77	618521	1443685	0.280	1.762	48.000
S78	618399	1443707	0.315	1.919	57.000
S79	618362	1443727	0.299	1.855	53.000
S80	618316	1443727	0.296	1.841	53.000

Table D-4 Vegetation Indexes values using by THEOSE in the reference site

Sampling plots	UTM Coordination		Vegetation Indexes		
	E	N	NDVI	RVI	DVI
R1	617964	1443828	0.187	1.460	49.000
R2	617990	1443807	0.266	1.726	45.000
R3	618023	1443782	0.232	1.603	38.000
R4	617919	1443782	0.030	1.062	4.000
R5	617950	1443755	0.015	1.030	2.000
R6	617978	1443725	0.129	1.297	19.000
R7	617856	1443724	0.200	1.500	31.000
R8	617885	1443696	0.203	1.508	32.000
R9	617902	1443657	0.225	1.581	36.000
R10	617819	1443698	0.203	1.508	32.000
R11	617852	1443659	0.266	1.726	45.000
R12	617871	1443624	0.253	1.677	42.000
R13	617746	1443628	0.225	1.581	36.000
R14	617766	1443603	0.233	1.607	37.000
R15	617790	1443560	0.262	1.710	44.000

Table D-5 Vegetation Indexes values using by Quickbird in the study site

Sampling plots	UTM Coordination		Vegetation Indexes		
	E	N	NDVI	RVI	DVI
S1	618338	1443464	0.13	1.29	51.16
S2	618374	1443464	0.29	2.05	193.89
S3	618398	1443451	0.42	2.45	235.13
S4	618207	1443463	0.51	3.09	295.39
S5	618225	1443441	0.41	2.40	279.53
S6	618249	1443430	0.43	2.49	228.78
S7	618180	1443375	0.45	2.63	184.38
S8	618210	1443380	0.41	2.36	266.84
S9	618232	1443389	0.46	2.70	314.42
S10	618247	1443345	0.55	3.46	384.2
S11	618255	1443328	0.44	2.57	260.5
S12	618273	1443303	0.54	2.80	308.08
S13	618107	1443150	0.52	3.15	346.14
S14	618137	1443155	0.58	3.75	441.3
S15	618181	1443167	0.49	2.94	298.56
S16	618013	1443272	0.52	3.17	244.64
S17	618525	1443084	0.54	3.32	330.28
S18	617986	1443337	0.46	2.72	292.22
S19	618421	1443037	0.42	2.45	184.38
S20	618038	1443218	0.55	3.48	327.11
S21	618185	1442950	0.52	1.20	67.02
S22	618135	1443366	0.46	2.80	320.77
S23	618181	1442994	0.41	2.42	212.92
S24	618149	1443327	0.51	3.11	327.11
S25	618169	1443029	0.46	2.72	308.08
S26	618171	1443281	0.56	3.54	371.52
S27	618317	1442953	0.11	1.24	35.3
S28	618310	1443449	0.34	2.01	212.92

Table D-5 Vegetation Indexes values using by Quickbird in the study site (Cont.)

Sampling plots	UTM Coordination		Vegetation Indexes		
	E	N	NDVI	RVI	DVI
S29	618333	1442911	0.06	1.12	22.61
S30	618346	1443402	0.46	2.74	301.73
S31	618301	1443004	0.52	3.17	327.11
S32	618373	1443371	0.46	2.72	292.22
S33	618600	1442949	0.48	2.82	304.91
S34	618431	1443424	0.38	2.24	219.27
S35	618633	1442968	0.51	3.05	263.67
S36	618458	1443357	0.35	2.07	152.66
S37	618676	1442989	0.44	2.61	241.47
S38	618438	1443336	0.28	1.80	136.8
S39	618435	1443008	0.50	2.98	330.28
S40	618499	1443387	0.34	2.74	266.84
S41	618376	1442793	0.60	3.44	346.14
S42	618628	1443110	0.50	3.01	320.77
S43	618575	1442864	0.62	4.33	415.92
S44	618573	1443145	0.46	2.67	263.67
S45	618836	1442955	0.44	2.61	159
S46	618539	1443134	0.52	3.17	358.83
S47	618830	1442999	0.49	2.96	270.02
S48	618533	1443045	0.51	3.97	320.77
S49	618812	1443046	0.45	2.65	276.36
S50	618545	1442998	0.45	2.67	289.05
S51	618982	1443083	0.44	2.61	282.7
S52	618952	1443119	0.46	2.69	244.64
S53	618931	1443155	0.49	2.98	285.88
S54	618664	1443158	0.48	2.82	314.42
S55	618698	1443173	0.50	3.01	266.84
S56	618755	1443187	0.46	2.67	266.84

Table D-5 Vegetation Indexes values using by Quickbird in the study site (Cont.)

Sampling plots	UTM Coordination		Vegetation Indexes		
	E	N	NDVI	RVI	DVI
S57	618595	1443371	0.38	2.22	190.72
S58	618633	1443336	0.23	1.58	70.19
S59	618674	1443302	0.49	2.90	342.97
S60	618626	1443525	0.37	2.20	219.27
S61	618667	1443502	0.32	1.93	155.83
S62	618698	1443470	0.37	2.20	235.13
S63	618646	1443595	0.41	2.24	254.16
S64	618681	1443595	0.38	3.05	285.88
S65	618714	1443601	0.56	3.52	358.83
S66	618949	1443332	0.45	2.67	250.98
S67	618910	1443326	0.27	1.74	108.25
S68	618861	1443319	0.43	1.84	168.52
S69	618892	1443498	0.34	2.03	203.41
S70	618851	1443495	0.44	2.53	231.95
S71	618799	1443494	0.22	1.55	95.56
S72	618880	1443613	0.50	2.98	298.56
S73	618838	1443616	0.51	3.09	317.59
S74	618788	1443626	0.56	3.57	406.41
S75	618604	1443674	0.59	3.96	311.25
S76	618578	1443682	0.53	3.23	431.78
S77	618521	1443685	0.54	3.32	415.92
S78	618399	1443707	0.60	3.98	304.91
S79	618362	1443727	0.54	3.38	393.72
S80	618316	1443727	0.57	3.71	365.17

Table D-6 Vegetation Indexes values using by Quickbird in the reference site

Sampling plots	UTM Coordination		Vegetation Indexes		
	E	N	NDVI	RVI	DVI
R1	617964	1443828	0.29	1.82	178.03
R2	617990	1443807	0.26	1.70	162.17
R3	618023	1443782	0.33	1.97	197.06
R4	617919	1443782	0.54	3.42	333.45
R5	617950	1443755	0.28	1.78	127.28
R6	617978	1443725	0.00	1.00	0.41
R7	617856	1443724	0.39	2.30	200.23
R8	617885	1443696	0.53	3.23	342.97
R9	617902	1443657	0.48	2.84	368.34
R10	617819	1443698	0.50	3.01	368.34
R11	617852	1443659	0.49	2.96	320.77
R12	617871	1443624	0.47	2.80	342.97
R13	617746	1443628	0.51	3.09	374.69
R14	617766	1443603	0.55	3.46	384.2
R15	617790	1443560	0.52	3.21	273.19

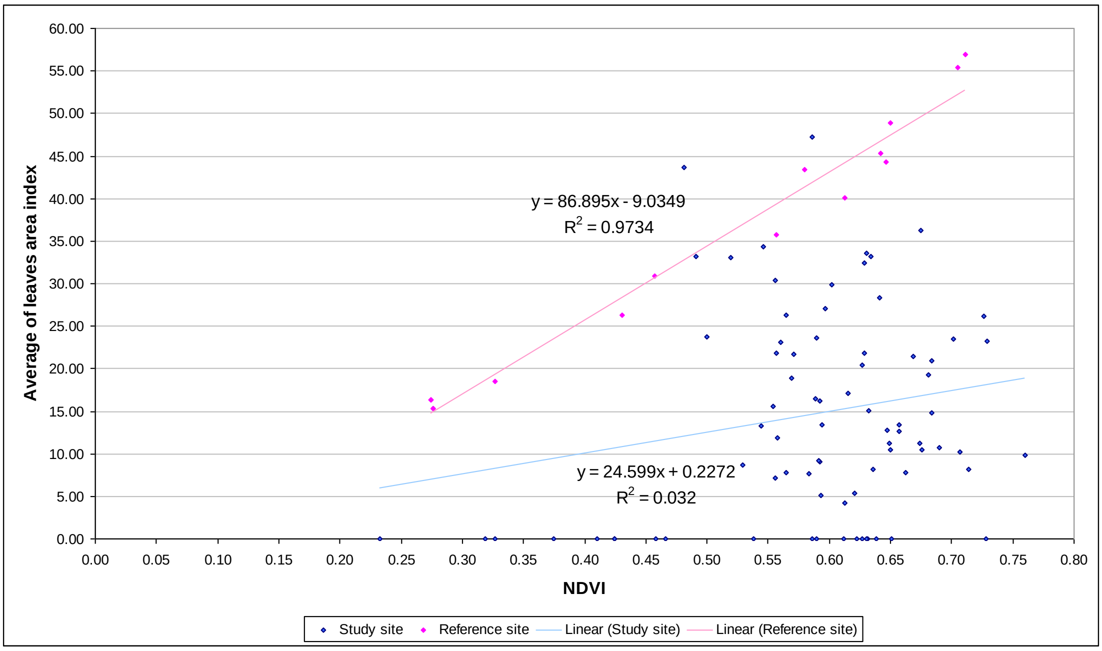

Figure D-1 Relationship between NDVI and LAI of LANDSAT satellite image by the linear model

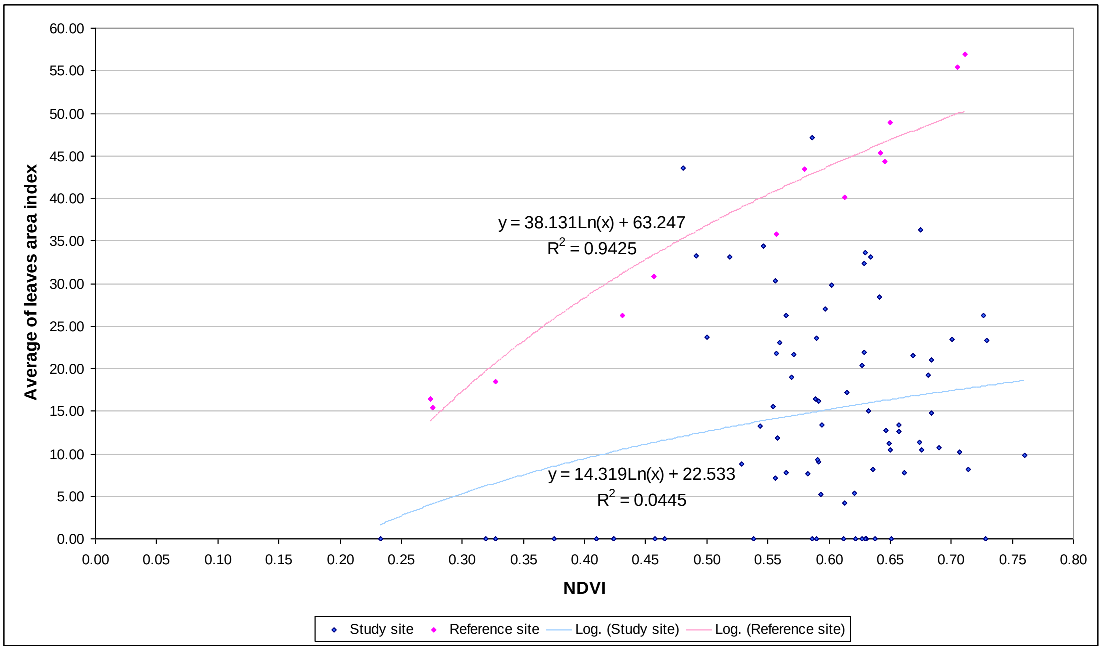

Figure D-2 Relationship between NDVI and LAI of LANDSAT satellite image by the logarithmic model

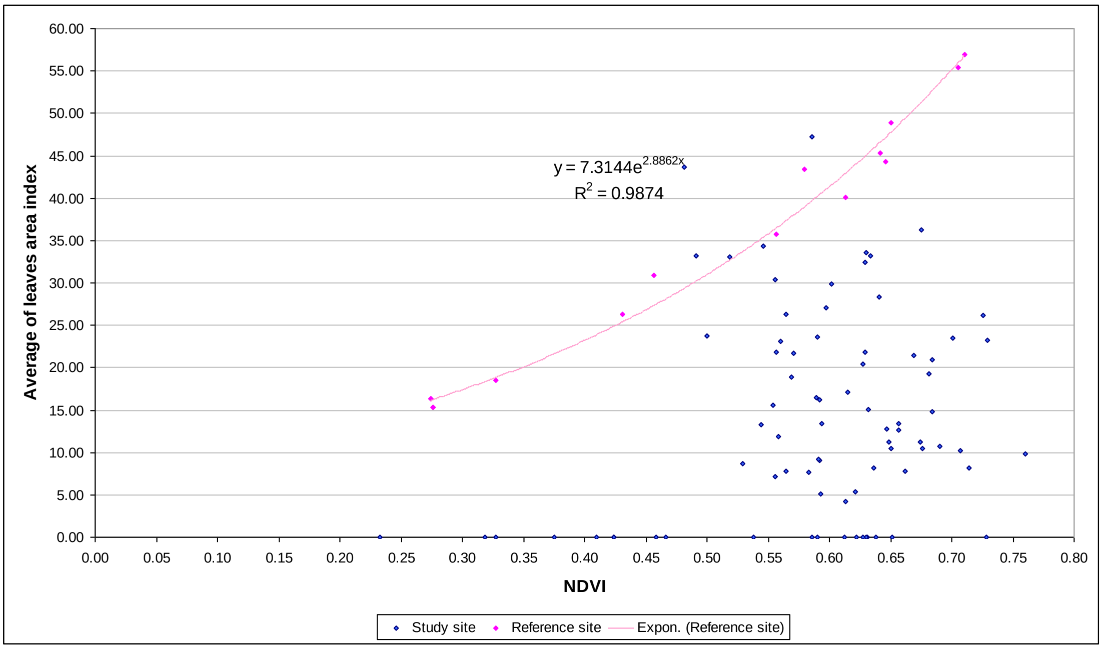

Figure D-3 Relationship between NDVI and LAI of LANDSAT satellite image by the Exponential model

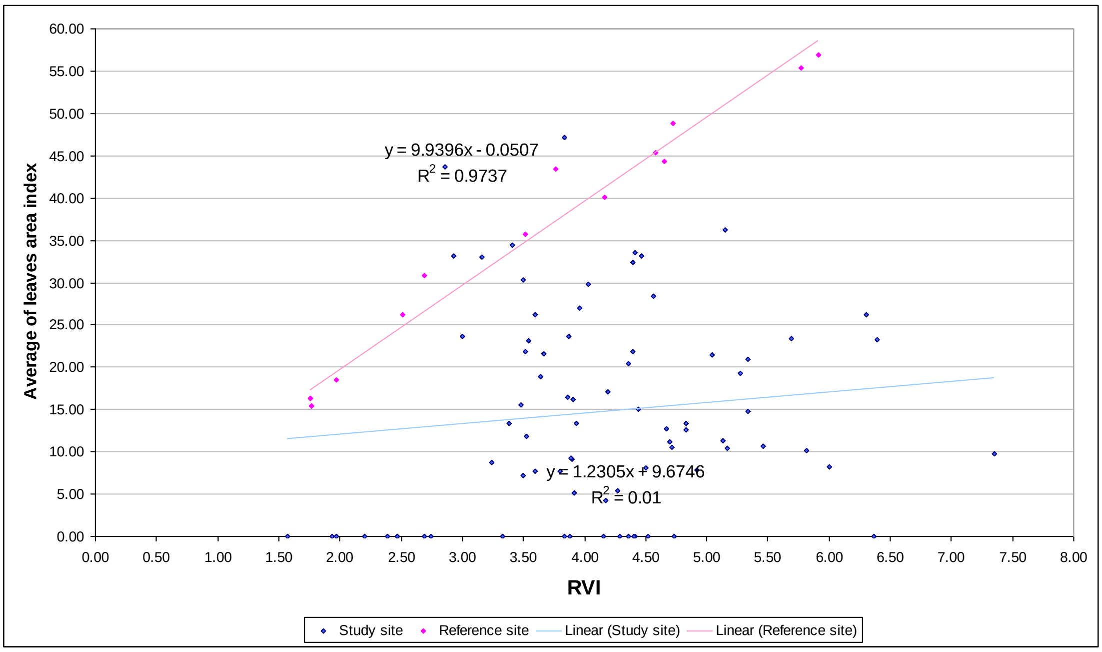

Figure D-4 Relationship between RVI and LAI of LANDSAT satellite image by the linear model

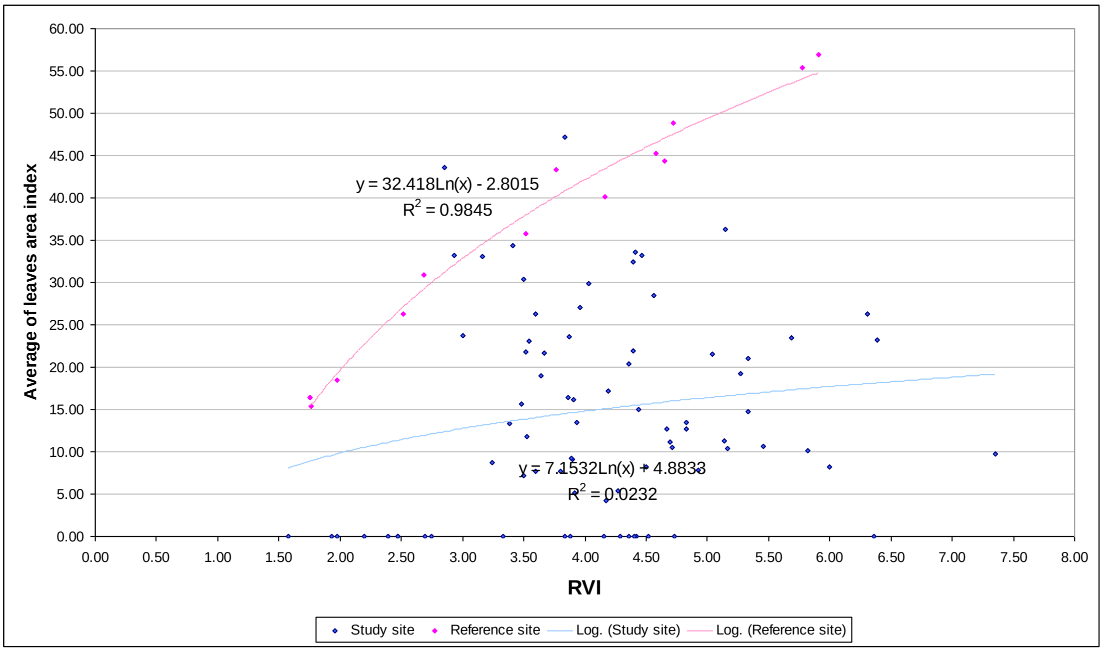

Figure D-5 Relationship between RVI and LAI of LANDSAT satellite image by the logarithmic model

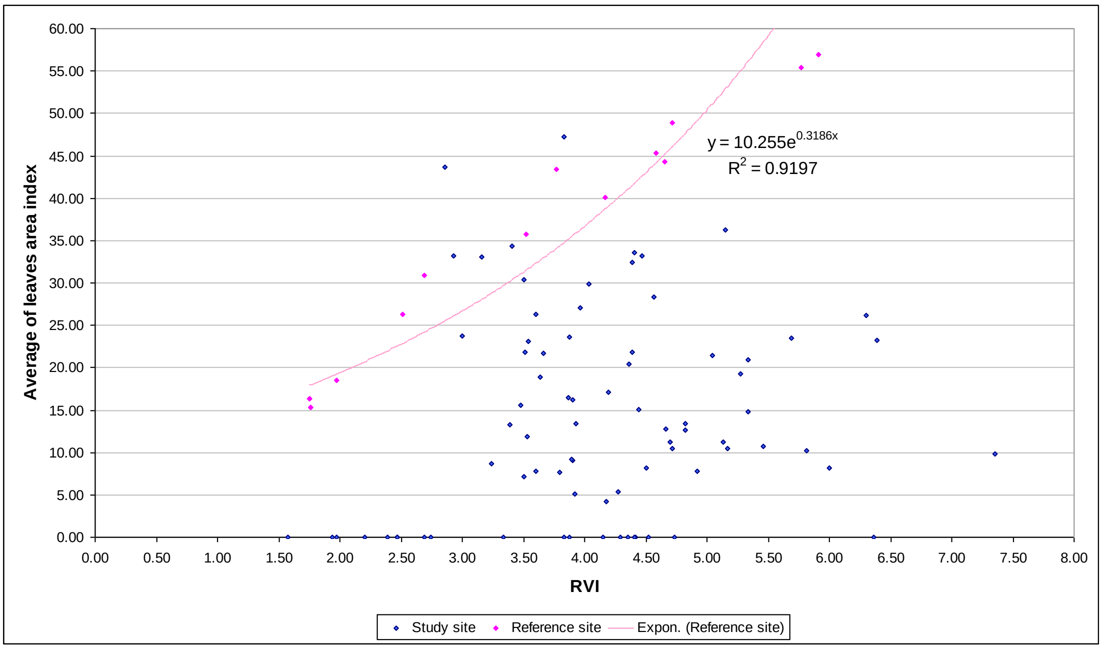

Figure D-6 Relationship between RVI and LAI of LANDSAT satellite image by the Exponential model

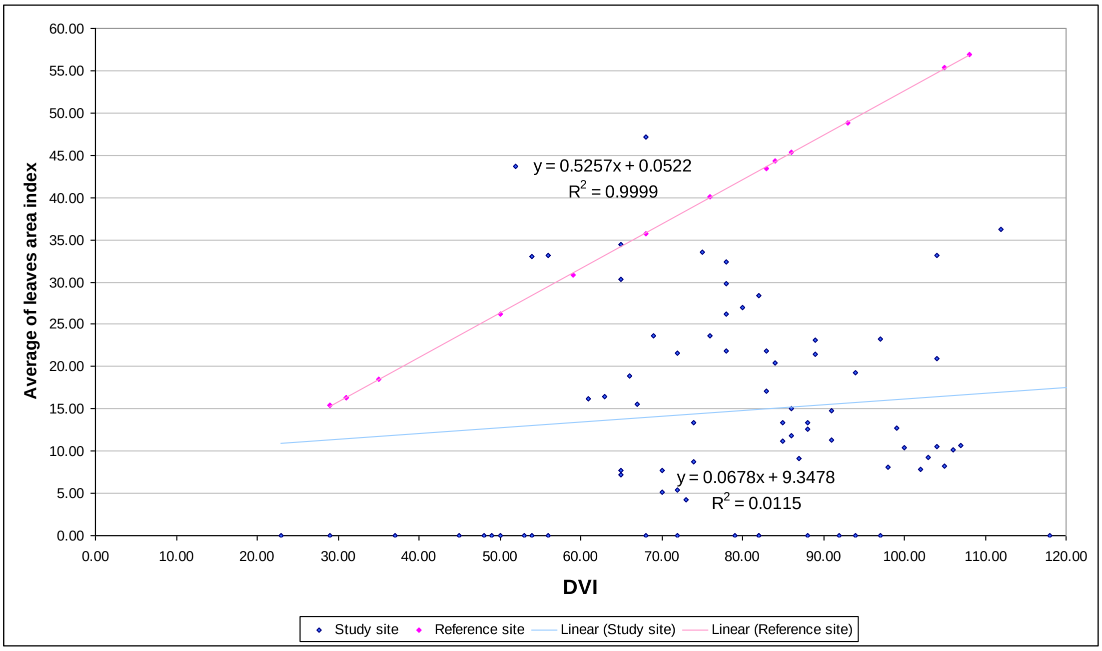

Figure D-7 Relationship between DVI and LAI of LANDSAT satellite image by the linear model

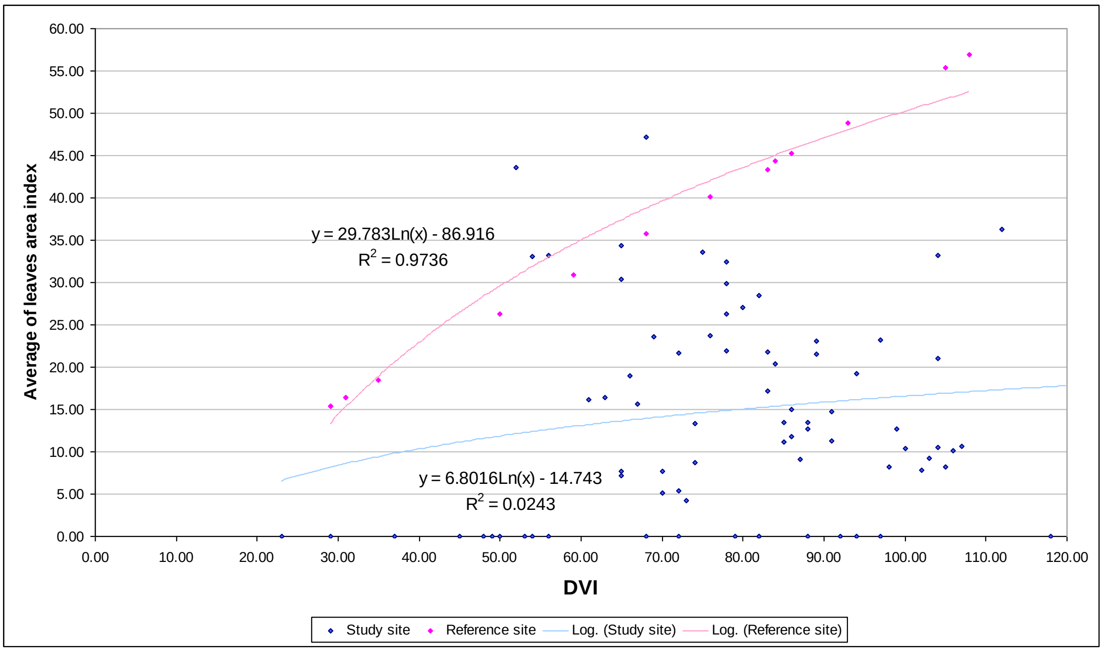

Figure D-8 Relationship between DVI and LAI of LANDSAT satellite image by the logarithmic model

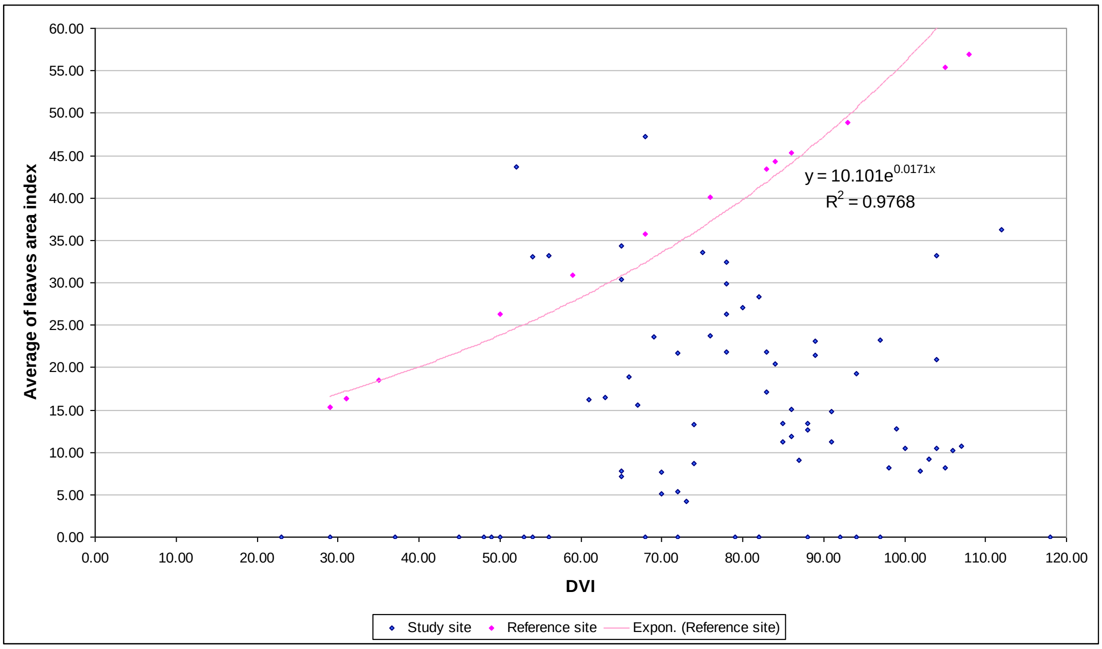

Figure D-9 Relationship between DVI and LAI of LANDSAT satellite image by the Exponential model

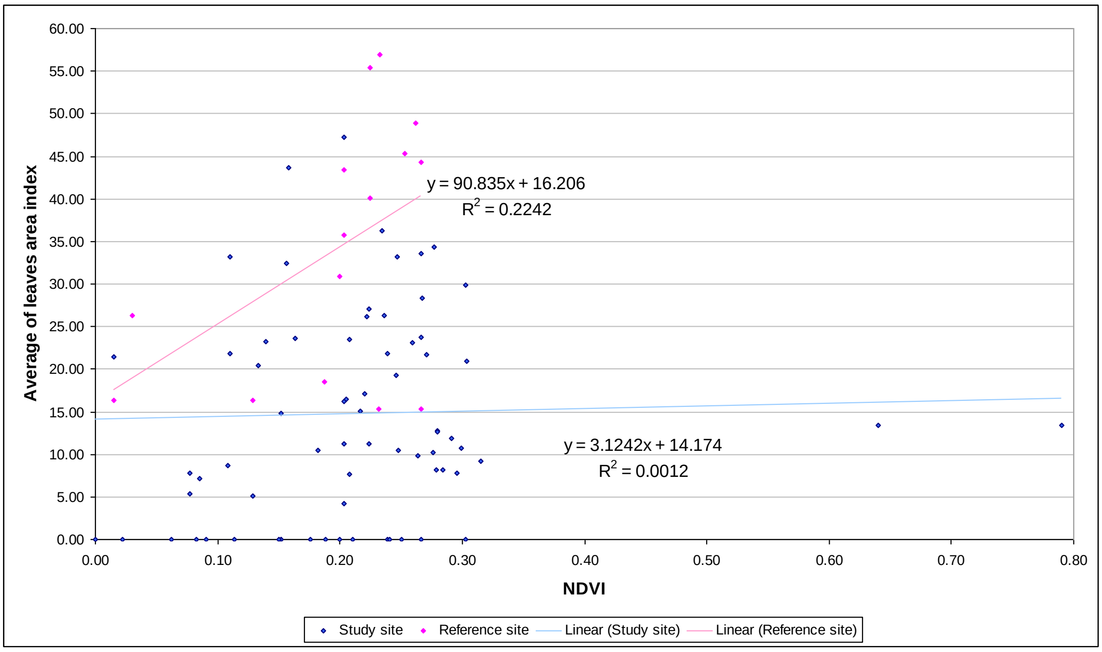

Figure D-10 Relationship between NDVI and LAI of THEOS satellite image by the linear model

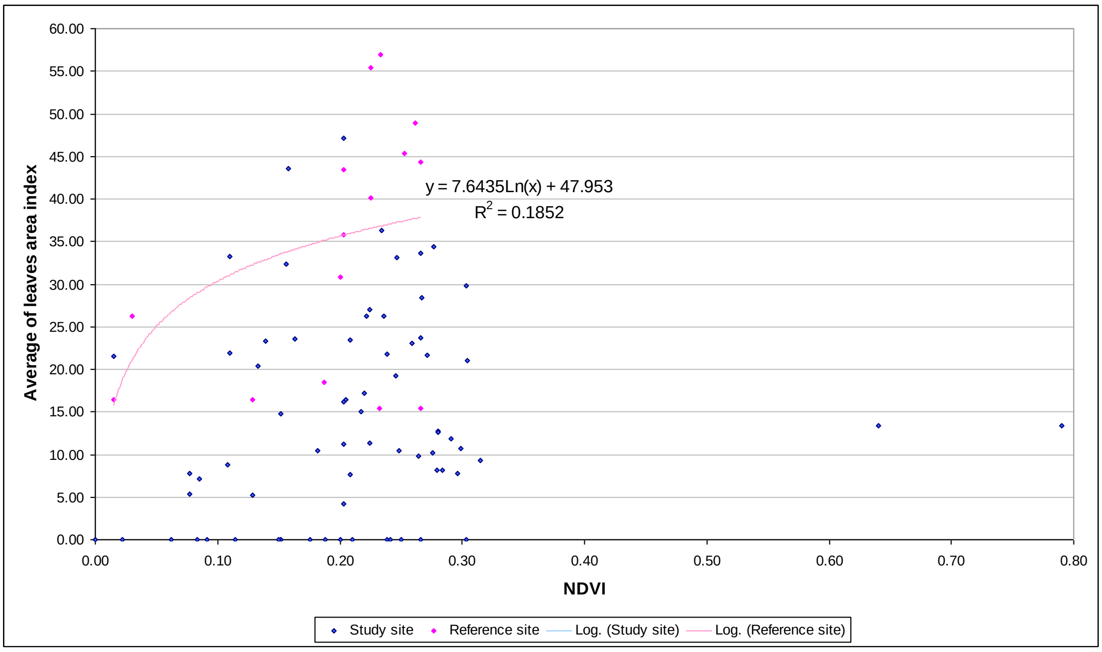

Figure D-11 Relationship between NDVI and LAI of THEOS satellite image by the logarithmic model

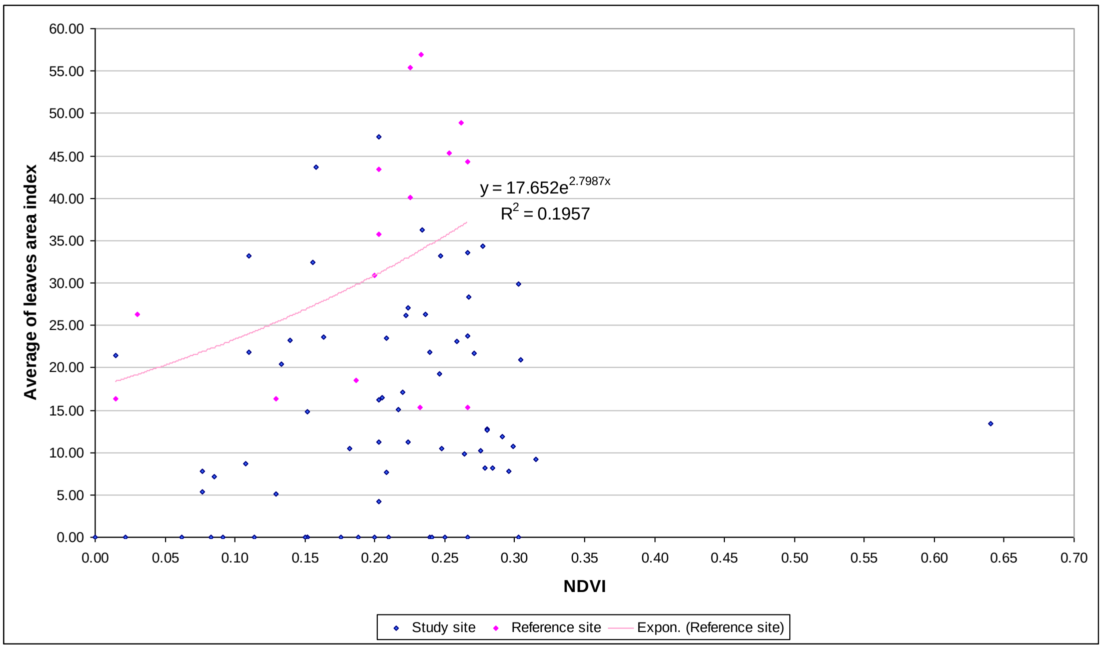

Figure D-12 Relationship between NDVI and LAI of THEOS satellite image by the Exponential model

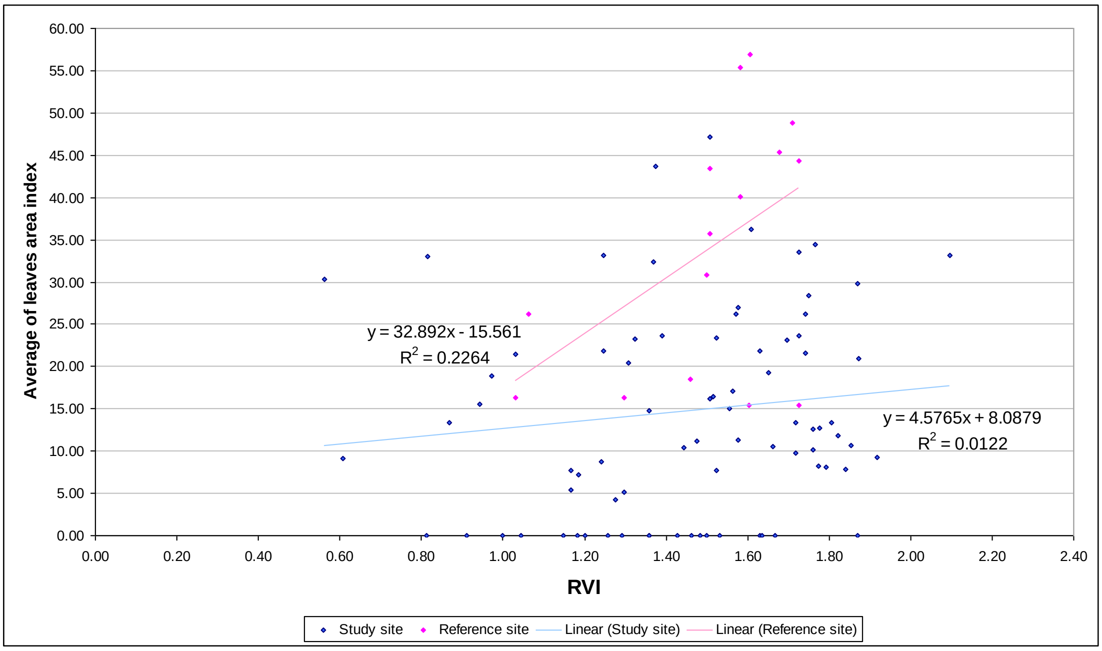

Figure D-13 Relationship between RVI and LAI of THEOS satellite image by the linear model

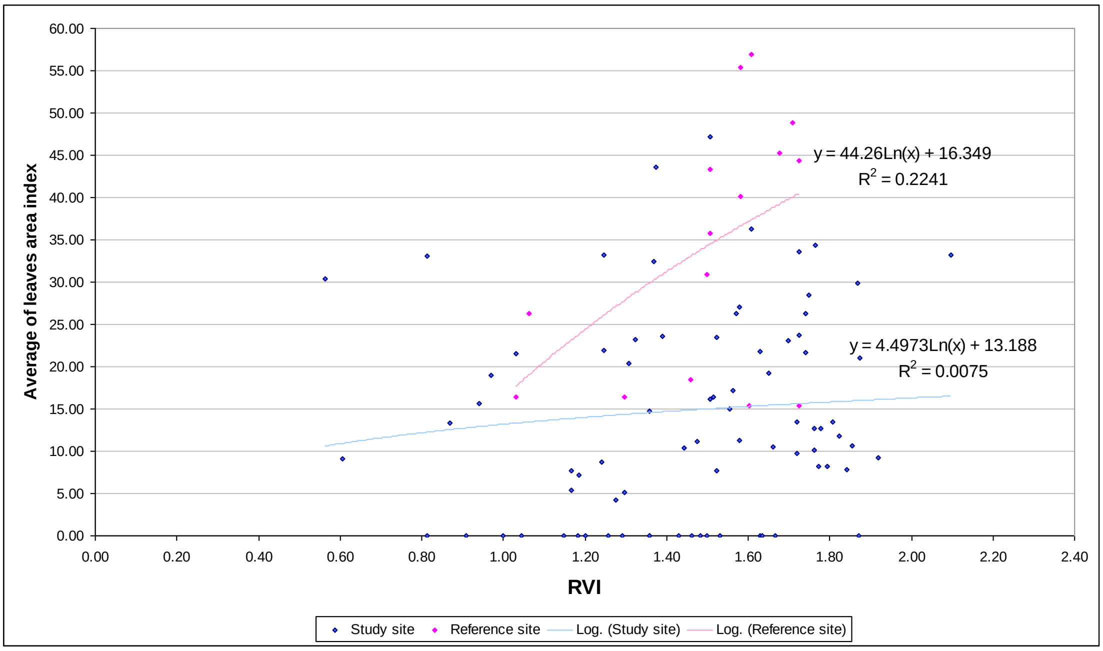

Figure D-14 Relationship between RVI and LAI of THEOS satellite image by the logarithmic model

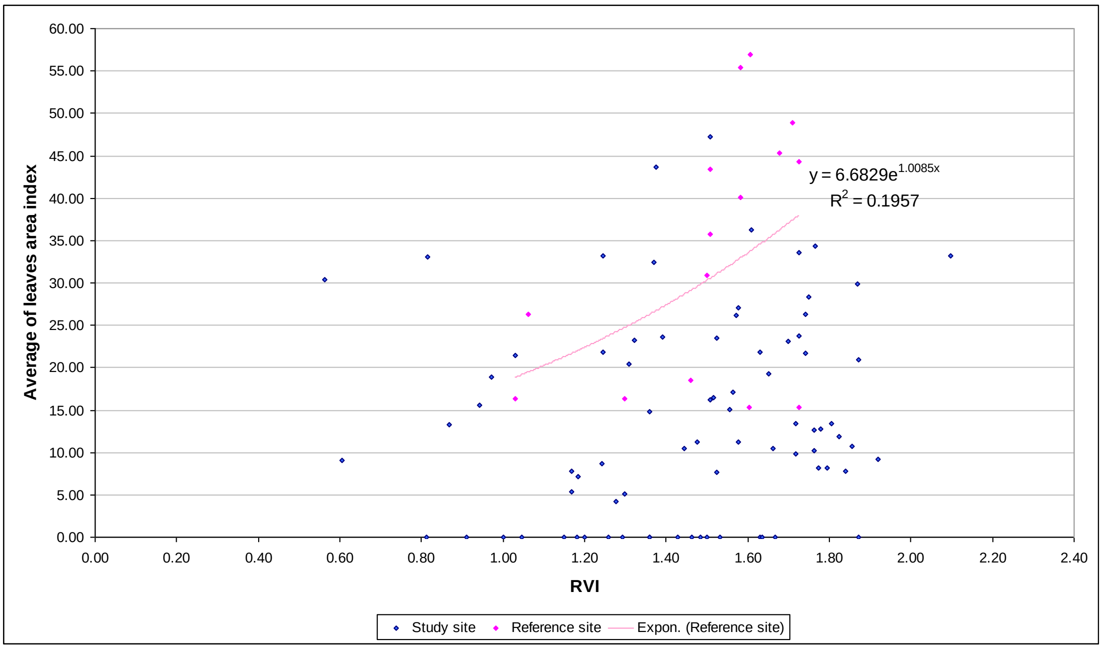

Figure D-15 Relationship between RVI and LAI of THEOS satellite image by the Exponential model

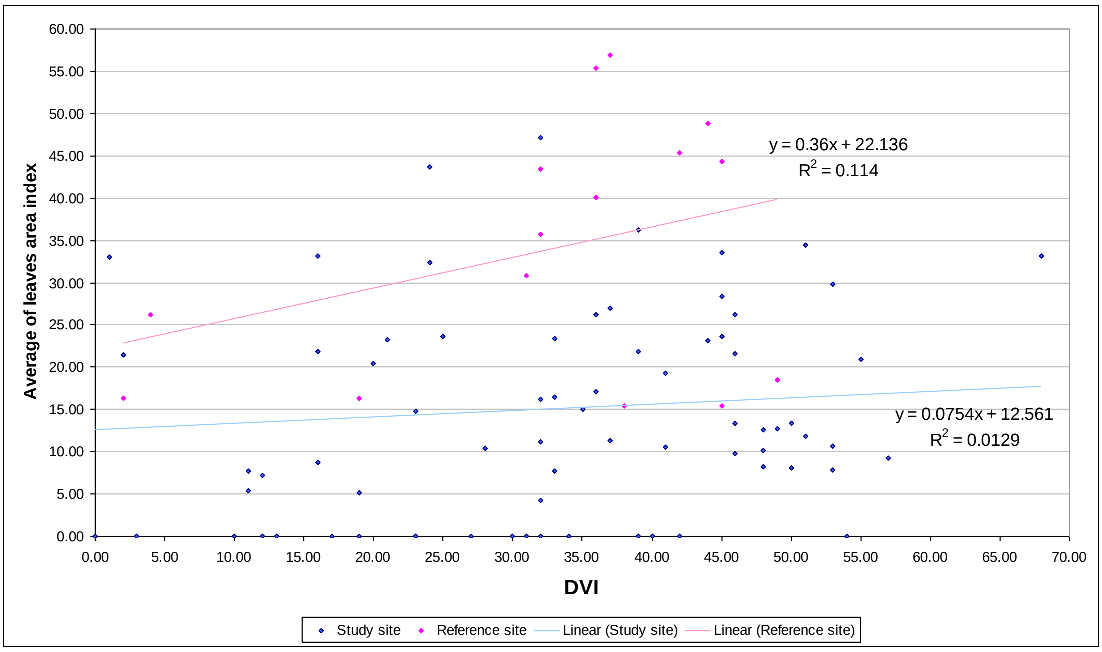

Figure D-16 Relationship between DVI and LAI of THEOS satellite image by the linear model

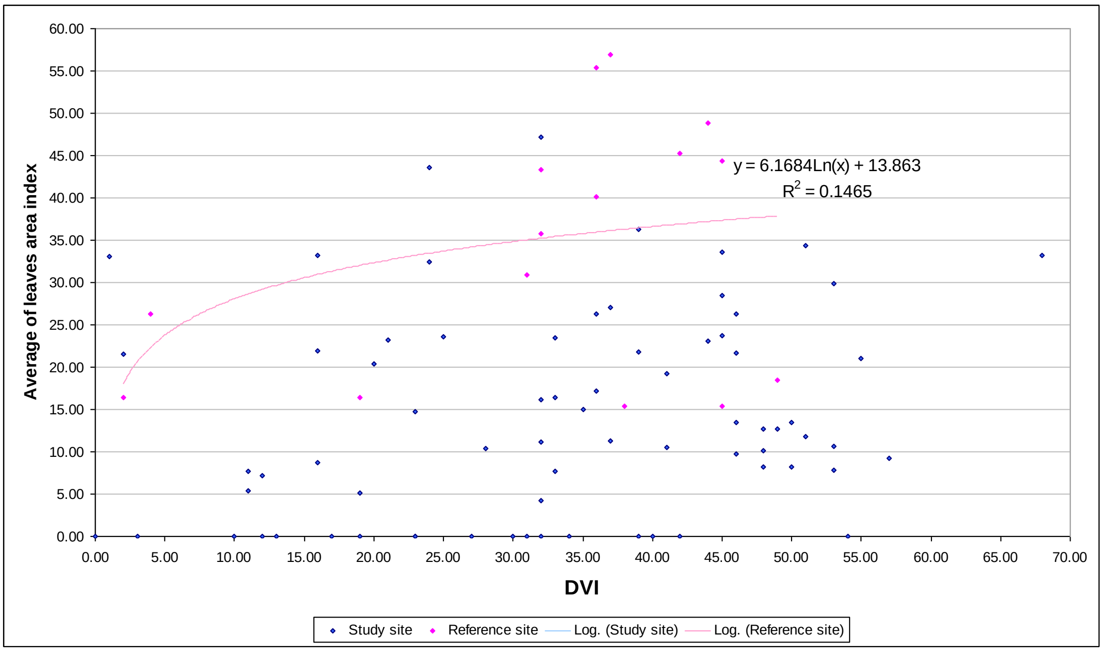

Figure D-17 Relationship between DVI and LAI of THEOS satellite image by the logarithmic model

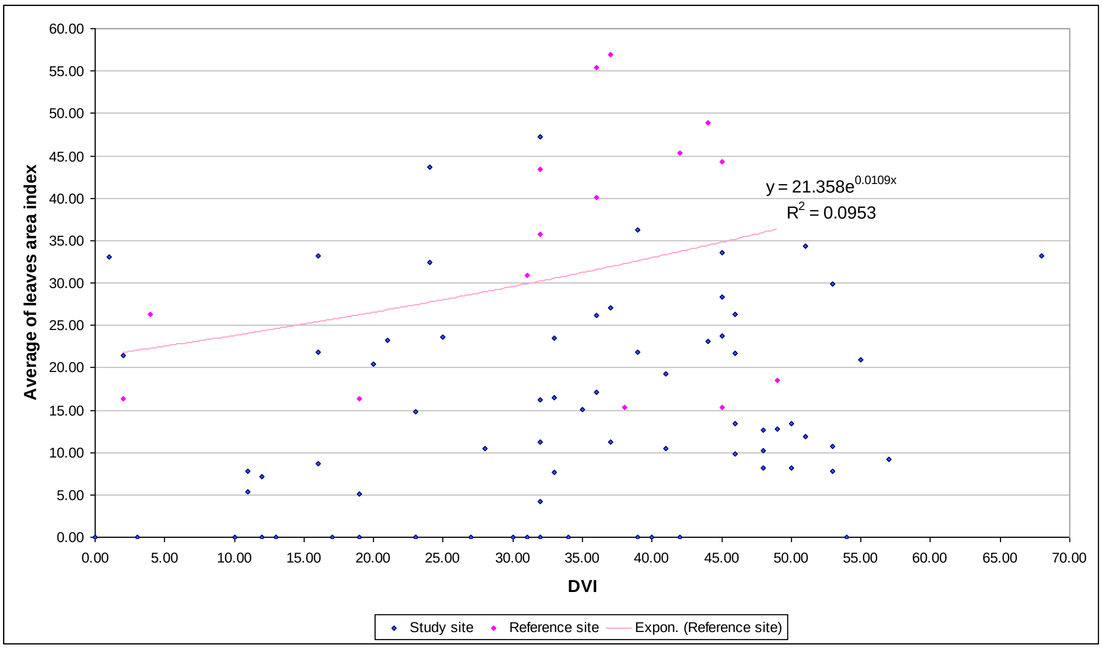

Figure D-18 Relationship between DVI and LAI of THEOS satellite image by the Exponential model

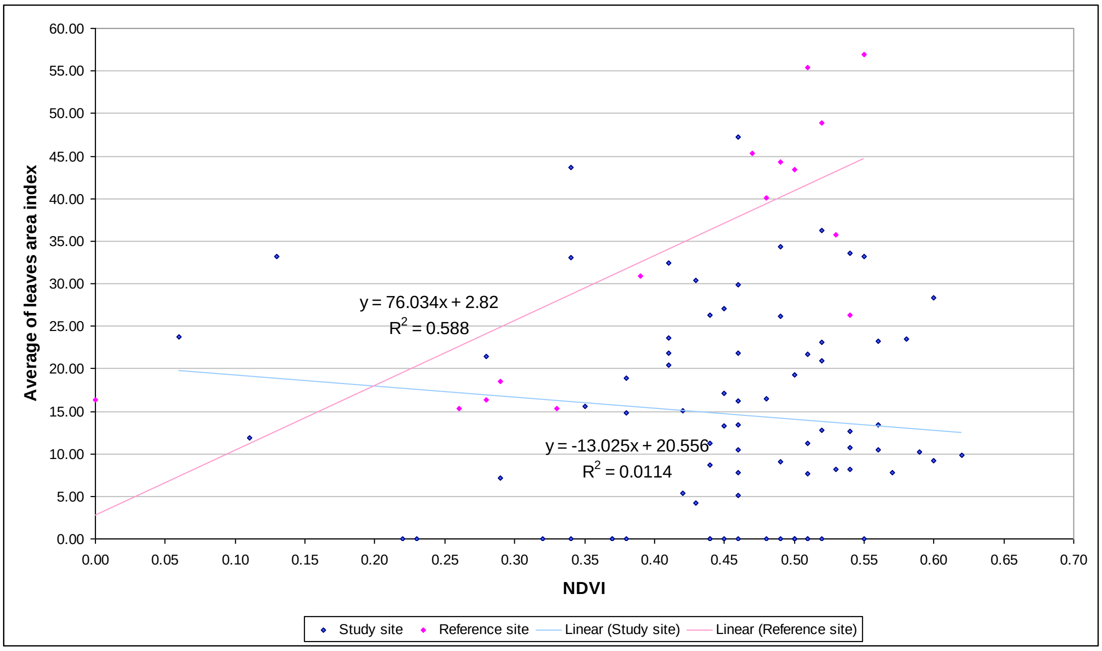

Figure D-19 Relationship between NDVI and LAI of Quickbird satellite image by the linear model

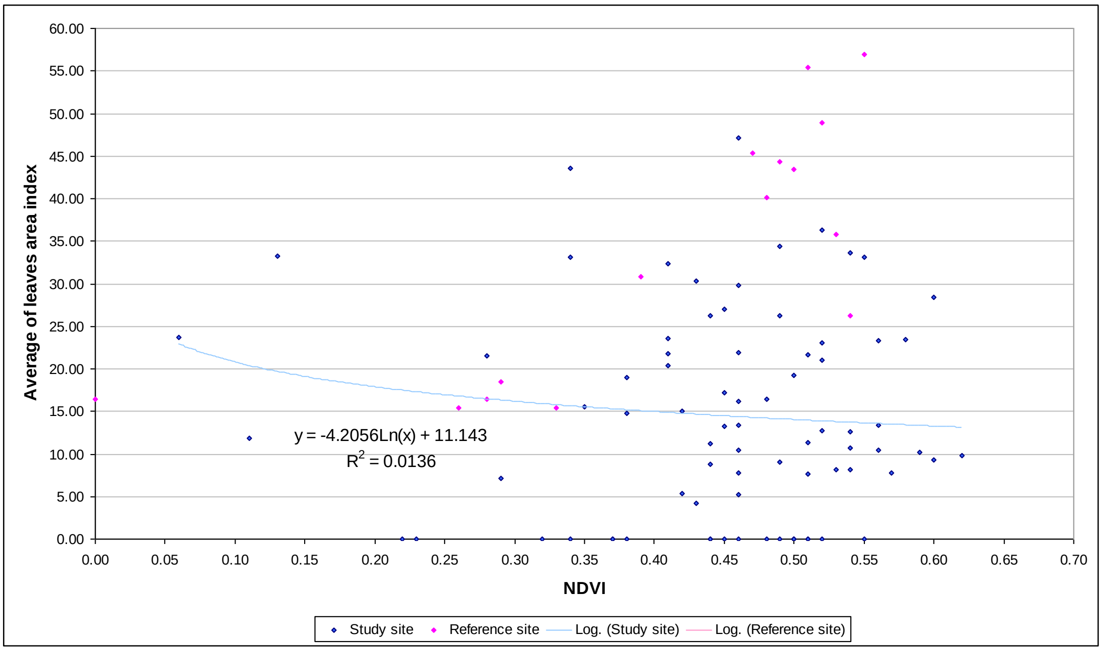

Figure D-20 Relationship between NDVI and LAI of Quickbird satellite image by the Logarithmic model

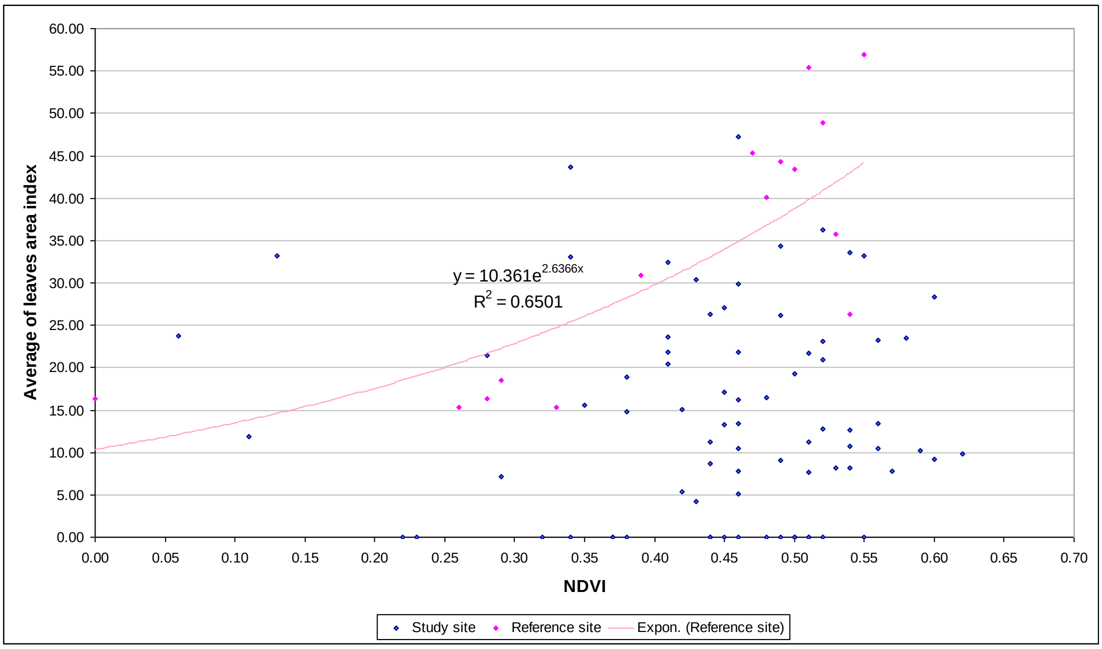

Figure D-21 Relationship between NDVI and LAI of Quickbird satellite image by the Exponential model

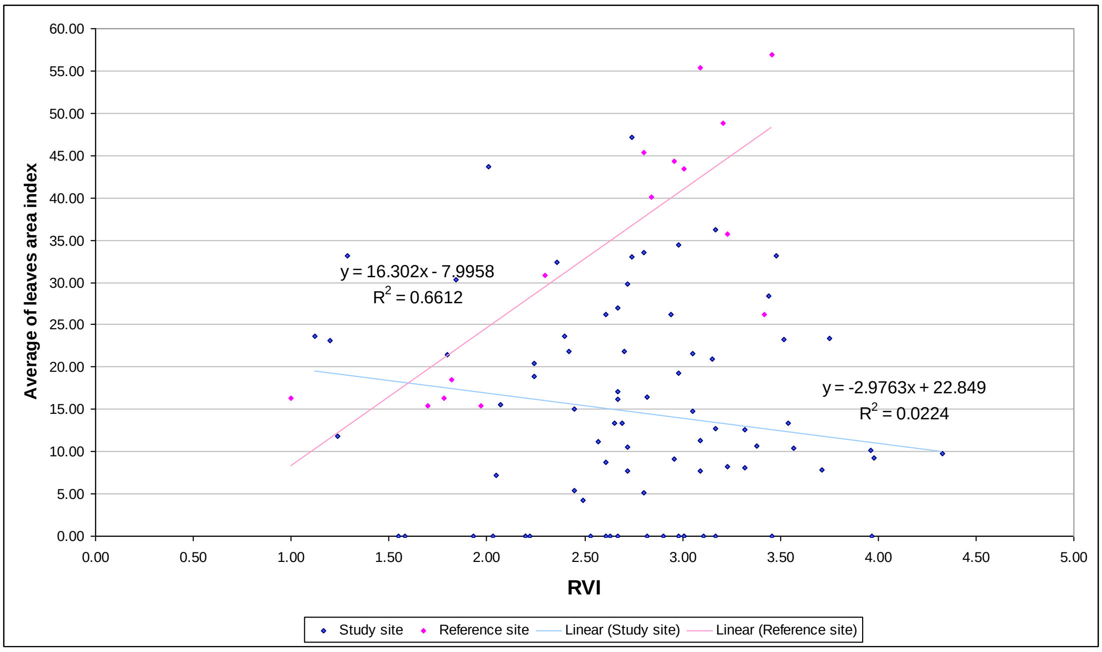

Figure D-22 Relationship between RVI and LAI of Quickbird satellite image by the linear model

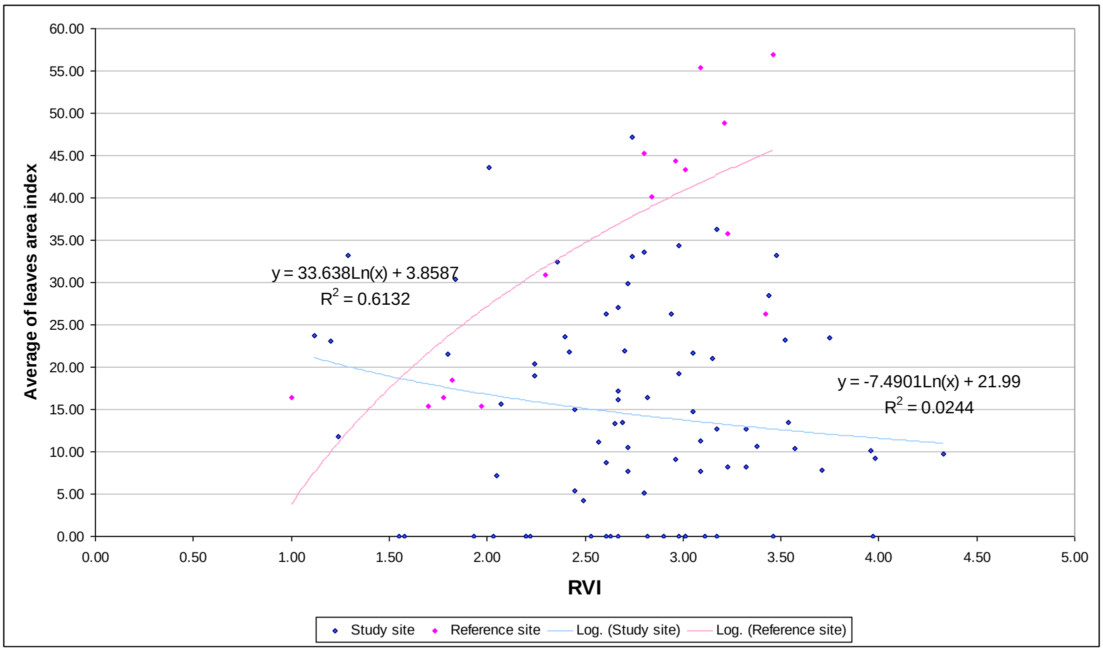

Figure D-23 Relationship between RVI and LAI of Quickbird satellite image by the Exponential model

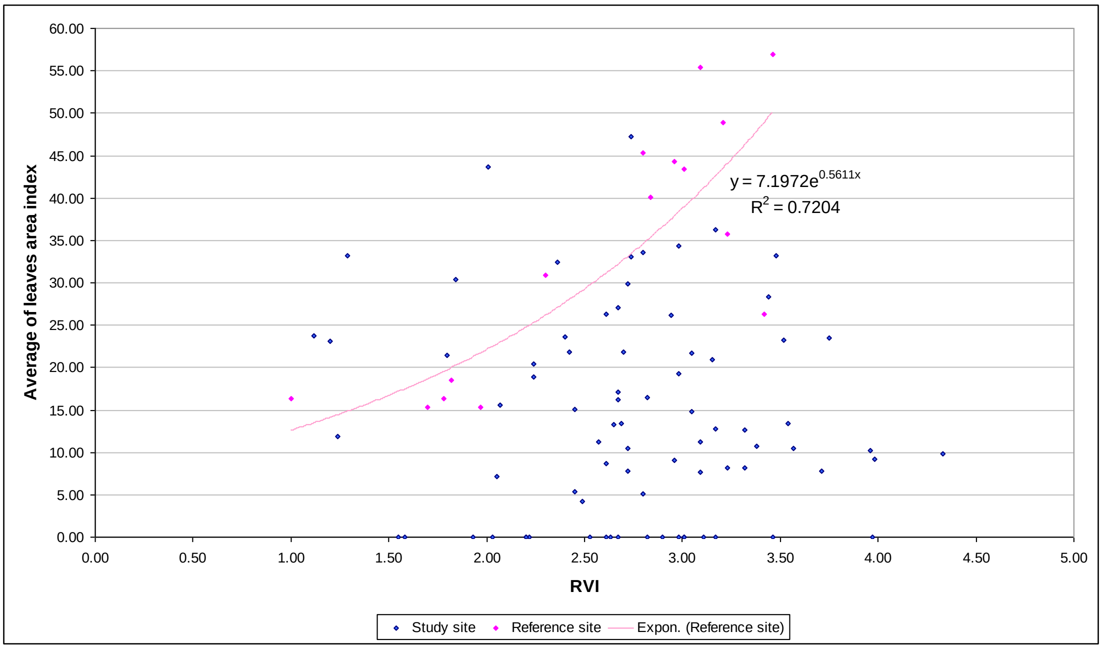

Figure D-24 Relationship between RVI and LAI of Quickbird satellite image by the Exponential model

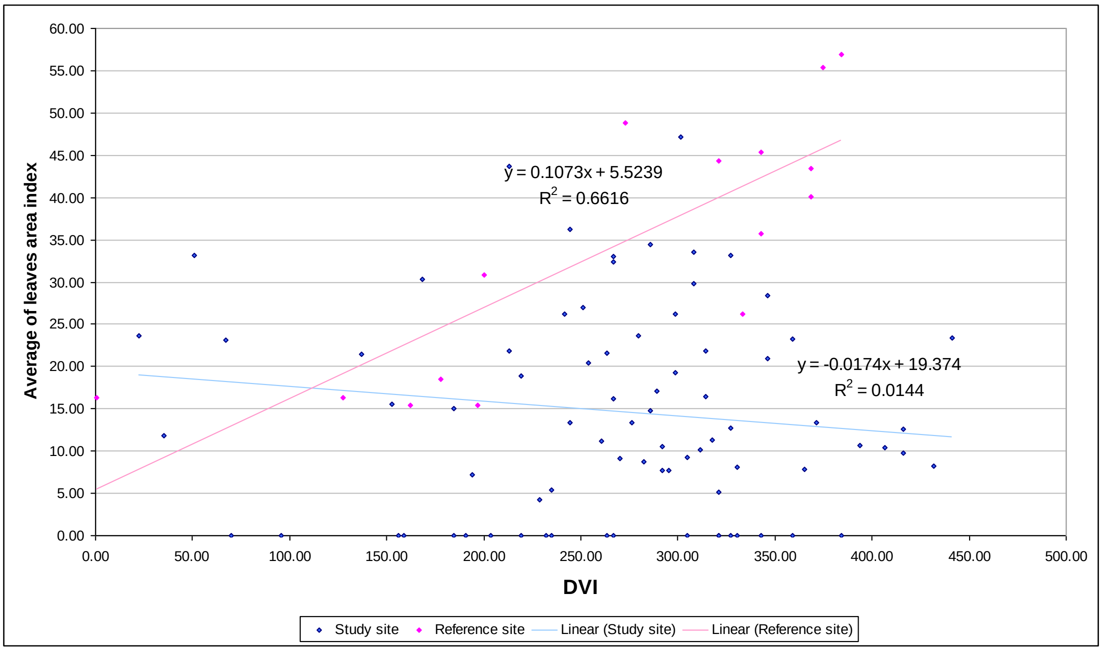

Figure D-25 Relationship between DVI and LAI of Quickbird satellite image by the linear model

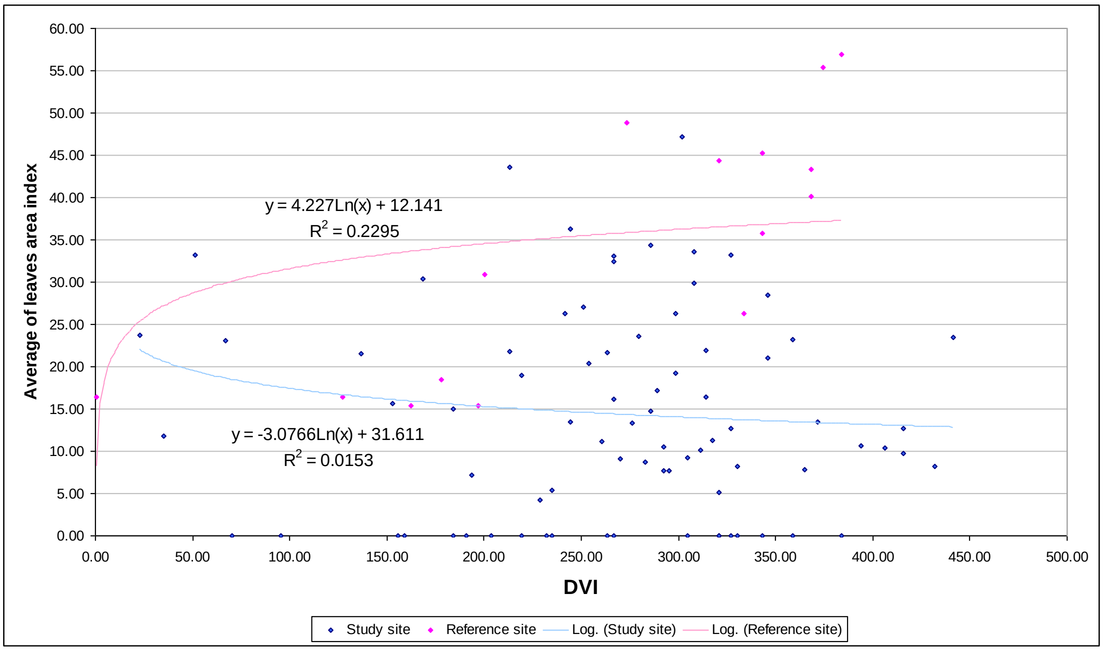

Figure D-26 Relationship between DVI and LAI of Quickbird satellite image by the logarithmic model

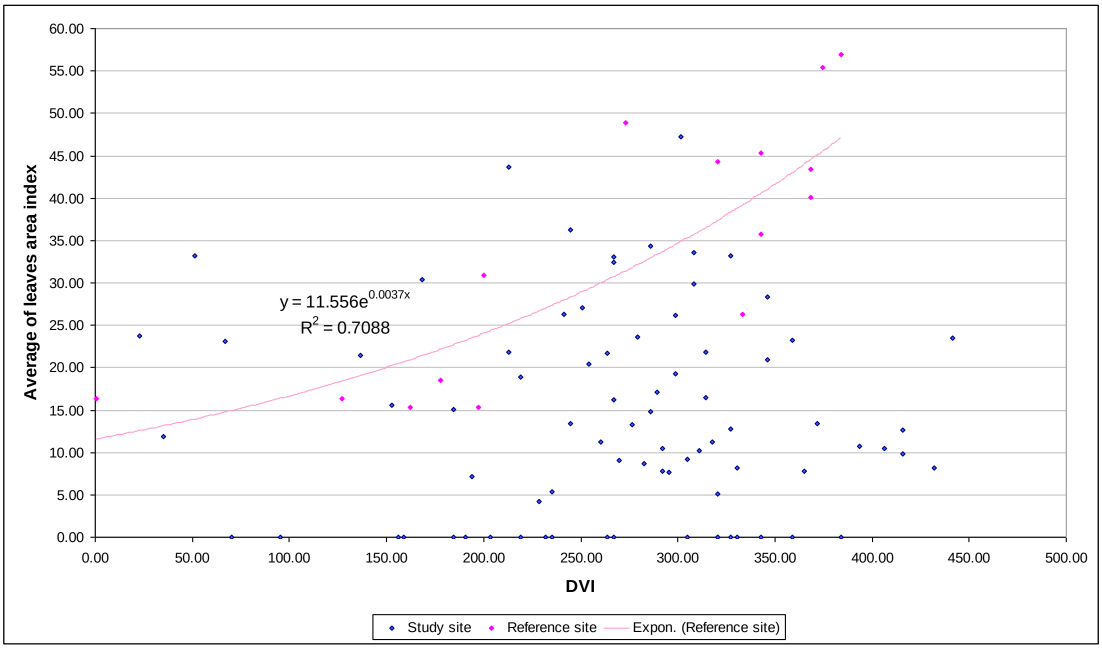

Figure D-27 Relationship between DVI and LAI of Quickbird satellite image by the Exponential model

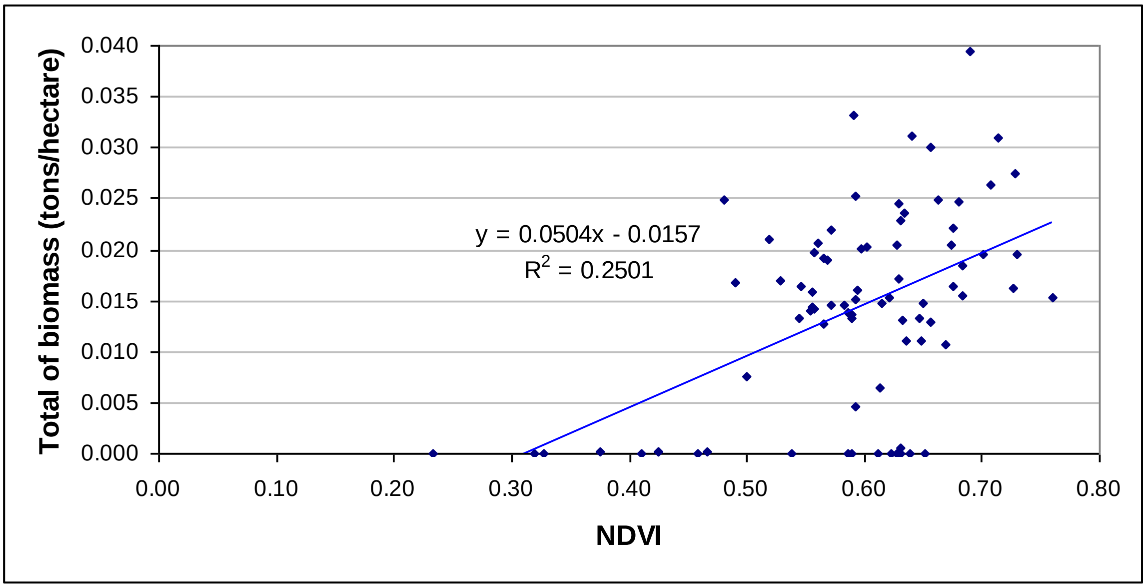

Figure D-28 Relationship between NDVI and Total of biomass of LANDSAT satellite image by the linear model in study site

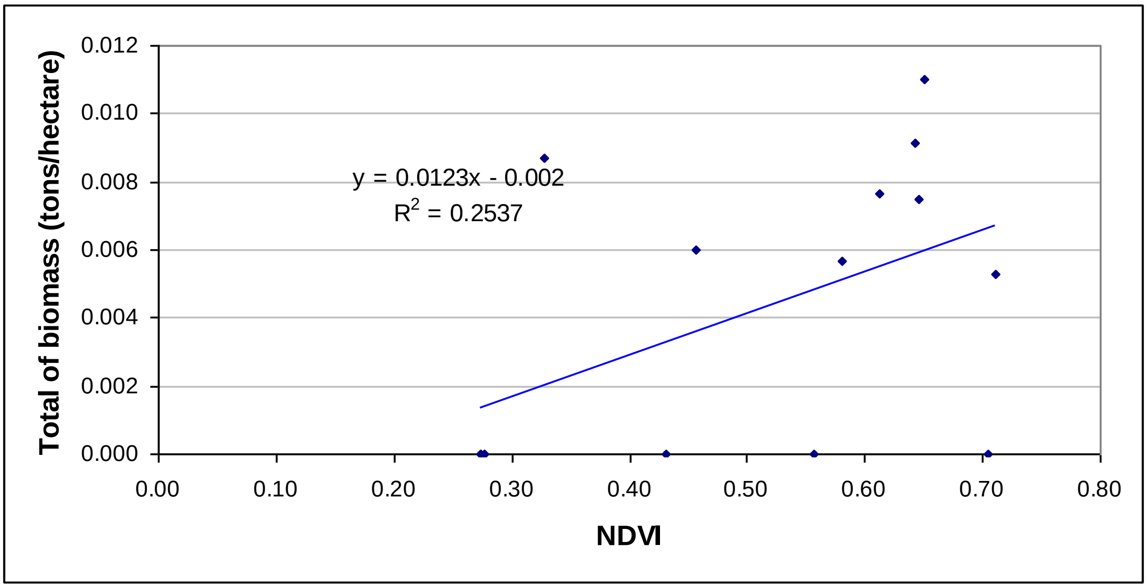

Figure D-29 Relationship between NDVI and Total of biomass of LANDSAT satellite image by the linear model in reference site

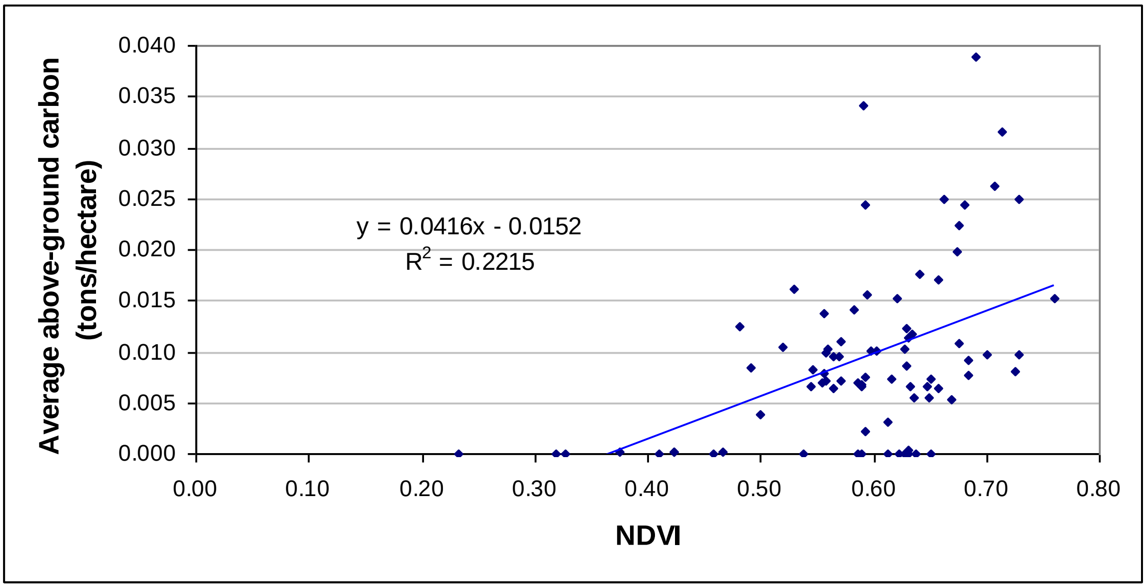

Figure D-30 Relationship between NDVI and Above ground carbon of LANDSAT satellite image by the linear model in study site

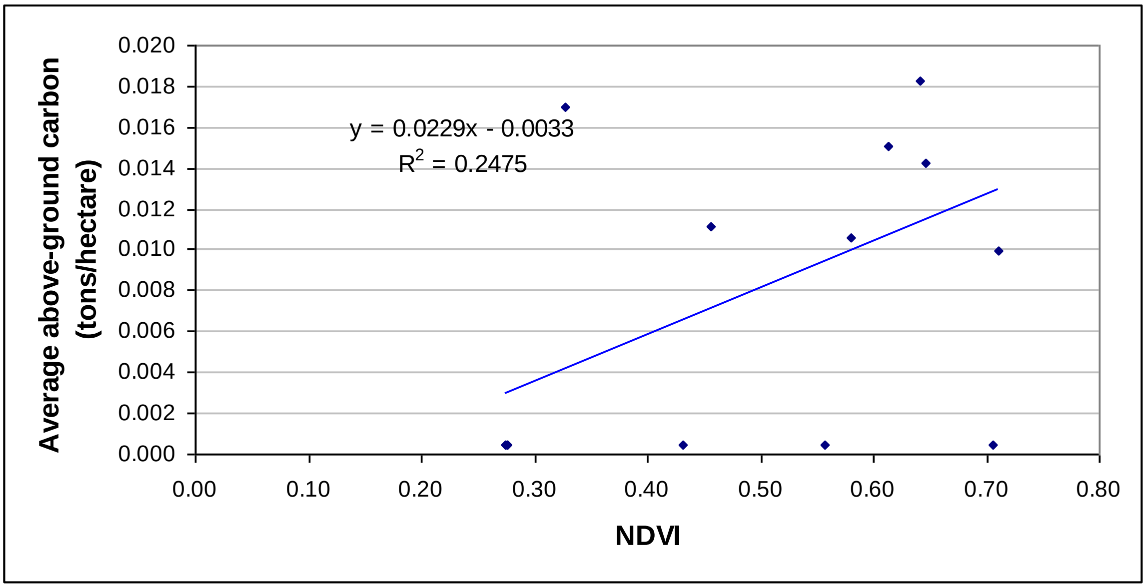

Figure D-31 Relationship between NDVI and Above ground carbon of LANDSAT satellite image by the linear model in reference

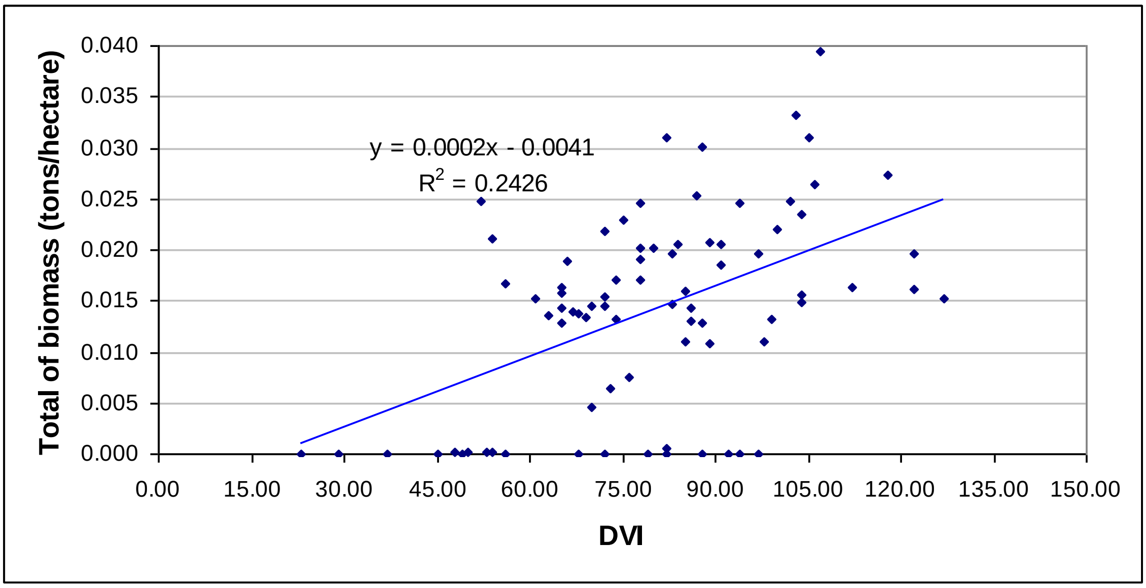

Figure D-32 Relationship between DVI and total biomass of LANDSAT satellite image by the linear model in study site

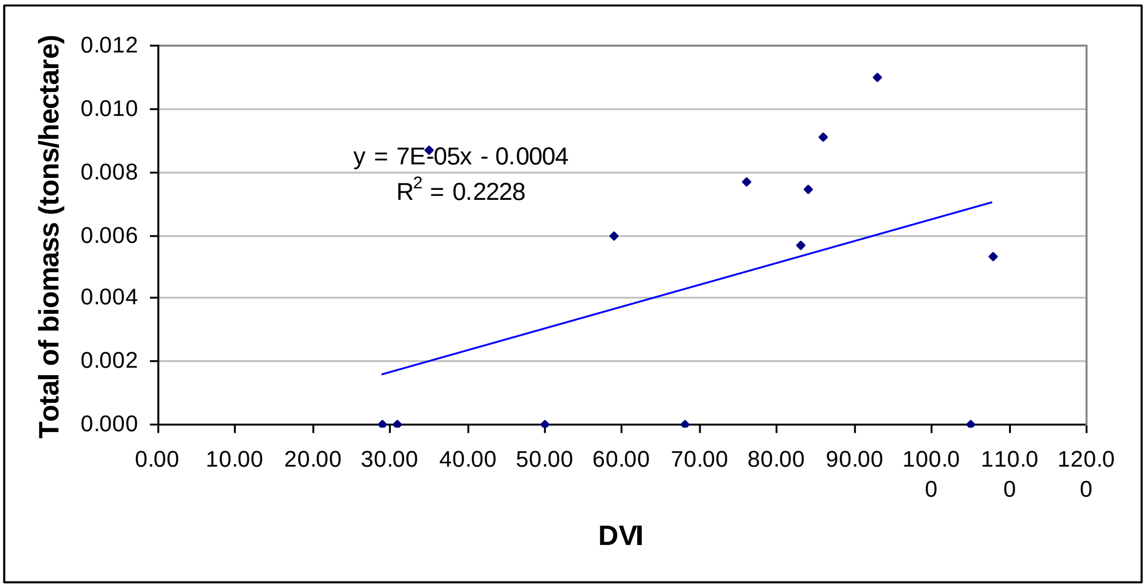

Figure D-33 Relationship between DVI and total biomass of LANDSAT satellite image by the linear model in reference site

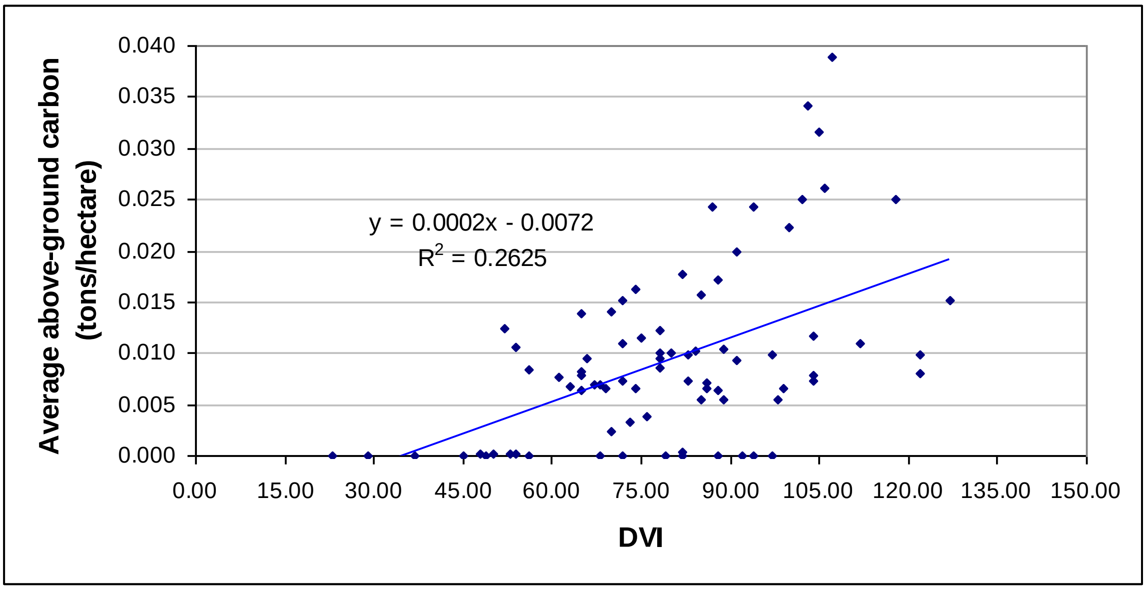

Figure D-34 Relationship between DVI and total biomass of LANDSAT satellite image by the linear model in study site

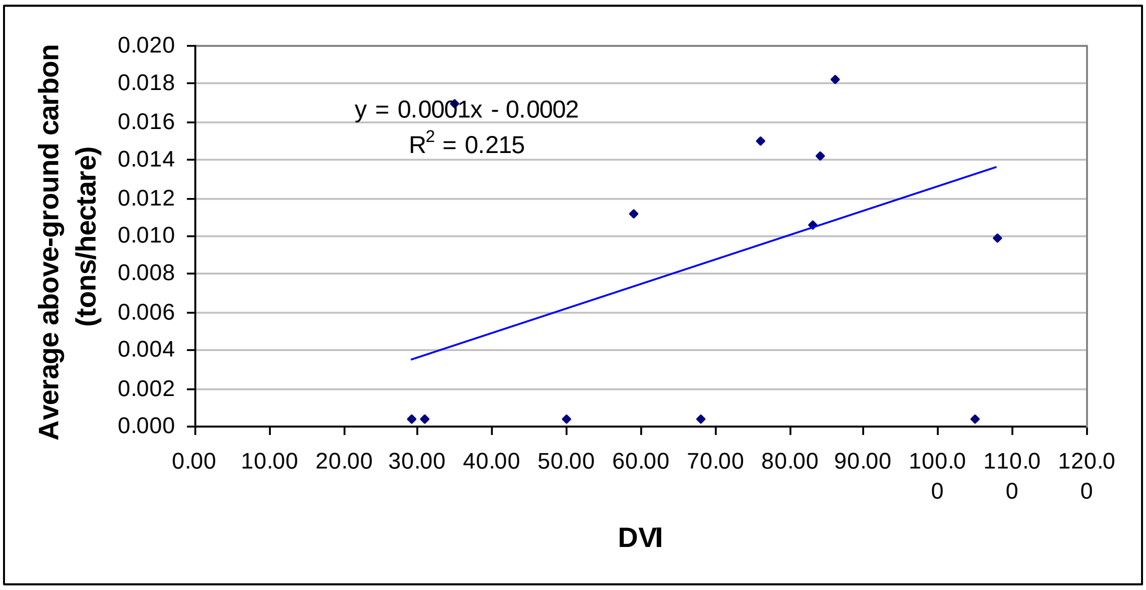

Figure D-35 Relationship between DVI and total biomass of LANDSAT satellite image by the linear model in reference site

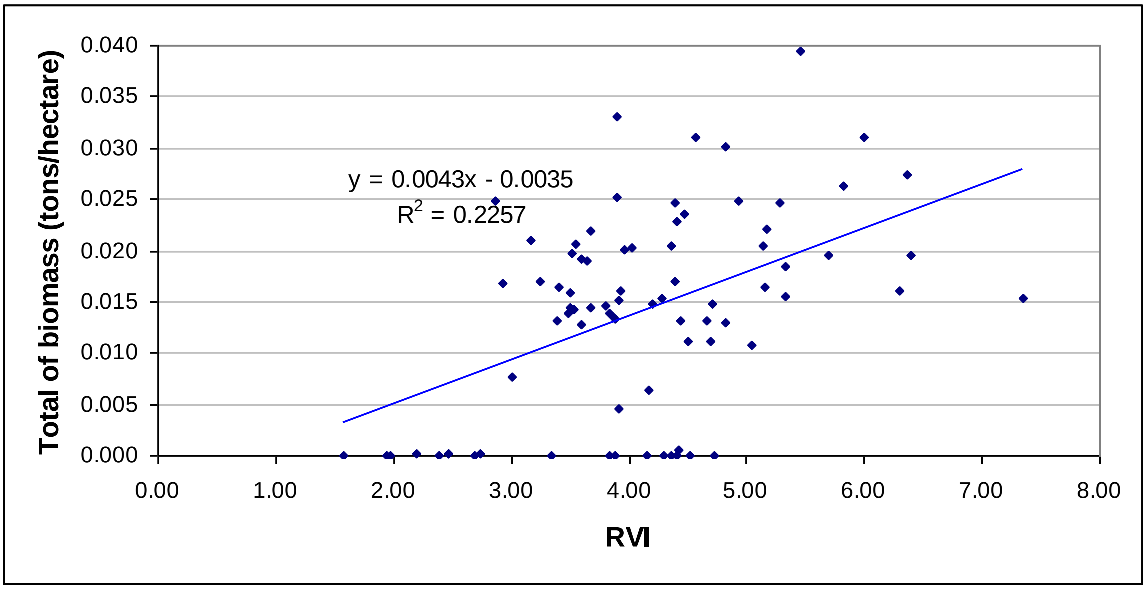

Figure D-36 Relationship between RVI and total biomass of LANDSAT satellite image by the linear model in study site

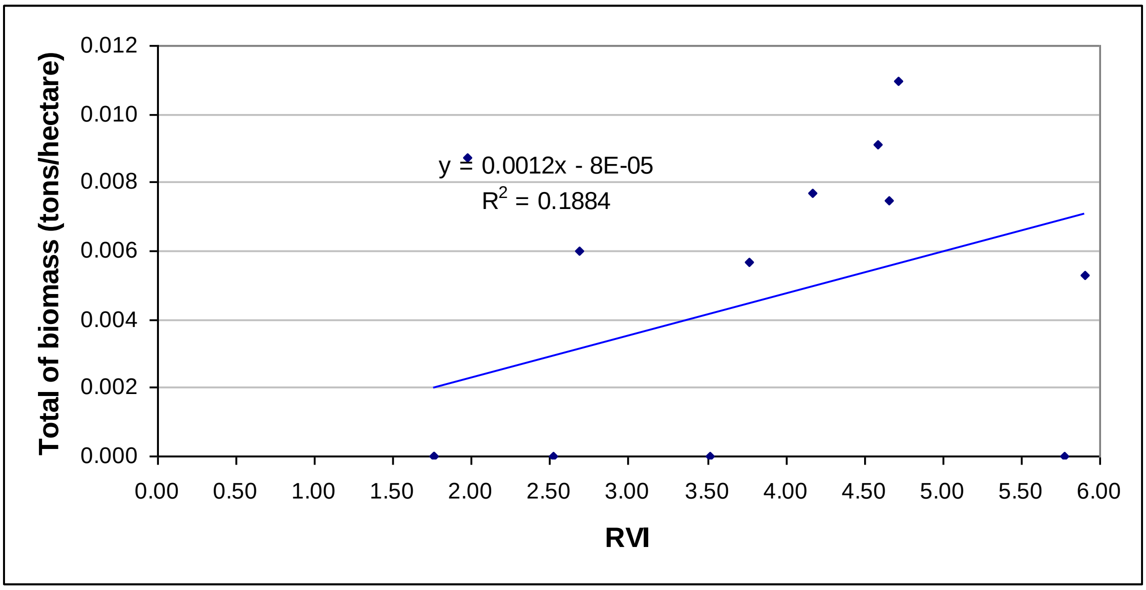

Figure D-37 Relationship between RVI and total biomass of LANDSAT satellite image by the linear model in reference site

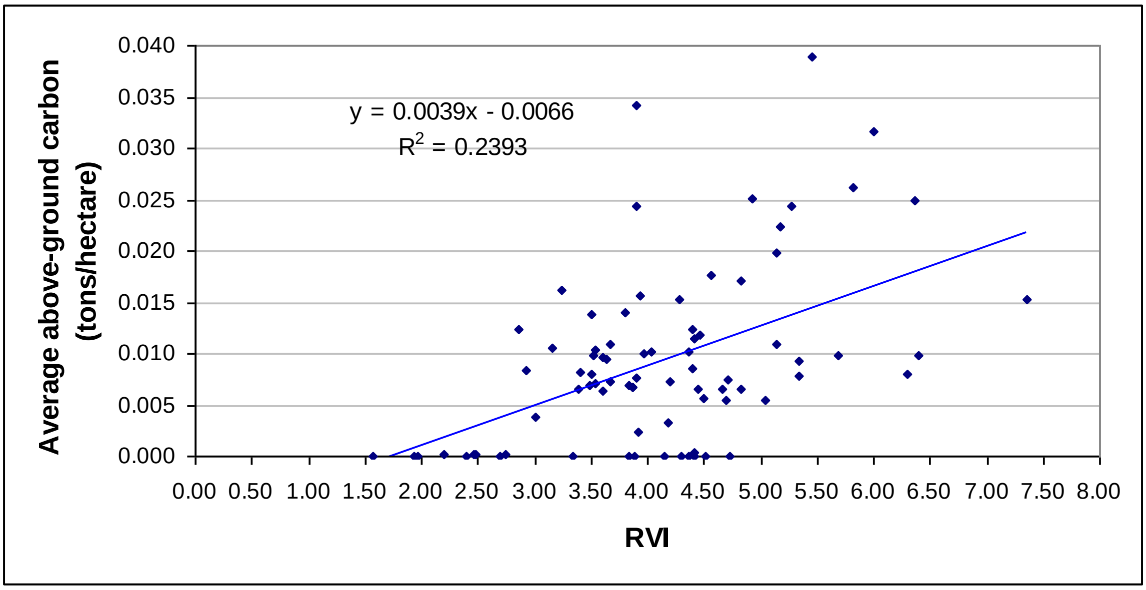

Figure D-38 Relationship between RVI and above ground carbon of LANDSAT satellite image by the linear model in study site

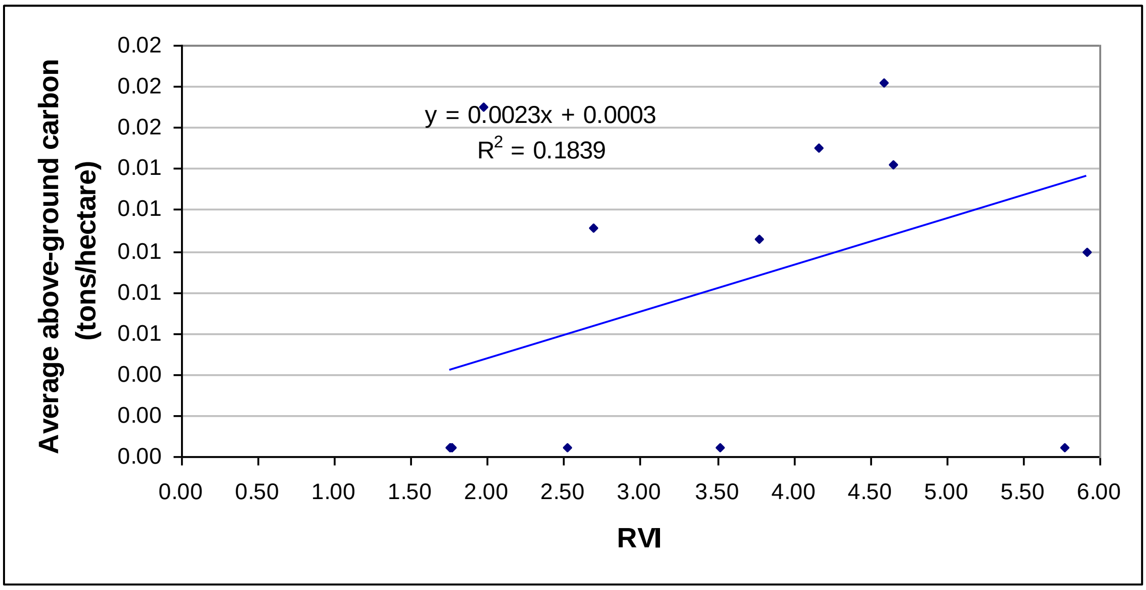

Figure D-39 Relationship between RVI and above ground carbon of LANDSAT satellite image by the linear model in reference site

APPENDIX E

Table E-1 Soil Organic Carbon Models

Sites	Parameter Relationships	Linear Model quations	R2	Logarithmic Model quations	R2	Exponential Model quations	R2
study site	pH sed-O.M. sed	=-4.1637x+36.696	.6044	=-29.038Ln(x)+63.943	.5778	$=4398.9e^{-0.9138x}$	.5203
	pH sed-O.C. sed	=-2.7481x+24.154	.6089	=-19.175Ln(x)+42.155	.5827	$=3236.1e^{-0.9314x}$	.5222
	pH sed-SOC	=-0.2452x+2.1895	.5687	=-1.7166Ln(x)+3.8074	.5480	$=113.24e^{-0.7874x}$	.5086
	O.M. sed-O.C. sed	=0.6571x-0.0491	.9988	=2.3912Ln(x)-0.639	.9742	$=0.8569e^{0.2284x}$	.9011
	O.M. sed -SOC	=0.0536x+0.0601	.7799	=0.2225Ln(x)+0.0138	.7518	$=0.1146e^{0.1817x}$	.7765
	O.C. sed -SOC	=0.0819x+0.0628	.7875	=0.2195Ln(x)+0.1146	.7572	$=0.1161e^{0.2766x}$	.7785
reference site	pH sed-O.M. sed	=-2.5722x+24.116	.0267	=-2.5722Ln(x)+24.116	.0267	$=2453.4e^{-0.8248x}$	.0362
	pH sed-O.C. sed	=-1.8934x+17.409	.0325	=-14.654Ln(x)+32.741	.032	$=2043.3e^{-0.8566x}$	.0372
	pH sed-SOC	=0.081x-0.4013	.0074	=0.6408Ln(x)-1.0861	.0076	$=0.0367e^{0.232x}$	.0032
	O.M. sed-O.C. sed	=0.661x-0.0427	.9843	=2.6334Ln(x)-0.4628	.8974	$=0.8265e^{0.2788x}$	.9781
	O.M. sed -SOC	=0.0543x+0.0134	.8200	=0.1912Ln(x)-0.0287	.7708	$=0.0848e^{0.2427x}$	.8566
	O.C. sed -SOC	=0.0807x+0.0206	.8048	=0.1861Ln(x)+0.0585	.7660	$=0.0872e^{0.3625x}$	.8493

Table E-2 Soil Organic Carbon-Water quality parameters Models

Sites	Parameter Relationships	Linear Model equations	R2	Logarithmic Model equations	R2	Exponential Model equations	R2
Study Site 1	BOD-SOC	= 0.0004x + 0.3758	.0001	= -0.0459Ln(x) + 0.4536	.0179	$= 0.3474e^{-0.0052x}$	.0014
	Conductivity-SOC	= 0.0037x + 0.1934	.0272	= 0.1141Ln(x) - 0.0661	.0134	$= 0.1844e^{0.0121x}$	.0251
	O-SOC	= -0.0005x + 0.3795	E-05	= 0.0066Ln(x) + 0.3738	.0006	$= 0.312e^{0.0329x}$	.0072
	pH water-SOC	= 0.1053x - 0.44	.0153	= 0.8427Ln(x) - 1.3494	.0160	$= 0.0076e^{0.4879x}$	.0285
	Salinity-SOC	= 0.0019x + 0.3215	.0047	= 0.0044Ln(x) + 0.3636	E-05	$= 0.2831e^{0.0059x}$	.0038
	Temperature-SOC	= -0.0278x + 1.2756	.0517	= -0.9158Ln(x) + 3.5578	.0535	$= 6.7415e^{-0.093x}$	.0500
	TOC-SOC	= 0.0041x + 0.2909	.1401	= 0.1648Ln(x) - 0.1054	.2524	$= 0.2525e^{0.0135x}$	.1323
Reference Site 2	BOD-SOC	= 0.0033x + 0.2063	.0174	= 0.0429Ln(x) + 0.1455	.0419	$= 0.2009e^{0.0146x}$	.0181
	Conductivity-SOC	= 0.0073x - 0.1598	.4992	= 0.421Ln(x) - 1.4448	.5289	$= 0.0405e^{0.0318x}$	.5002
	DO-SOC	= -0.0201x + 0.3073	.2847	= -0.0748Ln(x) + 0.3249	.2832	$= 0.3181e^{-0.0922x}$	.3116
	pH water-SOC	= -0.1976x + 1.7935	.2196	= -1.5611Ln(x) + 3.4587	.2167	$= 572.66e^{-0.9922x}$	.2893
	Salinity-SOC	= 0.0212x - 0.4298	.4570	= 0.6872Ln(x) - 2.1329	.4701	$= 0.0125e^{0.0925x}$	.4558
	Temperature-SOC	= -0.0347x + 1.3009	.1454	= -1.0695Ln(x) + 3.8983	.1445	$= 38.094e^{-0.1664x}$	.1750
	OC-SOC	= 0.0049x + 0.1438	.2229	= 0.0983Ln(x) - 0.0486	.2543	$= 0.159e^{0.0193x}$	.1826

Table E-3 Total Organic Carbon-Water quality parameters Models

Sites	arameter elationships	Linear Model equations	R2	Logarithmic Model equations	R2	Exponential Model equations	E2
Study Site 1	BOD-TOC	= -0.1265x + 22.215	.0011	= -1.0987Ln(x) + 23.28	.0012	$= 18.823e^{-5E-06x}$	E-09
	Conductivity-TOC	= 0.1191x + 15.548	.0033	= 2.3431Ln(x) + 12.35	.0007	$= 12.254e^{0.0086x}$	.0158
	DO-TOC	= -0.2664x + 22.104	.0006	= 0.5166Ln(x) + 21.119	.0004	$= 18.428e^{0.0091x}$	.0007
	pH water-TOC	= 12.119x - 72.717	.0241	= 96.179Ln(x) - 175.72	.0248	$= 0.2452e^{0.5585x}$	.0464
	Salinity-TOC	= -0.0706x + 23.58	.0008	= -2.805Ln(x) + 30.921	.0026	$= 18.59e^{0.0004x}$	E-05
	Temperature-TOC	= -1.0478x + 55.241	.0087	= -35.097Ln(x) + 143.33	.0093	$= 122.75e^{-0.0582x}$	.0243
Reference Site 2	BOD-TOC	= 1.1259x + 9.3493	.2184	= 9.2521Ln(x) - 0.5238	.2066	$= 10.982e^{0.0589x}$	.2140
	Conductivity-TOC	= 0.2874x + 2.5182	.0830	= 16.328Ln(x) - 47.018	.0845	$= 6.9338e^{0.0169x}$	.1031
	DO-TOC	= -0.5195x + 19.954	.0201	= -1.4148Ln(x) + 19.766	.0108	$= 20.112e^{-0.0405x}$	.0437
	pH water-TOC	= -2.4033x + 36.995	.0034	= -17.054Ln(x) + 53.254	.0027	$= 225.7e^{-0.3252x}$	.0226
	Salinity-TOC	= 0.6623x - 2.6971	.0475	= 20.933Ln(x) - 54.018	.0463	$= 5.0493e^{0.0394x}$	.0600
	Temperature-TOC	= -0.678x + 38.908	.0059	= -20.368Ln(x) + 87.831	.0056	$= 46.748e^{-0.0323x}$	.0048

Table E-4 Plant Models

Plants	Parameter Relationships	Linear Model equations	R2	Logarithmic Model equations	R2	Exponential Model equations	R2
Avicennia marina[1]	^{D2}H- W_B (g)	= 13.29x + 295.29	.8887	= 518.58Ln(x) - 984.27	.9679	= $373.48e^{0.0176x}$	.7459
	^{D2}H- W_L (g)	= 13.55x + 96.576	.9524	= 511.86Ln(x) - 1151.8	.9700	= $218.23e^{0.023x}$	.8350
	^{D2}H- W_T (g)	= 71.341x - 508.76	.9108	= 2451.4Ln(x) - 6269.1	.7692	= $502.11e^{0.0303x}$	.8065
	^{D2}H-Total leaf area (sqm)	= 0.0562x + 0.865	.8866	= 2.2034Ln(x) - 4.5814	.9753	= $1.2067e^{0.0206x}$	.7112
	Total leaf are (sq.m)-Dry weight (kg)	= 0.0871x - 0.0046	.9023	== 0.1493Ln(x) + 0.0753	.9387	= $0.0421e^{0.666x}$	.7820
Rhizophora mucronata[2]	^{D2}H- W_B (g)	= 16.656x + 85.953	.9567	= 275.99Ln(x) - 386.14	.9745	= $157.6e^{0.0467x}$	.8880
	^{D2}H- W_L (g)	= 27.005x - 10.042	.8829	= 448.74Ln(x) - 778.72	.9044	= $131.18e^{0.0656x}$	.7968
	^{D2}H- W_R (g)	= 50.627x + 154.86	.9563	= 830.83Ln(x) - 1259.6	.9855	= $395.77e^{0.0513x}$	.9229
	^{D2}H- W_T (g)	= 12.813x + 360.32	.9565	= 214.1Ln(x) - 7.4287	.9909	= $390.58e^{0.0223x}$	.9174
	^{D2}H-Total leaf area (sq.m)	= 0.1068x - 0.2276	.9720	= 1.6692Ln(x) - 2.9981	.8803	= $0.4583e^{0.0652x}$	.9934
	Total leaf are (sq.m)-Dry weight (kg)	= 0.1066x + 0.0877	.8320	= 0.4511Ln(x) - 0.0738	.9183	= $0.1974e^{0.2228x}$	.7664

Remarks: [1] N=6 , [2] N= 6, W_S = weight of trunks, W_L = weight of leaves, W_B = weight of branches, W_R = weight of roots,

W_T = weight of total

Table E-5 Vegetation Indexes-LAI Plant Models in study site.

Remote Satellite	Parameter Relationships	Linear Model		Logarithmic Model		Exponential Model	
		Equations	**R2**	**Equations**	**R2**	**Equations**	**2**
LANDSAT	NDVI-LAI	Y=24.599x+0.2272	0.032	Y=14.319ln(x)+22.533	0.0445	-	-
	DVI-LAI	Y=0.0678x+9.3478	0.0115	Y=6.8016ln(x)-14.743	0.0243	-	-
	RVI-LAI	Y=1.2305x+9.6746	0.01	Y=7.1532ln(x)+4.8833	0.0232	-	-
THEOS	NDVI-LAI	Y=3.1242x+14.174	0.0012	-	-	-	-
	DVI-LAI	Y=0.075x+12.561	0.0129	-	-	-	-
	RVI-LAI	Y=4.5765x+8.0879	0.0122	Y=4.4973ln(x)+13.188	0.0075	-	-
QUICKBIRD	NDVI-LAI	Y=-13.025x+20.556	0.0114	Y=-4.2056ln(x)+11.143	0.0136	-	-
	DVI-LAI	Y=0.0174+19.374	0.0144	Y=-3.0766ln(x)+31.611	0.0153	-	-
	RVI-LAI	Y=-2.9763x+22.849	0.0224	Y=-7.4901ln(x)+21.99	0.0244	-	-

APPENDIX F

Table F-1 Soil pH rating of United States Department of Agriculture, Soil Survey Investigations

Soil pH (H_2O 1:1)Range	**Rating**
<4.5	extremely acid
4.5-5.0	very strongly acid
5.1-5.5	strongly acid
5.6-6.0	moderately acid
6.1-6.5	slightly acid
6.6-7.3	near neutral
7.4-7.8	slightly alkali
7.9-8.4	moderately alkali
8.5-9.0	strongly alkali
>9.0	extremely alkali

Reference: USDA (1995)

Table F-2 The percentage of Organic Matter Range rating of United States Department of Agriculture, Soil Survey Investigations

% Organic Matter Range	**Rating**
<0.5	very low
0.5-<1	low
1.0-<1.5	moderately low
1.5-<2.5	medium
2.5-<3.5	moderately high
3.5-4.5	high
>4.5	very high

Reference: USDA (1995)

Table F-3 Water quality standard for surface water sources (selected indicators base on study basis)

Water quality indicators	**Type I**[1]	**Type II**[2]	**Type III**[3]	**Type IV**[4]
Temperature (◦C)	N[5]	Higher than „N“ level but less than 3	Higher than „N“ level but less than 3	Higher than „N“ level but less than 3
Acidity and alkalinity (pH)	N	5-9	5-9	5-9
Salinity (ppt)	N	-	-	-
Conductivity (mS)	-[6]	-	-	-
Dissolved oxygen (mg / litre)	N	Less than 6	Less than 4	Less than 2

Source: Department of Water Quality Standard (1991)

Notes: 1) Type I means water quality in natural conditions and without wastewater contamination.

2) Type II means water quality, which was discharged from some activities. This type of water quality can be used in several purposes such as fisheries, water sports, aquatic animals reservation, and human utilities but process of wastewater treatment and water sterilization need to be applied.

3) Type III means water quality, which was discharged from some activities. This type of water quality can be used for purpose of agriculture, and human utilities. Wastewater treatment and water sterilization process need to be applied by using general method.

4) Type IV means water quality, which was discharged from some activities. This type of water quality can be used for purpose of industry activities, and human utilities. Wastewater treatment and water sterilization process need to be applied by using advance method.

5) N means natural water condition, which has not been affected from human activities.

6) Dash symbol means standard measurement has not been indicated.

Table F-4 Water quality standard for coastal areas (selected indicators base on study basis)

Water quality indicators	Type I[1]	Type II[2]	Type III[3]	Type IV[4]
Temperature (◦C)	N[5]	33	Less than 33	Less than 33
Acidity and alkalinity (pH)	N	7.5-8.9	7.0-8.5	7.0-8.5
Salinity (ppt)	N	29-35	Can be changed within 10 % from „N" level	Can be changed within 10 % from „N" level
Conductivity (mS)	-[6]	-	-	-
Dissolved oxygen (mg / litre)	N	Less than 4.0	Less than 4.0	Less than 4.0

Source: Department of Water Quality Standard (1991)

Notes: 1) Type I means quality of sea water for a purpose of natural conservation.

2) Type II means quality of sea water for a purpose of coral conservation

3) Type III means quality of sea water for a purpose of natural conservative areas (coral area is not included).

4) Type IV means quality of sea water for a purpose of coastal aquaculture

5) N means natural water condition, which has not been affected from human activities

6) Dash symbol means standard measurement has not been indicated

APPENDIX G

Table G-1 pH in sediment statistics values

Sites	Season	Mean	S.D.		.D.D		Sig.
Study site [1]	wet season	1.94	1.64	.91	5.46	.73	.000
	dry season	1.85	5.5				
Reference site [2]	wet season	.34	.40	.96	.05	.34	.010
	dry season	.38	.39				

Remarks: N^1= 80

N^2= 15

Table G-2 The percentage of Organic Matter (O.M.) in sediment statistics values

Sites	**Season**	**Mean**	**S.D.**		**.D.D**		**Sig.**
Study site [1]	wet season	.66	.80	.45	.90	4.40	.000
	dry season	.22	.44				
Reference site [2]	wet season	.55	.17	.07	.27	.27	.000
	dry season	.48	.12				

Remarks: N[1]= 80

N[2]= 15

Table G-3 The percentage of Organic Carbon (O.C.) in sediment statistics values

Sites	**Season**	**Mean**	**S.D.**		**.D.D**		**Sig.**
Study site [1]	wet season	.86	.62	.02	.57	.27	.000
	dry season	.84	.82				
Reference site [2]	wet season	.64	.68	.49	.88	.21	.000
	dry season	.59	.86				

Remarks: N[1]= 80

N[2]= 15

Table G-4 Soil Organic Carbon (SOC) (t ha^{-1}) statistics values

Sites	**Season**	**Mean**	**S.D.**		**.D.D**		**Sig.**
Study site [1]	wet season	.38	.16	.01	.06	.29	.000
	dry season	.37	.16				
Reference site [2]	wet season	.24	.06	.02	.05	.38	.189
	dry season	.22	.07				

Remarks: N[1]= 80

N[2]= 15

Table G-5 LAI Statistics values

Sites	Season	Mean	S.D.		.D.D		Sig.
Study site[1]	wet season	1.94	1.64	.91	5.46	.73	.000
	dry season	1.85	5.50				
Reference site[2]	wet season	.34	.40	.96	.05	.34	.010
	dry season	.38	.39				

Remarks: N[1]= 80

N[2]= 15

Table G-6 Above Ground Biomass (AGB) (t ha^{-1}) Statistics values

Sites	Season	Mean	S.D.		.D.D		Sig.
Study site [1]	wet season	02.30	21.33	04.63	83.50	.1	.000
	dry season	06.93	90.59				
Reference site [2]	wet season	7.68	0.560	5.18	8.21	.86	.013
	dry season	.50	.66				

Remarks: N[1]= 80

N[2]= 15

Table G-7 Above Ground Carbon (AGC) (t ha^{-1}) Statistics values

Sites	Season	Mean	S.D.	.D.D			Sig.
Study site [1]	wet season	1.15	0.67	04.63	83.50	.10	.000
	dry season	03.38	45.31				
Reference site [2]	wet season	3.84	5.28	2.23	1.77	.10	.013
	dry season	.24	.32				

Remarks: N[1]= 80

N[2]= 15

BIOGRAPHY

Miss Sureeporn Nipithwittaya was born on September 11, 1979 in Bangkok, Thailand. She obtained her B.Sc. in Geography from the faculty of Social Sciences, Srinaknarinwirot University in 2001. She graduated with a Master‘‘s degree in Environmental Sciences from environmental collage, Kasetsart University, Bangkok, Thailand in June 2004.

Publication in international presentation

1. Nipithwittaya S., Vaiphasa, C., Dowreang, D., Rungsipanich, A., Lawawirojwong, S., Anan, T. (2006). Advanced Remote Sensing Techniques for Detecting Degraded Tropical Forests. Proceedings of International Conference on Space Technology & Geo-Informatics 2006: on CD-ROM.