Risk Assessment on Landscape Development using Geographic Information System (GIS)

Mazlan Hashim (UTM) Toshinori Okuda (NIES)

Introduction

The minimal impact risk attributed due to landscape development to its ecological regime has been the main concern in supporting sustainable development. However, in the tropical regions, risk assessment on landscape development still perceived to have minimum impact, judging from the rate of conversion of forested areas to other uses (eg. Yoshida et al 2003, Pulzl and Rametsteiner 2002, Adger et al 1995, Bishop 1999, Peters et al 1989). The catalysts of these conversions are mainly attributed to the perception within the decision, policy makers and stakeholders that forested land can be of better economic value if converted to other uses, such as agricultural land or its related agro-related industries. Conversion to agricultural land to enable large scale plantation for industrial crop such oil palm is perceive a good option in most developing tropical countries, economically other than creating better employment opportunities compared to the productive forest. Pasoh

In the economical term, the market value of a land is determined by its size, location and the infrastructural facilities accessible. The potential changes due its utilization status also influence the current land value, i.e. maintaining a forest reserve within designated residential area is favorable to the current and future value and vice-versa, deforestation for industrial plant will definitely decrease the market value of the residential area but the land values remained intact and in fact would increase due to the fact that industrial and commercial zone are both occupying the top spots in the property market (DTM,2003; DSM,2003). Apart from economic value, the ecological service values which are inherent to any piece of land area were not at all equated in present market values. Worst still these ecological values are evaluated based on scientific method to benefits human (Constanza et al,1997; de Groot,1992; de Groot,1987) not widely known to political masters, decision makers and even majority of the stakeholders in tropical regions, where majority are found in the developing countries. In these regions, sustainable economy and its growth seems to be the paramount agenda compared to sustainable development (ADB,2004), although such a growth only achievable through sustainable land-related development.

Within this context, this project was formulated aimed at simulating the effect and risk of such changes undertaken in the landscape development. This study focuses on the risk assessment on landscape development using GIS approaches. The main research question is: can we use GIS to produce a simplified output communicable on PC-display for policy, decision and planners that are related directly on landscape development and management. Most of previous GIS-based studies for tropical ecological research have concentrated effort to assess risks of any disturbance of the environment to the flora and fauna (eg Macdonald and Rushton 2003, Bojorquez-Tapia et al 2002, Mladenoff and Baker, 1999). There is no single technique to using GIS for landscape risk assessment; in fact each study or case is very unique and different in so many respects.

Using Pasoh Forest Region (PFR) as study area, this study is a part of joint research between Japan and Malaysia scientists in understanding various issue related to tropical forest ecosystem (NIES, 2004). In essence, the overall scope of the study ranges from collection of data, analyzing data into information, and finally to deliver vital ecological information to decision makers pertaining to forest-related industries and management. Most importantly this information is conveyed in simple form, easy to understand together with the economic values for any decision on developing the land or changing it use. In order to meet management needs, the landscapes models are required in assess the effects of different management scenarios. These scenarios often require decision-making horizons spanning broad temporal and spatial scales. Often, simulation models are the only way to assess alternatives that cannot be tested under such real-world conditions. Subsequently, this report highlights the results of the works undertaken in EFF 2003 beginning January 4 till March 2004.

Material and methods

Study area

The study area is shown in Figure 1, with estimated area of $90x90km^2$, referred hereafter as Pasoh Forest Region (PFR). The 50ha and 6ha sampling plots for primary and secondary is also shown in Figure 1, respectively. Detailed descriptions of the study site can be found in Okuda et al (2003). Pilot watershed (refer Fig 1) was established to emulate risk within the limited EFF03 period, with an area of 12,788 hectares. The main land use compositions found in area is made of 54 % forested land (51 and 3 % for primary and secondary) and the remaining 45% agricultural land is the oil palm (28%) and rubber (13%) plantations. With such composition it is best effect to visualize the impact of assessment on development of forested area into plantations and vice-versa.

Method

Within this EFF03, Figure 2 summarized the processes involved in the methodology undertaken to risk assessment and it intended conceptual visualization of the final output. The parameters for manipulators and expected results within EFF03 period rather limited, i.e. the present status of landscape values were confined to timber and non-timber as forest resources; the choice of option is restricted to land use scheme; and the simulated results of the option confines to determine risk in carbon storage and soil erosion while the profits were counted for sales commercial timber and agricultural products in per given area per year. The entire tasks carried out can be categorized into 3 parts, as the followings.

The creation of spatial data base

Employing the spatial database developed for PRF (Yoshida et al, 2002; Adachi et al 2000), and additional spatial information from adjacent area of 600 km^2 were compiled. Bulk of the time taken to build this database to ensure watersheds within PRF can be extracted. Simulating option of land use within watershed in more meaningful for operational point of view, and importantly the results can be shared and understood by the management authorities where watersheds or their sub-watershed is the preferable unit used in analyzing risk.

Structure of simulation model
There are 4 parts for the simulation in this study, namely: (1) The option – three manipulative variables were set for the land use, i.e. agriculture, productive forest, or protective forest, (2) The present status – values are assigned to three parameters of the present status of the forest resources namely the present value[#] of commercial trees, non-timber and carbon sequestration; (3)The risk simulator (virtual on display) – within this the risk based on the difference between present status and the option chosen. The difference is then equated in term of cost for three variable sets[#] i.e. decrease in carbon storage, soil erosion and decrease in option values; and (4) The results of simulation – embedded in the display on cost of impact/risk, graphical plots of option costs compared to present value at per given time. The total economic values are also annotated for present year, short and long terms.

The absolute values any ecological services are very critical in making the results realistic as in real world. As guidelines to such approach, adaptations to special paper released by FAO (Bann, 98) and other related studies (Fearnside,1997; Torras,2000). Other relevant related reports (MPOB,2001) were used in this study. The ecological services focused for PRF are those related only forest resources, namely, commercial trees, non-timber products, land use, carbon sequestration, water holding capacity and biodiversity. Only first 4 ecological services are reported in this document.

Estimation of carbon storage
The carbon storage is estimated from total above ground biomass (TAGB). Apart from the conventional method for determining TAGB from in-situ tree census, this study also has emphasized to estimate TAGB from satellite remote sensing data. The Landsat Thematic Mapper (TM) and JERS-1 SAR[*] data were used in this study. Samples collected from in-situ measurement were used to establish correlation between TAGB and both the TM reflectance and radar backscatters[1] of the JERS-1 SAR data. These models would be useful in estimation the carbon for the entire designated forest compartment.

Two experimental plots established each representing primary and secondary forest. For each of the plot, detailed tree census at diameter breast height (dbh) of equal and more than 1 and 5cm were conducted. The area of primary and secondary plots is 50ha and 6 ha, respectively. In order to synthesize the tree census with information collected on raster-based satellite data, the TAGB derived from each individual trees are averaged at 4 different

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[#] the cost values for commercial trees, non-timber and carbon storage were set at US$229.45/ha/yr (Torras,2000), US$6.44/ha/yr (Torras,2000), and US$7.30/ha/yr (Fearnside,1997), respectively. The soil erosion is set at US$0.60/ton/yr (Torras, 2000) and oil palm is value at US$1647.15 /ton/yr (*MPOB annual report,2001*).

[*] JERS-1 SAR is an acronym for Japanese Earth Resource Satellite-1 (JERS-1) and its sensor known as Synthetic Aperture Radar (SAR).
[1] Reflectance is the percentage of reflected incidence ray by the surface within optical spectral range and radar backscatter is the term of radar responses from any objects or surface in the microwave spectral region.

mesh sizes, namely 10, 20, 50 and 100m. The SAR data were resampled to the four mesh sizes during geometric correction process. Although the JERS-1 SAR data resolution is 13x18m, the resampling of this data to the corresponding above 4 mesh sizes would give best opportunity to investigate on the spatial variations within biotic condition to the relationship of the radar backscatter and TAGB. Consequently, the carbon storage is estimated by multiplication of agreed factor, eg. 0.5 as coefficient for each of the mesh. At this stage of work, a multiplication factor of carbon from TAGB is under investigation, however, most practices reviewed in similar studies used 0.5 as a factor.

<u>Piloting simulation</u>

Simulating changes have been based on watershed, where the erosion risk yielding from variables set attributed due to land use options were based. The erosion risk has been based on the universal soil loss equation (USLE) (Morgan, 1974), given by:

$$A = R.K.LS.CP \qquad (1)$$

Where *A* is soil loss (ton/ha/yr), *R* is rainfall erosivity factor, *K* is soil erodibility factor, *L* is slope length factor, *S* is slope-steepness, *C is* cover management factor and *P* is erosion control practice factor.

The *CP* factor can be replaced by vegetation management factor, and for Peninsular Malaysia the values of CP classes found in PFR is tabulated in Table 1. Changing the use of land option reflects to simply change in the related CP values. To change the land use option, say for example from its present land use oil palm plantation to housing the value of resultant C*P would shift to 0.125 from 0.125 which means that tendency of erosion is lessen from its present land use. Within the confined watershed the total soil loss calculated per set given land option is therefore can be use as basis for landscape risk assessment.

The change in land use option also means the change in the density of TAGB in any selected area. Hence the carbon storage from its present status to new option of land use can be determined. The end product of simulation of options taken is translated to economic values (please refer section 3.2). The main issue in translating the risk assessment into economic values is in fact form a sensitive issues to related many parties, be it the policy, decision makers or the stakeholders. In this regards, the economical values presented in this report varies only relatively to simulating changes, and it absolute truth once the “agreed” values for each of the parameters were used. Spatial modeler of the GIS system is use to host such change scenarios. In this study the ArcView[2] GIS system was used, while the Erdas Imagine[3] Image Processing system is employed in processing satellite data for estimation of TAGB.

The *LS*, referred to as length slope factor combined the slope gradient and the length of eroding surface into a single factor. This is an overland flow path which is the distance from the start of overland flow to where it enters a major flow concentration. The modified equation for computation of the LS factor in GIS in finite difference form for erosion in a

[2] ArcView is a trademark for Environmental Systems Research Institute, Inc. USA.
[3] Erdas Imagine is a trademark for ERDAS, Inc. USA.

grid cell representing a hillslope segment was derived and simplified in this study based on Mitasova et al (1996). The continuous form of the equation used in computation of the *LS* factor at a point r=(*x*,*y*) on a hillslope, is given by

$$LS(\mathbf{r}) = (m+1)\ [\ A(\mathbf{r}) / a_0\ ]^m\ [\ \sin b(\mathbf{r}) / b_0\ ]^n \qquad (2)$$

where $A[m]$ is upslope contributing area per unit contour width, b [*deg*] is the slope, m and n are parameters, and a_0 = 22.1m is the length and b_0 = 0.09 = 9% = 5.16deg is the slope of the standard USLE plot. The LS itself has been argued in the usage of the USLE as an empirical method in predicting the erosion risk. Indeed, we realized that this is more crucial when come to forested area where the overland path flow is difficult to define. Another project attaching to the parent project focusing on this issue is described in Zulkifli (2004).

Results and discussions

<u>Total above ground biomass and carbon storage estimation</u>

Two types of satellite remote sensing data, acquired in visible and radar spectral wavelengths from Landsat TM and JERS-1 SAR systems, respectively. Within the ground leaving reflectance examined from TM data within the primary plot, there is no correlation of reflectance and TAGB. Apart from analyzing direct relationship of reflectance to the corresponding TAGB samples, various types of vegetation index were derived aiming at enhancing such correlations if exist through normalization of external effects. The forest canopy density (FCD) indicies (Rikimaru and Miyatake,1997) were also derived and its relationship to the corresponding TAGB samples were also analysed. Although FCD were found favorably sound for visualization of TM data in particular for monitoring the regeneration of tropical forests, they were found not correlated at all with TAGB. The reason for non-correlation is mainly due to fact that relatively matured growth which made of tall canopy as in this primary forest area, the TAGB is only partially contributed by the canopy which is “accessible” by reflectance but the majority part of it TAGB is inherent in the woody mass that made-up of the main structure in primary forest. The same is also valid for matured secondary forests (20 years or more) such as in this study where the average canopy height of more than 7m within 10x10m mesh sample and average TAGB of more than 1Mg/ha. Detailed discussion of reflectance-biomass relations within TM spectral bands is given in Hashim et al (2002) and Hashim et al (2003), hence is not pursued further in this report.

With regard to relationship of SAR data, the responses of JERS-1 SAR data to TAGB information analyzed were examined as the following approaches: (i) one-to-one relationship between SAR responses (the backscatter) to the corresponding TAGB, and (ii) grouped of radar backscatter classes against TAGB variations. For the first approaches both the primary and plots were analyzed and the results were tabulated in Table 2, while the second is given in Table 3, respectively.

The variations in mesh sizes (10, 20, 50 and 100m) used in the sampling for density of TAGB are meant for investigating the effect of the spatial variation (often associated with the pixel size) to the biomass-backscatter relationship. In this context, with one-to-one relationship analysed, the results indicated that there exist a spatial variation of both backscatters and TAGB within the samples. Within the secondary forest, the best relationship of radar backscatters and TAGB is observed in the 20m mesh size (see Table 1). Despite the low r^2 and insignificant probability (p>0.005), the 20m mesh indicated the highest score in both r^2 and p apart from the relatively sound statistical trend (see Figs 3, 4 and 5). From Table 2(a-b), it is clearly evident that 10m mesh might be an "over-sampling" of radar backscatters where the large variation of TAGB cannot be represented. Similarly, "under-sampling" occurred to other larger mesh sizes, i.e. 50 and 100m where small-range variations within TAGB cannot be adequately differentiated by backscatters, hence reflected in inferior relationships shown.

The second issue of spatial variation of SAR backscatters not able to record the absolute ranges of TAGB. Take for instant in the 10m mesh, the backscatters recorded is only 12dB (i.e. -4 to -16dB), compared to range of 450Mg/ha of TAGB observed in 10m secondary plot, and could even higher for primary forest. Quantification of the TAGB as quoted within the 12dB range suggested that such relationship if exist is not linear. More important to note that small variation in backscatter reflects relatively large variations in TAGB. On such variations it is more relevant to analyze these relationships of both variables at regular intervals – the second approach of JERS-1 SAR backscatter –TAGB relationship analyses.

The tree compositions that make-up TAGB in a given area were also considered in this study. Three sets of TAGB each derived from dbh>=1cm, dbh>=5cm and the average of both TAGB from dbh>=1 and 5cm were employed in the analysis. The results as illustrated in (Table 2, Fig 3 and 4), indicated within the secondary plot, there is no significant different in the response. Similarly pattern was also shown in the primary forest. In term of coverage, TAGB samples derived from dbh>=1cm provide better assurance of all trees being counted, inclusive of those of dbh>=5cm be included. In this context, all further analysis of radar backscatters-TAGB relationship to dbh>=1cm only.

On the second approach analysis is the interpretation of radar backscatters and TAGB relationship is to minimize the spatial variations. Table 3 tabulates the summary of the relationships examined. In the secondary plot, both the 10 and 20m mesh samples were grouped at 0.1 and 0.5dB interval of the radar backscatters. This reduce variations relatively drastic can be observed by the improved r^2 and importantly the significance level p(<=0.05) is acceptable for all cases tested. Similar characteristic is also evident in primary forest plot (see Table 3b). The best compromise for achievable of the TAGB and SAR backscatter responses from JERS-1 is best seen by group of 0.5dB interval which in both secondary and primary forest given the highest score in their respective groups (see Fig 8b and Fig 10c). However, with larger number of observation group (n=146) in the primary, adapting the relationship exhibited with primary forest is best option, i.e.

$$y=2.6 \ln(x) -24.5 \quad {\scriptstyle (r^2=0.4,\ n=146,\ p<0.001)} \qquad (3)$$

where y is the TAGB and x is the radar backscatters of JERS-1 SAR.

Adapting (2), reverse computation of the TAGB using SAR backscatters, the result obtain is shown in Figure 11. Over both forest the range only despicable is between 100-381Mg/ha at 20m mesh size. Comparing this to observed TAGB, the corresponding range at 20m mesh is 140-374g/ha and 101-486Mg/ha in the secondary and primary plots, respectively. In the 50ha primary plot, the total sum of TAGB estimated using SAR backscatter employing (2) is 367,310.531Mg/ha compared to 394,385.436Mg/ha of the tree census at dbh>=1cm, shortfall of 27,083Mg/ha. In comparisons with previous similar studies on using SAR data for estimation for biomass (eg. Le Toan et al 1992, Dobson et al 1995, Romshoo and Shimada 2002, and Hoekman and Quinones, 2000) none of these studies, a few even if any work of sort to examine radar backscatter response to samples of TAGB used exceeding 100Mg/ha. In fact the relationship model at Amazonian virgin tropical forest (Luckman et al 1998) only used maximum sample range up to 40Mg/ha. The limitation to acquire TAGB sample for this kind of study is very time consuming and costly for the tree census. Due to this the ideal sampling for SAR-TAGB relationship study that require a representative min-max range say from sparely vegetated ground of less than 1 Mg/ha to up densely undisturbed tropical forest is very difficult to achieved. Such sampling requirement even if can be fulfilled will need to use multi-temporal and multiple scenes generated at particular sites, making such study very costly indeed, and suggest to none of such sort attempted and reported. Even in this study the completion of tree census (which took about 1 year to complete) is not coincide direct with the time of acquisition. The tree census for every dbh>=1 and 5 cm used are completed in November 1998 while the JERS-1 SAR data used was acquired in August 1996. The JERS1-SAR was malfunctioned in this period of time and no archived SAR data later than this date over PFR. Due to non-dynamic behavior of TAGB, such delay is thereby justify. To seek wider range of more representative TAGB samples for enabling estimation from SAR data, complimentary samples from other forest sites is required and will be carried out in the near future once resources become available. Accurate estimation of carbon storage for carbon sequestration anticipated in the ultimatum output of the risk assessment also require input factors such as soil respiration rate and edaphic condition (Okuda et al 2003) which need to be determined from in-situ measurement.

(2) Results of simulation of risk assessments on landscape development

The risk simulations carried out within limited scope of EFF03 is as summarized in Table 4, where the comparison of nett profits of certain land use options selected. The nett present value (NPV) can be used to determine the realistic value of certain “ecological services and goods” we intent to opt, but in this report only unique values representing the ecological values adopted based on the rate mentioned earlier in section 3.2.2. At the stage, the risk assessments made were merely on limited parameters, thus, this preliminary results only portray the conceptualized change in profits or loss due to the options of land use selected as exhibited by the 2 scenario settings (see Table 4) against the present land use. The discussion on its absolute benefits to landscape development as through the simulation tool as rapid assessment but the number of parameters to be manipulated must be representatives in addressing the real needs of the stake holders apart from addressing the sustaining development taking into account for ecological services and goods as parameters. The results of risk assessments on landscape development with partials parameters used is tabulated in Table 5.

Conclusion

The results and progress made so far for the risk assessment of landscape development using GIS, a project anticipated undertaken in 3 terms of EFF program. The main focus of the work carried out is to conceptualize the risk of changes in land use options to the landscape development, which are categorized into: (i) creation of spatial database from baseline information, (ii) structuring the simulation model based on spatial analysis in the GIS, and (iii) the estimation of total above ground biomass (TAGB) from satellite remote sensing data using JERS-1 SAR data. Results obtained so far have been confined to completion of task (i) and (ii) while preliminary for (iii). With regard to TAGB estimation from SAR data, best correlation of examined for primary and secondary forest examined in PFR is given by y=2.6 Ln(x) -24.5 (r^2=0.4, n=146, $p<0.001$). This relationship however only represents the higher density biomass range which require further samples of less dense forests/vegetation to compliment the validity of TAGB estimation model from SAR obtained with better accuracy. However, such relationship can be viewed as viable estimator compared to “rough” estimation of forest biomass estimation based on random in-situ samplings is average around r^2=0.5, apart of lacking the spatial information of the samples taken. The spatial analysis used in creating “landscape risk assessor” has been completed with limited ecological services parameters as manipulators on the smaller area within PFR – a pilot watershed. Realistic parameters and compromising values of ecological services and goods used in the pilot watershed has yet to acceptable against stakeholders and well as sound to the policy makers as we anticipated such rapid assessor not for modeling per se but it implementation of sustainable landscape development.

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Fig. 5: Response of JERS-1 SAR toTAGB (1995) at secondary forest plot resampled at 50m: (a) dhb>=1cm, (b)dbh>=5cm, and (c)dbh average 1and 5cm.

Fig. 6: Response of JERS-1 SAR toTAGB (1995) at primary forest plot with dbh>=1cm for mesh dimension size of: (a) 10x10m, (b) 20x20m., (c)50x50m, and (d) 100x100m.

Fig. 7: Response of JERS-1 SAR toTAGB (1995) at secondary forest plot resampled at 10x10m,with dbh>=1cm, where the TAGB were averaged (a) 0.1 dB intervals, (b)0.5dB interval.

Fig. 8: Response of JERS-1 SAR toTAGB (1995) at secondary forest plot resampled at 20x20m, for dhb>=1cm, where TAGB are grouped and averaged at interval of: (a) -0.1dB ; (b) -0.5dB.

Fig. 9: Response of JERS-1 SAR toTAGB (1995) at primary forest plot resampled at 10x10m; TAGB are averaged at interval of -0.25dB within the range of backscatter of the 50 ha plot.

Fig. 10: Response of JERS-1 SAR toTAGB (1995) at primary forest plot resampled at 20m; (a) TAGB are grouped at interval of -0.1dB, (b) -0.2dB, and (c) -0.5dB; within the range of backscatter of the 50 plot.

Fig. 11: The JERS-1 SAR image used in the study, overlaid on forest reserve boundary in the Pasoh Forest Region (left), and the TAGB derived from backscatter of JERS-1 SAR data (right).

Table 1: The C and P factors found in PFR for simulating the risk of landscape management options (a), and the K factor used (b)

(a)

Land use options	C	P	C*P
1. Agriculture			
• Oil Palm plantation	0.5	0.25	0.125
• Rubber plantation	0.2	0.25	0.100
• Orchard (inc sundry tree cultivation)	0.3	0.5	0.015
• Pasture	0.02	1	0.020
2. Forest			
• Primary Forest	-	-	0.003
• Commercial forest (secondary forest)	-	-	0.015
• Shrubs (*belucar*)	0.02	1	0.020
• Clearings due to logging	-	-	0.015
3. Built-up areas			
• Urban	0.005	1	0.005
• Housing	0.003	1	0.003
• Cleared/barren land	1	1	1

(after Roslan and Tew, 1997)

(b)

Soil Series	Symbol	% clay	% silt	% fine sand	% organic matter	K
Reverine Alluvium Telemong	RVA-TMG	62	21	10	6.25	0.071
Rengam- Tampin	RGM-TPN	22.5	6.5	26.5	2.5	0.190
Bungor- Durian	BGR-DRN	26.5	21	46.5	1.6	0.180
Batu Anam Durian	BTM-DRN	37	24.5	34	1.515	0.290
Tampin- Rengam	TPN-RGM	22.5	6.5	26.5	2.495	0.190
Durian-Malacca	DRN-MCA	42.5	20	35	1	0.260
Bungor- Malacca	BGR-MCA	42	15	35.5	1.6	0.230
Durian-Tavy	DRN-TVY	34.5	30.5	31.5	0.5	0.350
Inland-Swamp-Local Alluvium	ISA-LAA					0.280

(after Zulkifli, 2004)

Table 2: Summary of "one-to-one" relationship between JERS-1 SAR backscatters and TAGB for: (a) Secondary forest plot, and (b) Primary forest plot.

(a)

Mesh size (m)	Dbh>= (cm)	Equation*	r^2	n	Significance, p	Reg plot in Fig.
10x10	1	Linear y = 0.0008x – 10.442	0	600	Insignificant	3(a)
		Non-linear y = 0.2494 Ln(x) – 11.575	0		0.128	
	5	Linear y = 0.0008x – 10.441	0	600	Insignificant	3(b)
		Non Linear y = 0.251Ln(x) – 11.588	0		0.133	
	Ave of 1 and 5	Linear y = 0.0008x – 10.442	0	600	Insignificant	3(c)
		Non-linear y = -0.0073 Ln(x) - 10.191	0		0.128	
20x20	1	Linear y = 0.0023x - 10.945	0.02	150	Insignificant	4(a)
		Non-linear y = 0.8611Ln(x) - 15.09	0.02		0.246	
	5	Linear y = 0.0024x - 10.949	0.01	150	Insignificant	4(b)
		Non-linear y = 0.861Ln(x) - 15.066	0.02		0.231	
	Ave of 1 and 5	Linear y = 0.0024x - 10.947	0.01	150	Insignificant	4(c)
		Non-linear y = 0.8613Ln(x) - 15.079	0.02		0.238	
50x50	1	y = 3.4925Ln(x) - 29.39	0.05	24	Insignificant 0.245	5(a)
	5	y = 3.4789Ln(x) - 29.236	0.06	24	Insignificant 0.230	5(b)
	Ave of 1 and 5	y = 3.4872Ln(x) - 29.325	0.01	24	Insignificant 0.237	5(c)
100x100		Too inferior relationship, therefore details are not shown				

* Note: Two broad categories identified from previous studies on relationship of SAR backscatters to biomass, namely the linear function and nonlinear (natural logarithmic or exponential, depending on the dependent /variable arrangement). Majority of these studies reported as nonlinear to cater for the small backscatter changes within the density of TAGB. In every equation given, y is SAR backscatter in unit of dB (decibel) and x is TAGB given in Mg/ha. The tree census for every dbh>=1 and 5 cm used are completed in November 1998. while the JERS-1 SAR data used was acquired in August 1996.

Table 2: One-to-one relationship between JERS-1 SAR backscatters and TAGB for: (a) Secondary forest plot, and (b) Primary forest plot.

(b)

Mesh size (m)	Dbh>= (cm)	Equation*	r^2	n	Significance, p	Fig.
10x10	1	Linear y = 0.000x - 10.134	0	600	Insignificant	6(a)
		Non-linear y = 0.01Ln(x) - 10.157	0	0	p>0.05	
20x20	1	Linear y = 0.0002x - 10.205	0	125	Insignificant	6(b)
		Non-linear y = 0.0906Ln(x) - 10.645	0	0	p>0.05	
50x50		y = 0.2663Ln(x) - 11.556	0	200	Insignificant	6(c)
					p>0.05	
100x100		y = 1.1092Ln(x) - 16.258	0	50	Insignificant	6(d)
					p>0.05	

Table 3: Summary of relationship between JERS-1 SAR backscatters and TAGB, analyzed using group interval of both radar backscatter and corresponding TAGB for: (a) Secondary forest plot, and (b) Primary forest plot.

(a)

Mesh size (m)	dB#	Dbh>= (cm)	Equation*	r^2	n	Significance p	Fig.
10x10	0.1	1	y = 1.21Ln(x) – 161.46	0.03	112	0.05	7(a)
	0.5	1	y = 10.71Ln(x) - 70.36	0.32	24	0.003	7(b)
20x20	0.1	1	y = 5.112Ln(x) - 38.883	0.3	94	0.001	8(a)
	0.5	1	y = 12.872Ln(x) - 82.688	0.7	19	0.001	8(b)

(b)

Mesh size (m)	dB#	Dbh>= (cm)	Equation*	r^2	n	Significance p	Fig.
10x10	-1dB	1	y = 0.0217x - 16.895	0.2	31	0.01	9(a)
			y = 5.2081Ln(x) - 40.006	0.2	31	0.01	
		5	y = 0.0219x - 16.853	0.2	31	0.01	9(b)
			y = 5.136Ln(x) - 39.511	0.2	31	0.01	
		Ave	y = 0.0218x - 16.874	0.2	31	0.01	9(c)
			y = 5.1723Ln(x) - 39.76	0.2	31	0.01	
20x20	0.5	1	y = 7.1Ln(x) - 50.6	0.3	23	0.01	10(a)
	0.1	1	y= 2.292Ln(x) - 22.883	0.3	690	<<0.01	10(a)
	0.2	1	Y= 2.49Ln(x) - 23.97	0.34	372	<<0.01	10(a)
	0.5	1	y = 2.589Ln(x) - 24.462	0.403	146	<<0.01	10(a)

dB interval used in the grouping and average.

* In every equation given, y is SAR backscatter in unit of dB (decibel) and x is TAGB given in Mg/ha. The tree census for every dbh>=1 and 5 cm used are completed in November 1998. while the JERS-1 SAR data used was acquired in August 1996.

Table 4: Scenario settings for simulating risk assessments of landscape development.

Land use option	Risk assessments made	Landscape development scenario
Existing Land Use Status	Profit in term of NPV of ecological services and goods, i.e.: 1) forested land (timber and non-timber), 2) water storage capacity, 3) carbon sequestration, 4) agricultural goods (eg rubber, oil palm) 5) etc.(can be added up for ecological services and good of the interest in the landscape, inclusive of socio-economic aspects related if necessary)	Control
Scenario 1	Total Profits of the present land use status Minus the LOSS of ecological services and goods due to landscape development selected, i.e.: 1) Erosion risk based on amount of soil loss (t/ha/yr), 2) Reduction in carbon storage due to shrinkage of carbon pool,	Conversion of secondary forest and small fragmented isolated primary forest to large scale plantation (eg oil palm)
Scenario 2	Total Profits of the present land use status Minus the LOSS of ecological services and goods due to landscape development selected, i.e.: 1) Erosion risk based on amount of soil loss (t/ha/yr), 2) Reduction in carbon storage due to shrinkage of carbon pool,	Conversion of relatively large area forested land converted to large scale plantation (eg oil palm)

Table 5: Risk assessments on landscape development of a Pilot watershed (12,788ha) based on 3-scenarios land use options. The US$ were used in computing the profits and losses.

(a)

Land use	Area (ha.)	Percent
Grass	54.51	0.4
Oil palm	3599.08	28.1
Paddy	138.65	1.1
Pforest	6517.67	51.0
Rubber	1635.61	12.8
Sforest	421.36	3.3
Sundry	421.71	3.3
Total area	12788.60	

(b)

Land use	Control[*]	Scenario1	Scenario2
Oil palm	$5,928,226.27	$6,622,266.10	$18,142,266.84
Forest (timber)	$1,592,160.89	$1,495,480.30	-
Forest (Non-timber)	$44,687.37	$41,973.82	-
Rubber	$126,269.17	$126,269.17	-
Carbon storage[4]	$12,356,142.06	$11,894,755.05	-
Water yield[2]	TBD	TBD	TBD
PROFIT	**$20,047,485.76**	**$20,180,744.44**	**$18,142,266.84**
Erosion risk	$96,838.81	$337,826.44	$502,361.20
Carbon loss	-	$461,387.01	$12,356,142.06
Ecological services[3]	TBD	TBD	TBD
LOSS	**$258,234.83**	**$1,362,257.51**	**$13,695,772.14**
Nett Profit	**$19,789,250.93**	**$18,818,486.93**	**$4,446,494.70**

[*] Control designated as existing land use act as control of other land use option selection, scenario 1 change all fragmented secondary forests into oil palm plantation, and scenario 2 changing all forested lands in the watershed into oil palm plantation.

[4] Carbon storage are derived based on TAGB of 500ton/ha and 300ton/ha for primary and secondary forests, respectively. A multiplier factor of 0.5 is adopted for carbon storage determination from TAGB.

[2] Computational models for determination of water yield are still being examined.

[3] Still being compile and yet to be agreed with stakeholders on the categories involved.

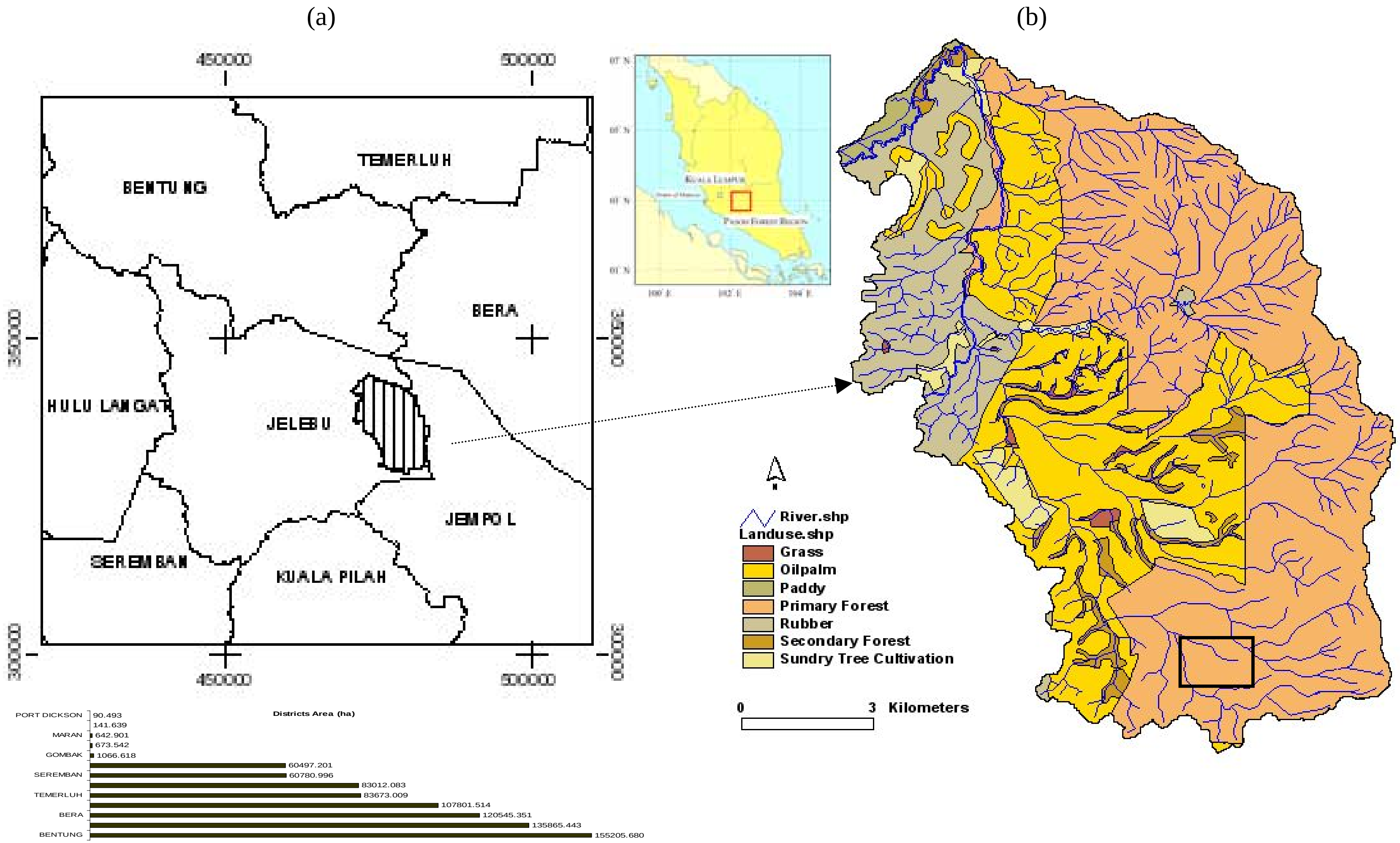
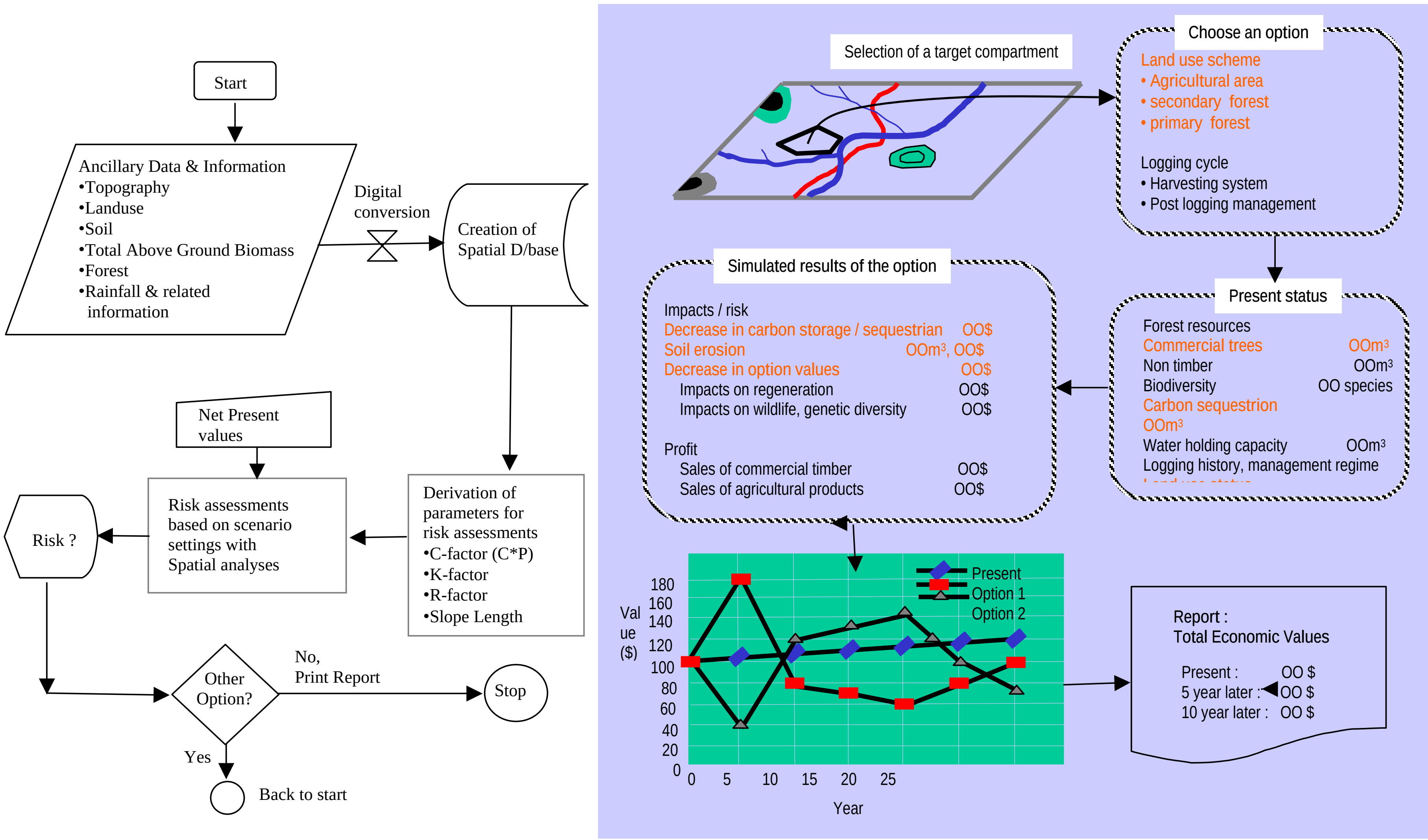


Figure 1: (a)The entire study area, PFR where the final simulation will be carried out for an area of 80,9996 ha covering 7 major districts, and (b) the pilot watershed where progress of EFF03/04 is reported. Note that the Pasoh's representative of primary forest sampling for TAGB is carried out in 50ha plot, demarcated by-rectangular polygon in (b).



(a) (b)

Figure 2: Flowchart of processes employed in the methodology (a), and the conceptual display of the ultimatum output of the study (b)

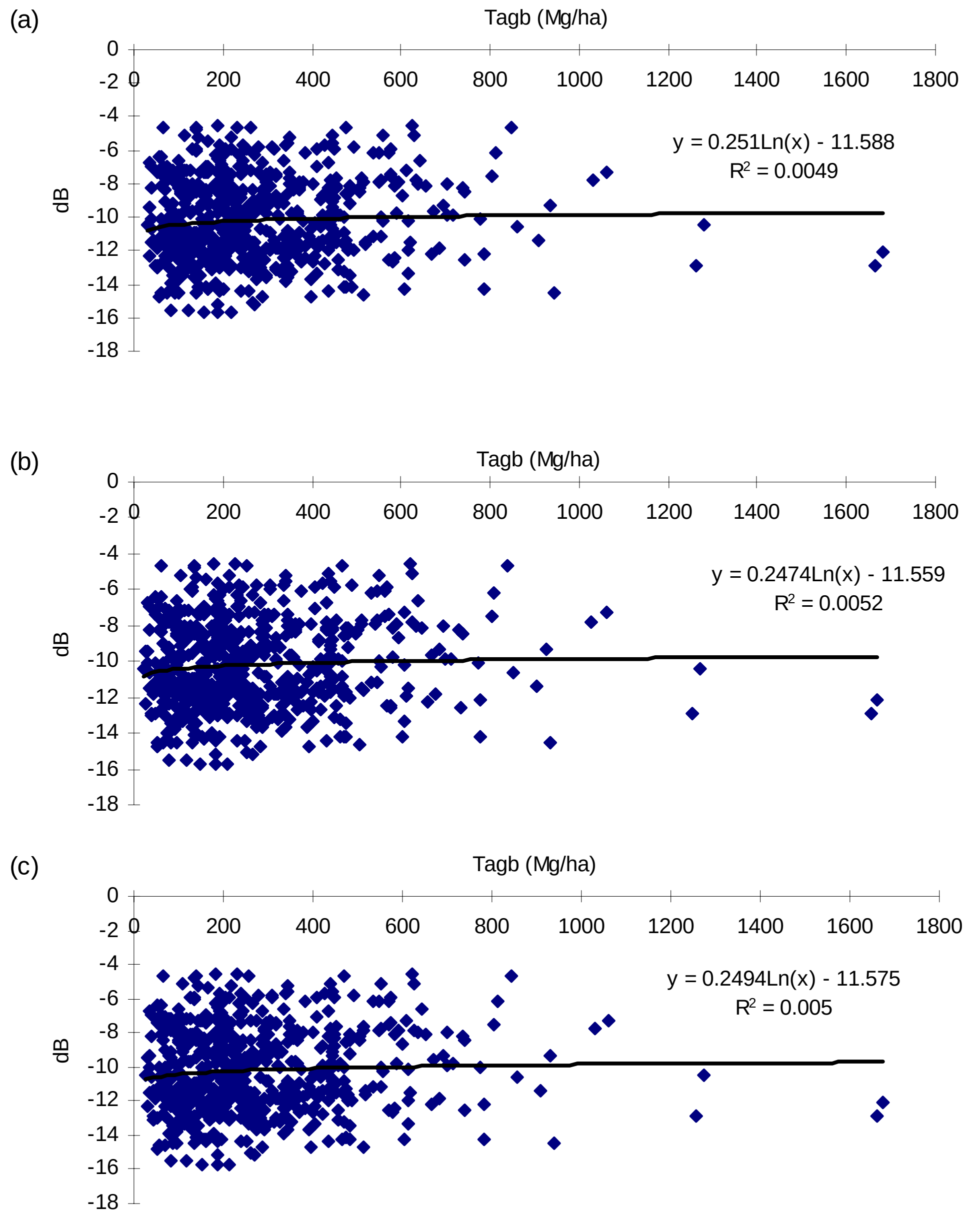


Fig.3 : Response of JERS-1 SAR toTAGB (1995) at secondary forest plot resampled at 10m: (a) dhb>=1cm, (b)dbh>=5cm, and (c)dbh average 1and 5cm. Note: JERS-1 SAR was acquired in 1996 (Aug), tree census for dbh of >= 1 cm, carried out in Nov. 1998

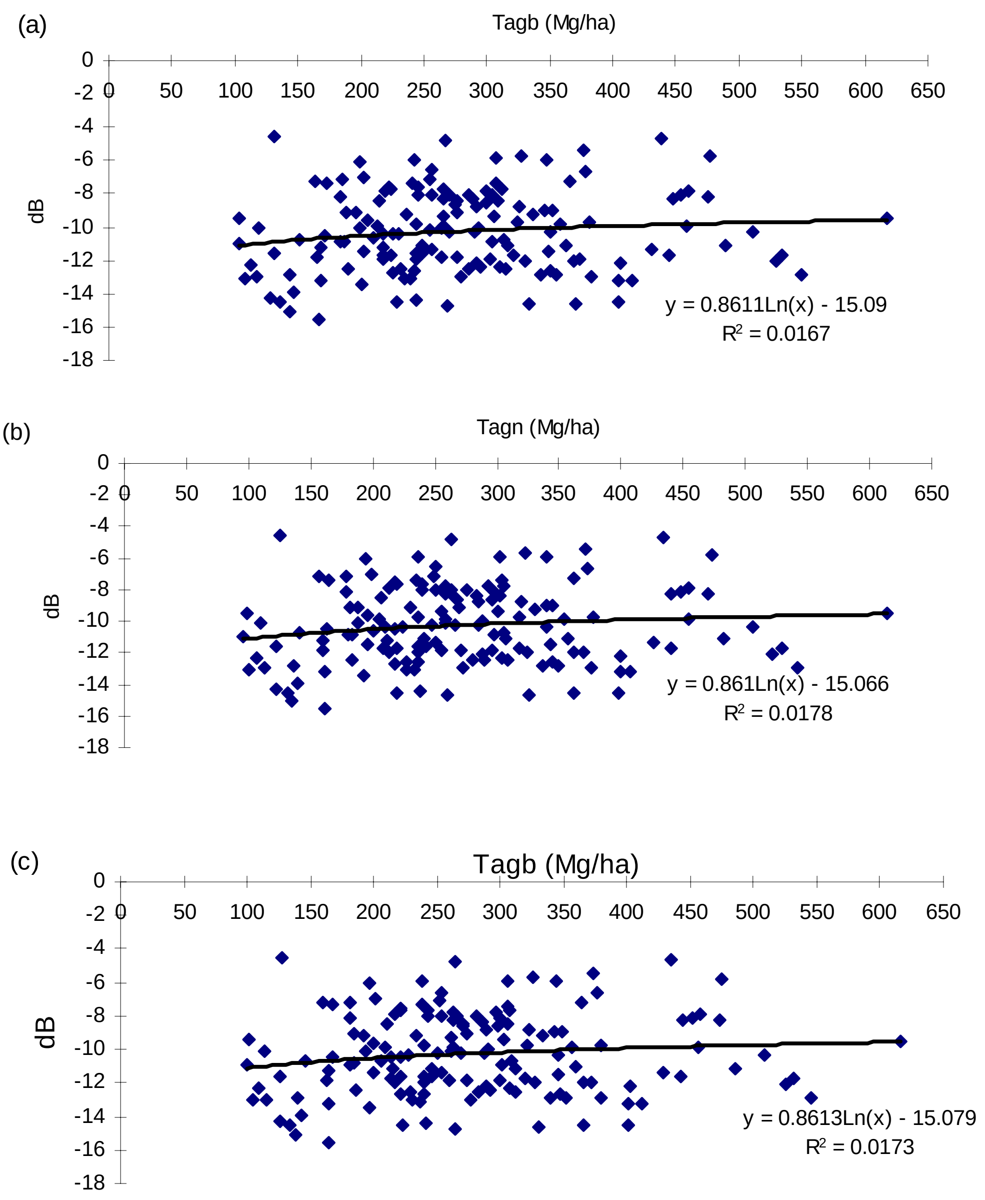


Fig.4 : Response of JERS-1 SAR toTAGB (1995) at secondary forest plot resampled at 20m: (a) dhb>=1cm, (b)dbh>=5cm, and (c)dbh average 1and 5cm. Note: JERS-1 SAR was acquired in 1996 (Aug), tree census for dbh of >= 1 cm, carried out in Nov. 1995

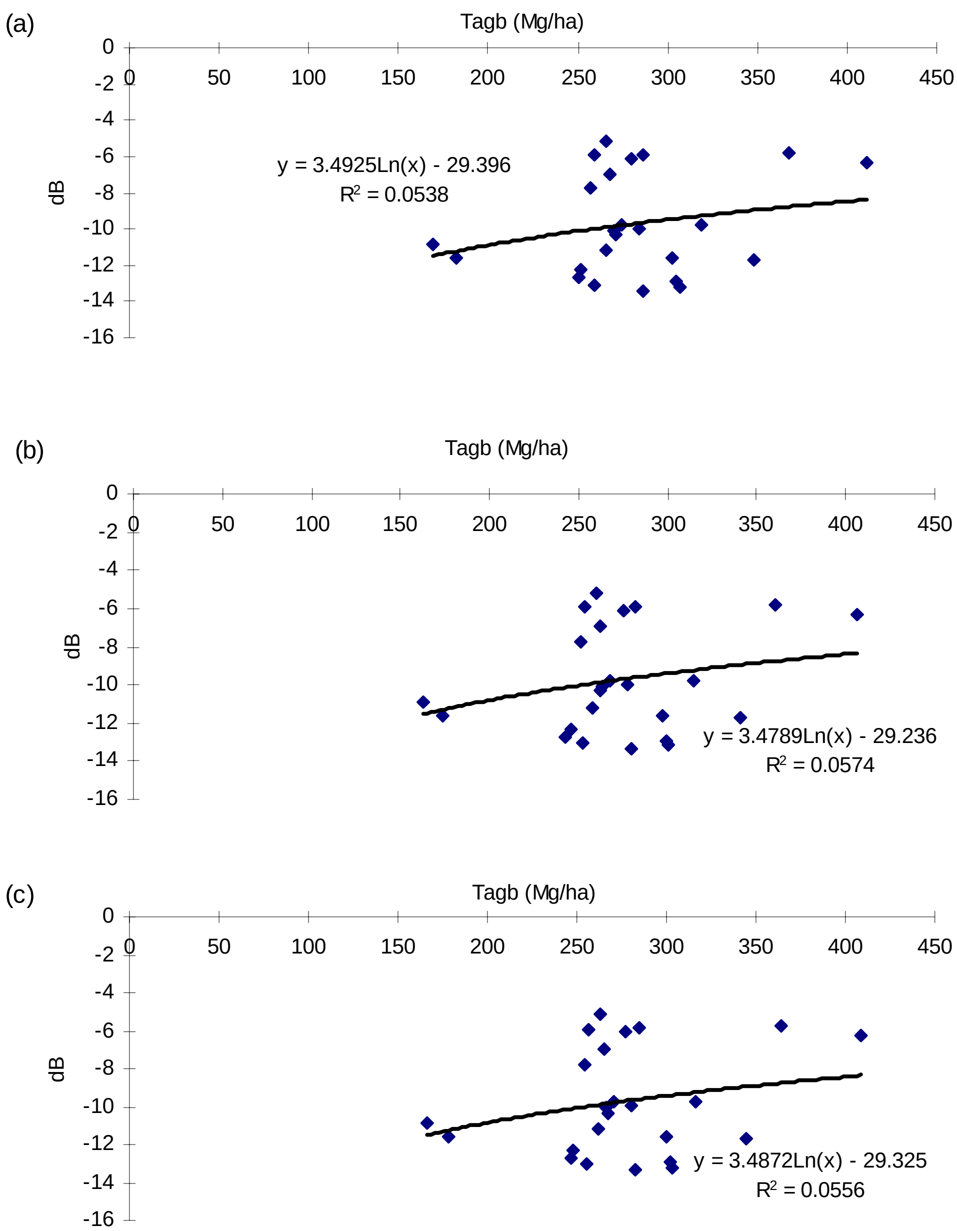
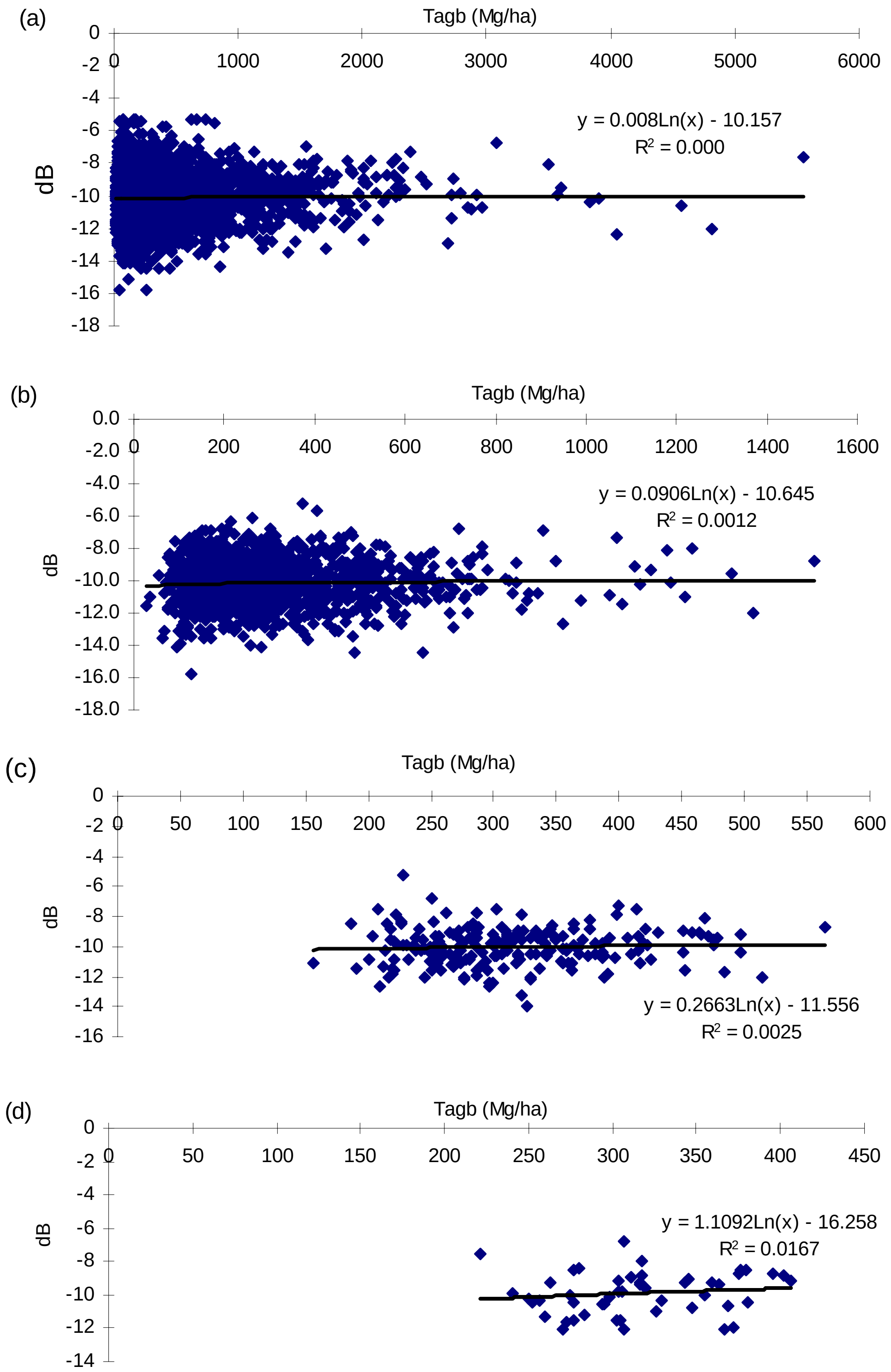
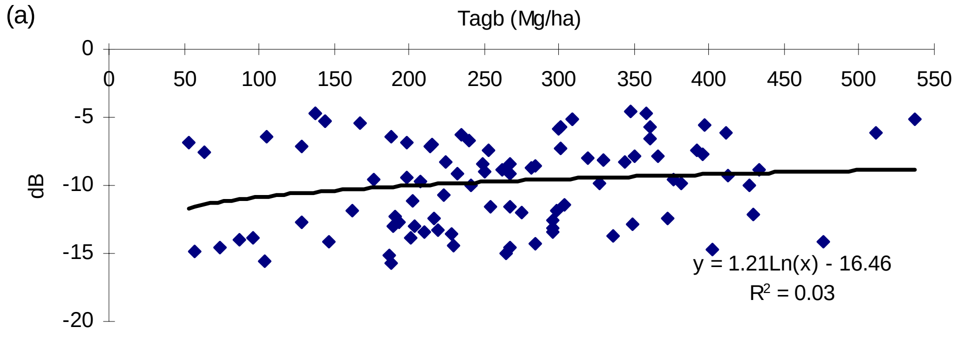


Fig.5 : Response of JERS-1 SAR toTAGB (1995) at secondary forest plot resampled at 50m: (a) dhb>=1cm, (b)dbh>=5cm, and (c)dbh average 1and 5cm. Note: JERS-1 SAR was acquired in 1996 (Aug), tree census for dbh of >= 1 cm, carried out in Nov. 1995



<u>Fig.6</u>: Response of JERS-1 SAR toTAGB (1995) at primary forest plot with dbh>=1cm for mesh dimension size of: (a) 10x10m, (b) 20x20m., (c)50x50m, and (d) 100x100m. <u>Note</u>: JERS-1 SAR was acquired in 1996 (Aug), tree census for dbh>=1 and 5 were carried out in Nov. 1995



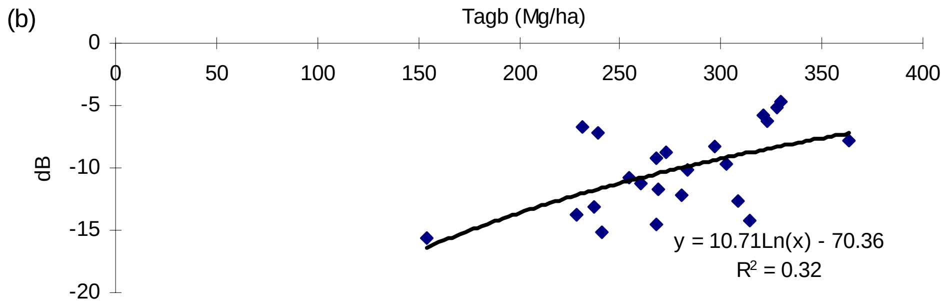
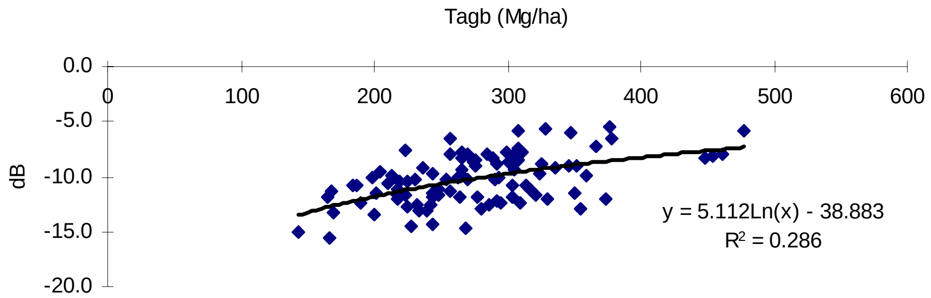


Fig.7 : Response of JERS-1 SAR toTAGB (1995) at secondary forest plot resampled at 10x10m,with dbh>=1cm, where the TAGB were averaged (a) 0.1 dB intervals, (b)0.5dB interval

(a)



(b)

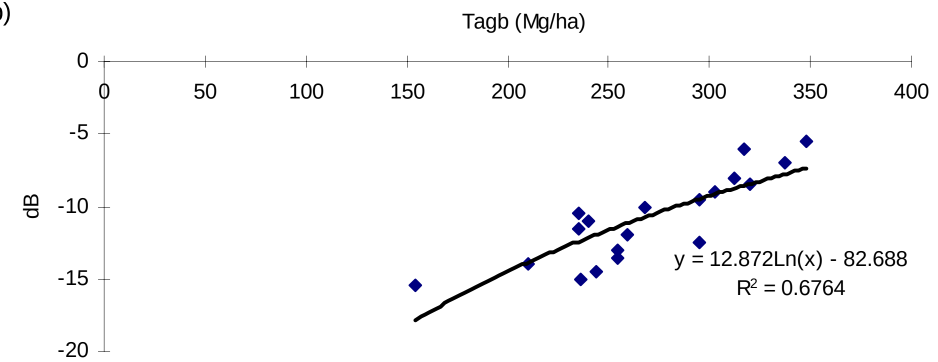
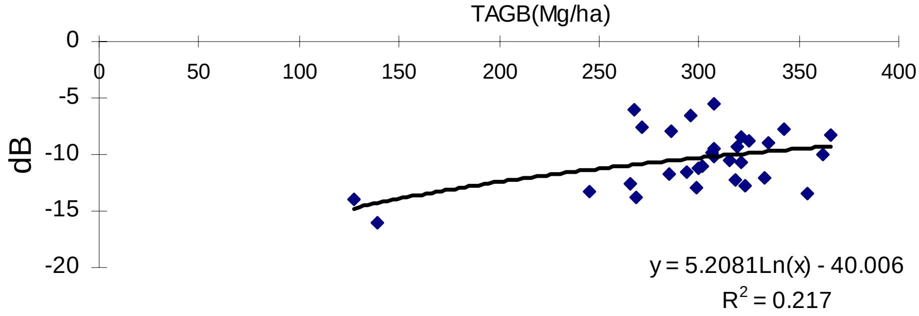
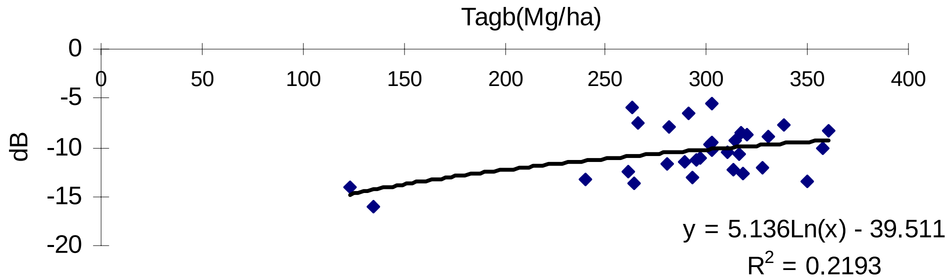


Fig.8 : Response of JERS-1 SAR toTAGB (1995) at secondary forest plot resampled at 20x20m, for dhb>=1cm, where TAGB are grouped and averaged at interval of: (a) -0.1dB ; (b) -0.5dB.

(a) Primary plot, 10m mesh, dbh>=1cm



(b) Primary plot, 10m mesh, dbh>=5cm



(c) Primary plot, 10m mesh, ave dbh>=1 and 5cm

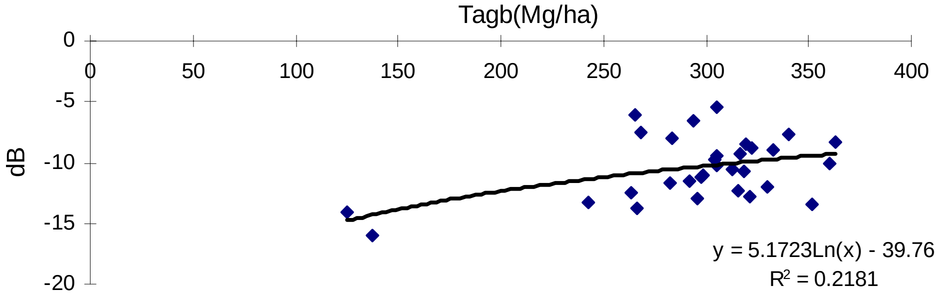


Fig.9 : Response of JERS-1 SAR toTAGB (1995) at primary forest plot resampled at 10x10m; TAGB are averaged at interval of -0.25dB within the range of backscatter of the 50 ha plot.

Note: JERS-1 SAR was acquired in 1996 (Aug), tree census for dbh of >= 1 cm, carried out in Nov. 1995

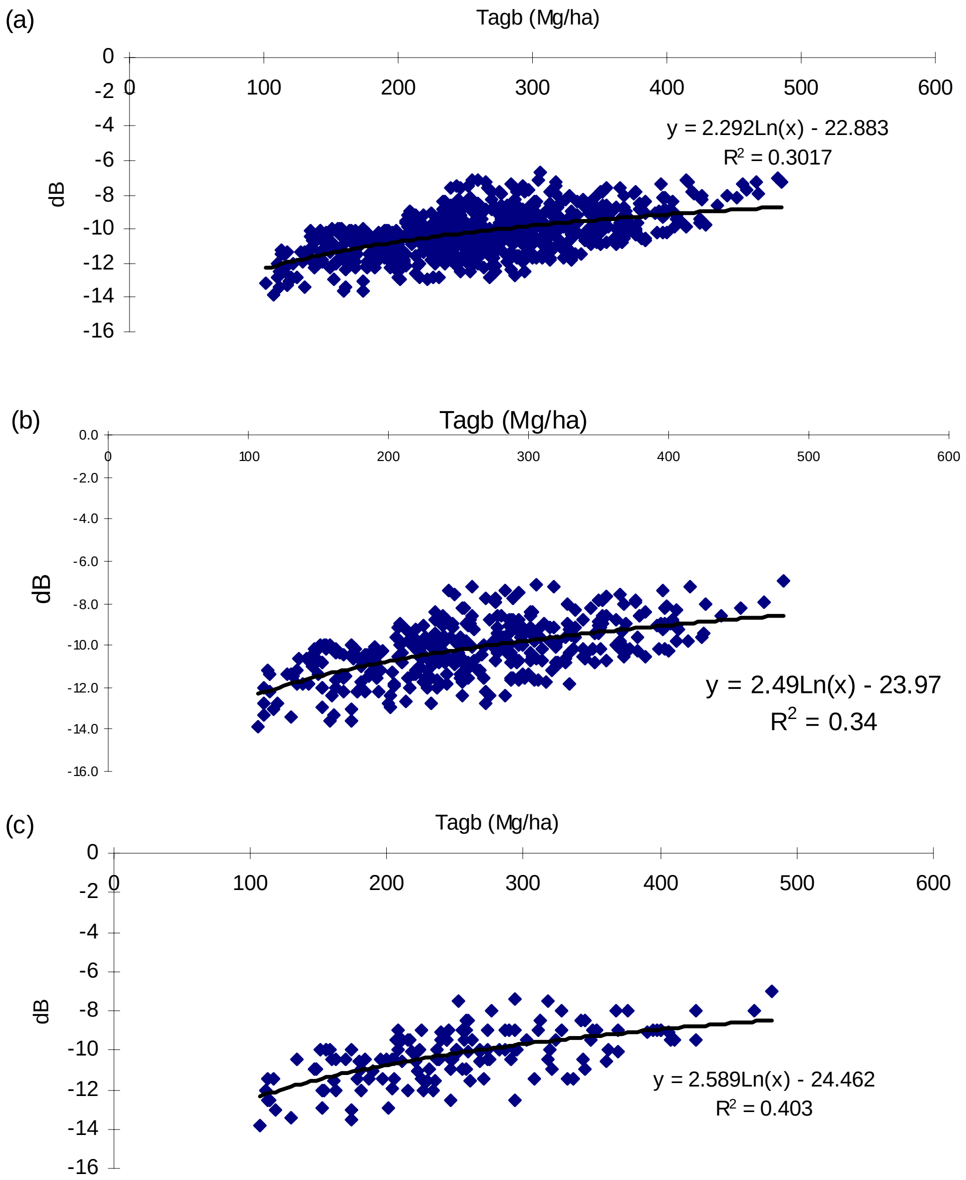


Fig.10 : Response of JERS-1 SAR toTAGB (1995) at primary forest plot resampled at 20m; (a) TAGB are grouped at interval of -0.1dB, (b) -0.2dB, and (c) -0.5dB; within the range of backscatter of the 50 plot.

Note: JERS-1 SAR was acquired in 1996 (Aug), tree census for dbh of >= 1 cm, carried out in Nov. 1995

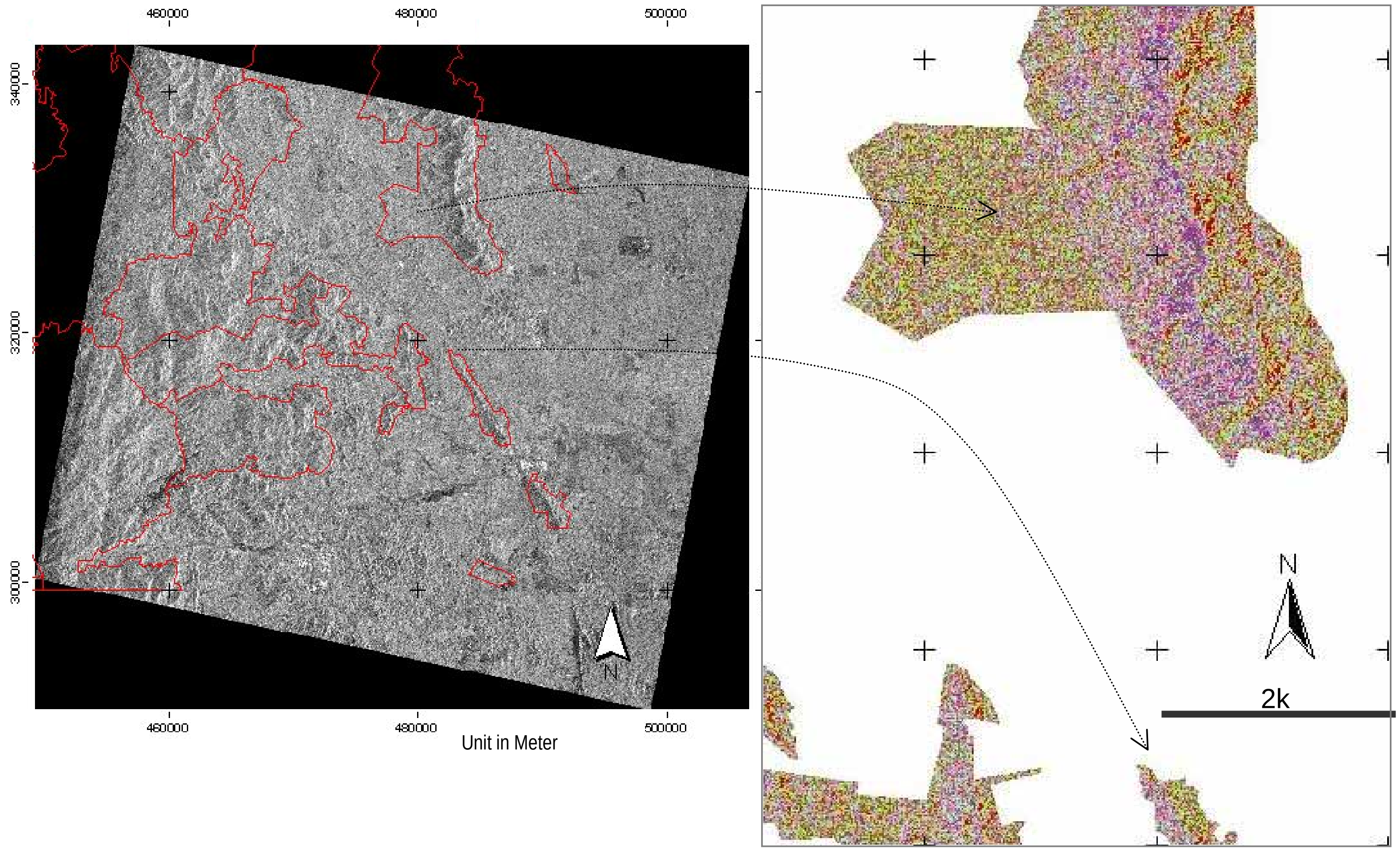


Figure 11 : The JERS-1 SAR image used in the study, overlaid on forest reserve boundary in the Pasoh Forest Region (left), and the TAGB derived from backscatter of JERS-1 SAR data (rigt).