Reclassifying forest type to a new forest class based on vegetation and lithology characteristics using geographic information system at southern Johore, Malaysia

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Abstract**--**Recently forest resources management with regard to precision forestry concept has been highlighted by forest managers, in order to fulfill the demand on quality and reliable information about forest area. According to the Malaysian National Forestry Act 1984, forest is classified into several types by general classification which is based on vegetation types broadly into dipterocarp forest, peat swamp forest and mangrove forest. In applying precision forestry approach, details classification and information are required to render more accurate about managed forest. Therefore, this study was carried out to reclassify forest type to a new forest class based on vegetation and lithology characteristic using GIS technique. Ten new classes were successfully generated and mapped by fusing layer of forest vegetation types and lithology layer in Southern Johore, namely Dipterocarp-Igneous, Dipterocarp-Sediment, Dipterocarp-Alluvial, Peat-Igneous, Peat-Sediment, Peat-Alluvial, Mangrove-Igneous, Mangrove-Sediment, Mangrove-Alluvial and Limestone forest. In this study, *Syzygium* spp. (19.83 %) was found in abundance in two new forest classes; Dipterocarp-Igneous and Dipterocarp-Sediment forest in Hulu Sedili Permanent Forest Reserve (PFR). Beside that, *Elateriospermum tapos* (9.92 %) and family of Lauraceae (7.22 %) were found to be the most dominant species in the Dipterocarp-Sediment forest, while *Macaranga* spp. (11.21 %) and *Elateriospermum tapos* (11.02 %) found dominant in Dipterocarp-Igneous forest. From the sample plot, Dipterocarpaceae family constituted only 3.09 % whereas the non-Dipterocarpaceae family was 96.91 %. Hence, this study indicated that there is variation in species dominancy at different lithology of the same forest vegetation site.

Keywords**--**Geographic information system, reclassify, new forest class, precision forestry, dominant species

I. INTRODUCTION

Forest consists of flora and fauna which make up forest ecosystem. There are interactions between trees and animals and they are dependent upon each others. Malaysia is very fortunate to be well endowed with a relatively large tract of rich and diverse tropical rain forests which has been acknowledged to be amongst the most complex ecosystem in the world. According to the Ministry of Natural Resource and Environment Malaysia (2006), in year 2004, Malaysia has a total forested land of about 19.5 million or 59.4% of the total land area. About 17.05 million hectares (87.5%) of forested land is dipterocarp forest, 1.54 million hectares (7.9%) is peat swamp forest, 0.58 million hectares (3%) is mangrove forest and forest plantation is about 0.31 million hectares (1.6%).

Generally, forested area in Malaysia is classified into several types based on their functions and category. From the National Forest Policy (1997), forest was classified into rational land use concept and functions; (i) conservation forest, (ii) yield forest, (iii) recreation or amenity forest, and (iv) research and education forest. Meanwhile National Forestry Act 1984 Section 10 required the forested land to be further classified into eleven functional classes; (i) production forest, (ii) soil protection forest, (iii) soil reclamation forest, (iv) flood control forest, (v) water catchments forest, (vi) forest sanctuary for wildlife, (vii) virgin jungle reserved forest (VJR), (viii) amenity forest, (ix) education forest, (x) research forest, and (xi) forest for federal purposes. Besides that, the Forestry Department Peninsular Malaysia (2003) also enable forest area to be classified based on forest land productivity, forest contents and classification bases on climate, soil and floristic. This is due to fact that managing a broad range of natural forest resources not just for timber but forests provides resources for grazing land for animals, wildlife habitat, water resources and recreation areas.

Current broad classification types of forest in Malaysia which is based on vegetation such as dipterocarp forest, peat swamp forest, mangrove forest and so on need more detail classification in order to allow a new concept for forestry practices called ‘Precision Forestry’ to be applied to manage forest more wisely. Different management approach is needed for different classified forest and more detail information is required to sustain our forest. Harem (1999) stated that there is a need for forester and community forestry manager to have a good tool to assist them in developing new forest classification based on special characteristics from spatial information. Generally, precision forestry applies a site-specific management concept. According to Alias (2005) it uses the latest technology and analytical tools to collect highly accurate measurements, activities and processes of forested landscapes that are critical in making sustainable management decision that support site specific, and environment concerns. Each measured parameter can be incorporated into GIS and individual tree attributes can be used by GIS program to identify different management types. Most of this information can be adequately displayed as maps, which should be accurate, “corrected” and at a scale that provides sufficient details for the purposes required (Mohd Hasmadi *et al.*, 2007). Karisa (1997) stressed that up to date forest data is paramount required for effective and accurate management. For example forest cover map could take 20 years or more with expensive manual drafting. With the use of geographic information system (GIS) technology nowadays, the forest cover maps can be updated on a constant basis and it provides the forest managers with more recent data than what was previously available. GIS technology could reduce the average age of the information of the forest data from 20 years to only a few weeks even where there are many forest functional classes and forest types. In fact, GIS technology has been widely accepted by public as well as private forestry agencies for manipulation of spatial data hence as a decision support tool. The GIS can store and analyze forest information in ways that could not be previously done.

In order to manage forest sustainably according to each classification, forest can be classified to new forest class by fusing vegetation and lithology types where lithology characteristic may have a strong influence on element cycling and the chemistry of drainage waters (Pavel *et al.,* 1997). On the other hand, forest vegetation can be influenced by lithology indirectly. Soils derived from a number of different parent materials or lithologies (Nakos, 1984) which, lithology is subdivision of petrology focusing on macroscopic hand-sample or outcrop-scale description of rocks. It involves three branches; igneous, metamorphic and sedimentary (Drewes, 1996). Comprehending this, new classification of forest can be established using GIS technology. Therefore, the objectives of this study were to develop a new classification forest based on vegetation and lithology characteristic at the Southern Johore using GIS and to identify dominant species of each new class.

II. MATERIALS AND METHODS

A. *Description of study area*

The study was conducted at the Southern Johore State, Peninsular Malaysia (Fig. 1). It is located within longitude 0 30’ 06” E to 10 21’ 32” E and latitude 1030 45’ 40” N to 1040 16’ 10” N. South Johore covers an area about 653,380 ha of which about 147,791 ha is forested land and of that about 54,473 ha is under permanent forest reserve (PFR). It rich and diverse with vegetation such as mangrove forest about 23,753 ha, peat swamp forest about 12,849 ha and dipterocarp forest about 111,188 ha. In this area, dipterocarp forest has been logged since 1970’s until 2004 of which about 109,909 ha. Peat swamp forest has been logged since 1990’s until year 2000 of which about 12,849 ha. While mangrove forest has converted to plantation which about 9,435 ha and the remaining forest about 25,181 ha. This area is characterized by flat topography. The mean annual air temperature is 26.70C with 82.45% relative humidity and annual precipitation averages 2756 mm. Johore state comprise five soil types based from parents material as sedimentary soil from igneous rocks, sedimentary soil from metamorphic rock, soil from alluvium, soil from sub-recent alluvium and soil from recent alluvium. Lithology types at the Southern Johore were composed by four main types as Alluvial (201,515 ha), Igneous rocks (264,022 ha), Limestones (74 ha) and Sedimentary/Metamorphic rocks (647,604 ha). PFR have five lithology types which igneous rocks and sedimentary rocks are abundant in dipterocarp forest while alluvium is more abundant in mangrove forest. However, limestone rock is only present in dipterocarp forest area covers about 74 ha of Hulu Sedili Permanent Forest Reserve. **Fig 2** showing the forest and lithology type in the study area.

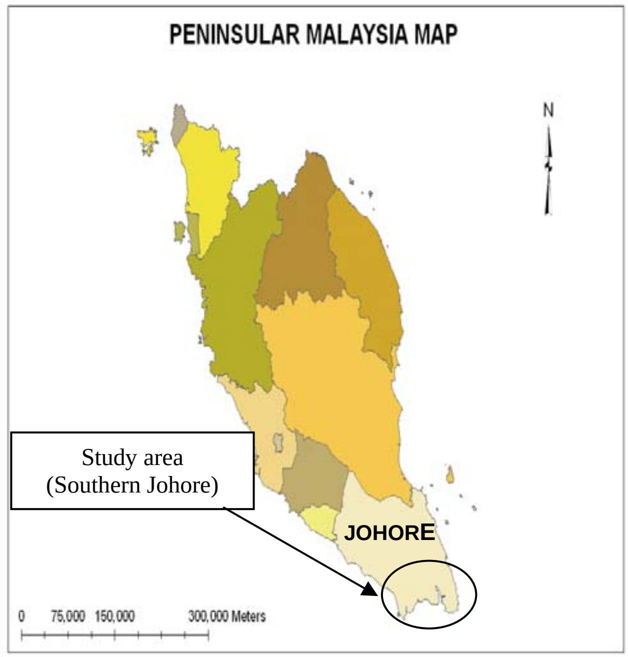

Fig. 1: Location of study area in Peninsular Malaysia

B. *Methods*

There are two data group which first group is in digital form and compatible with GIS environment for spatial data editing. It is important to adding, deleting and modifying features in digital layer. They are two types of digital map; primary and secondary. The primary digital data used is the map of 1:5000 scale of forested area over southern Johore obtained from the Forest Department Peninsular Malaysia (FDPM) and Johore State Forest Department. While lithology type map (Scale 1:50000) was acquired from the Mineral and Geosciences Department Malaysia. Then, the digital map was converted into the Arc GIS format (*.shp). Universal Transverse Mercator (UTM) coordinate’s system was set to all features layers to ensure they are easily georeferenced. The second group is field survey data.

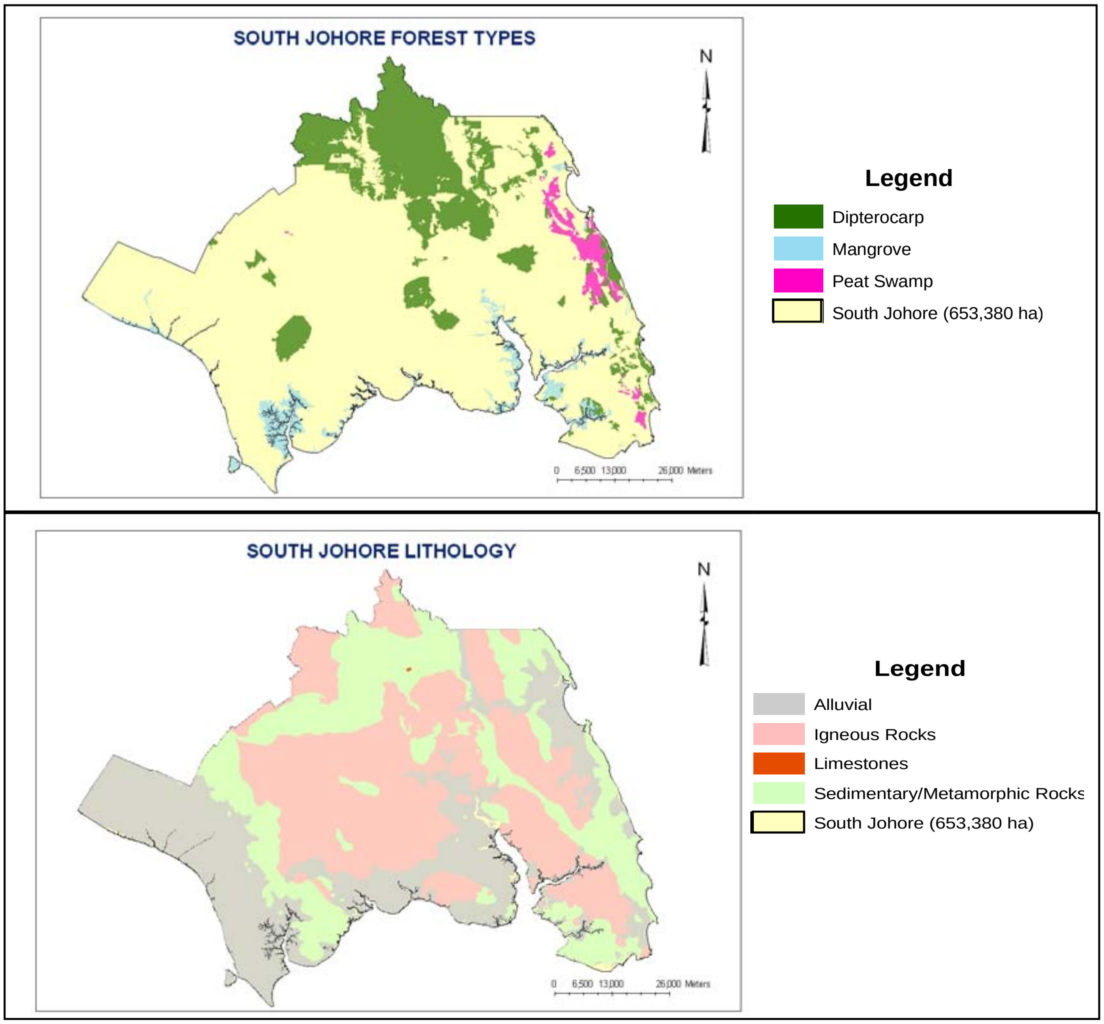

Fig. 2: The Southern Johore maps showing forest and lithology types

C. *Spatial data editing*

Upon acquisition, forested area and lithology boundary layers were (Fig. 2) ‘clipped’ with the Southern Johore forest district boundary for the region of interest in this study using ArcGIS software version 9.2. Both digital map of forested area and lithology boundary in Southern Johore were displayed and overlaid to see how they fit, and to rectify their coordinates. In order to make the new forest class map better orientate, map of river and lake scales 1:50,000 was edited to the region of interest.

They are two type of field data; survey data and GPS data. Survey data consisted post-felling (post-F) data inventory obtained from Johore State Forest Department. A GPS receiver is used to determine its precise position on earth surface (Chang, 2007). Survey data not required scanning. However, it just goes trough added value process. The value is added in attribute data for a related layer from existing layer as the new forest class developed. To edit the attribute data, spatial data editing is important in the last steps of database preparation. All the above process is known as decision making database which is preparation of database for a spatial analysis tools (Chang, 2007).

D. *Spatial analysis*

The next step continued with spatial analysis once the database preparation completed. The basic operation in spatial analysis of GIS for decision support is ad hoc query and display features and their related database. Using the GIS, question ‘what’ and ‘where’ the resources can be answered quickly. Information or attribute about spatial features can also be retrieved because of the existence of linkage between the features and their attribute in the database. The features are queried using Simply Query Language (SQL) commands provided by the GIS software (Ismail, 1999). Thus, the new polygon or new map created of forest class derived with new database as attribute data edited with species identified from post-F survey. This process was illustrated in Fig. 3.

There were nine attributes tables for geographic information of the primary layers of the Southern Johore Forest Reserve. The database structure were layers such as Southern Johore boundary, permanent forest reserve land, forest type, litology type, forest compartments, road, river and lake. The attribute tables contain items such as name, area, area/hectare, perimeter, forest type, length and other relevant data. In this study, resulting unioned layers of the vegetation and lithology were combined to determine how they 'union' and what's the new polygon produced to name the new forest type. Possible new forest classes were; (i) Dipterocarp layer + Igneous layer = Dipterocarp Igneous Forest (Dip-Ig), (ii) Peat Swamp layer + Sedimentary layer = Peat Swamp Sedimentary Forest (Peat-Sed), and (iii) Mangrove layer + Alluvial layer = Mangrove Alluvial Forest (Man-Al).

The new forest classes produced from clipping and union operations were analyzed with data from post felling (Post-F) inventory. Identification of tree species was carried out by the South Johore Forest District. Sample plot for species dominancy identification was chosen at compartment 67, 101 and 103 of Hulu Sedili forest reserve. The diameter at breast height (dbh) of the dominant tree species were ranged from 15 cm to 95 cm, respectively.

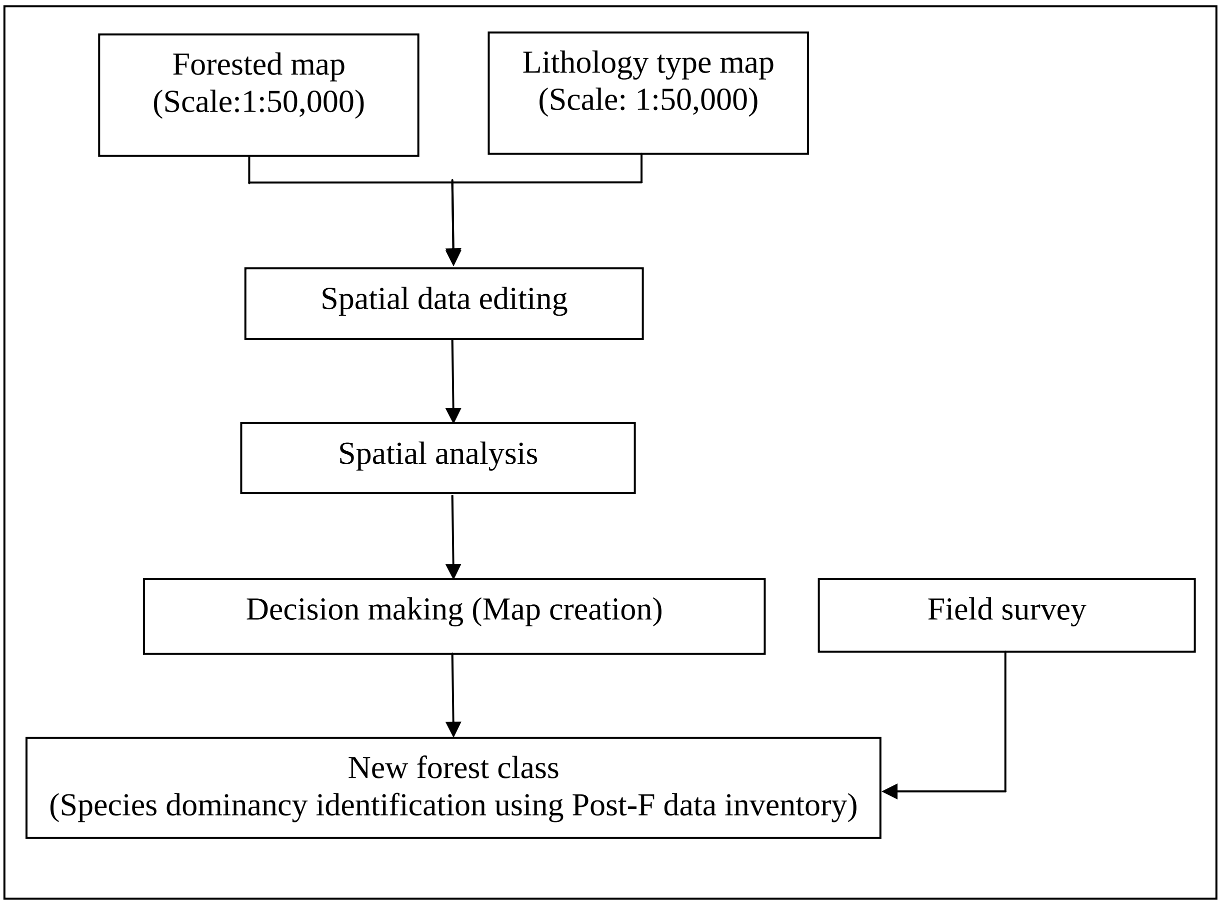

Fig 3:

III. RESULTS AND DISCUSSION

A. *New forest class*

In this study, the generation of new forest classes has increased the forest categories from three types to ten types. There are nine potential names for these new forest types as illustrated in Table 1. From this study, in spite of limestone was found inside with dipterocarp forest, the new class generated was not given a name of Dipterocarp Limestone forest because there is no dipterocarp vegetation at all at this area and, usually limestone is the type of rocks that gives us caves vegetation (Richard, 1992). Hence, this new class remains as Limestone forest. The new classification forest type map generated from overlaying of both lithology and forest type of Southern Johore is shown in Fig. 4. Generation of the new forest classes comprised of 15 Permanent Forest Reserves (PFR). From analysis done through spatial analysis process, peat swamp forest is not included in PFR in the region of interest in this study. As National Forestry Act (1984)- Section nine (9) states PFR is considered if the State Authority expedient to constitute any land, not being a State land or reserved land vested in the State Authority.

The new PFR classes have illustrated in Table 2 and there includes of Hulu Sedili Forest Reserve which was located at most of the top of Southern Johore. In fact Hulu Sedili Permanent Forest Reserve was identified having three new forest classes.

The overall post-F inventory results depicted that both new forest classification were dominated by non-Dipterocarpaceae family (96.91%) particularly Myrtaceae (19.83%) and Euphorbiaceae (10.23%). They comprises a total of 9,276 trees which 4.434 trees (47.8%) are from 15.00-29.99 cm dbh, 2,873 trees (30.97%) 30.00-49.99cm dbh and 1,074 trees (11.58%) of >50.00 cm dbh. Post-F inventory results also showed that Dipt-Sed and Dipt-Ig were dominated by two species from Dipterocarpaceae family which is *Dryobalanops sumatrensis* and *Cotylelobium spp*. These species represents 4.33 % or 187 trees from 6,449 of the other species.

Table 1: A New forest class developed by fusing vegetation and lithology characteristics

New Forest Classification	**Area (ha)**
Dipterocarp Alluvial (Dipt-Al)	5,600
Dipterocarp Sedimentary (Dipt-Sed)	47,274
Dipterocarp Igneous (Dipt –Ig)	58,192
Limestone Forest	74.0
Peat Swamp Alluvial (Peat-Al)	9,017
Peat Swamp Sedimentary (Peat-Sed)	2,800
Peat Swamp Igneous (Peat-Ig)	1,010
Mangrove Alluvial (Man-Al)	18,481
Mangrove Sedimentary (Man-Sed)	1,925
Mangrove Igneous (Man-Ig)	1,026
Total	

Table 2 New forest classification at Permanent Forest Reserve at South Johore.

No.	Permanent Forest Reserve	New Forest Classification (ha)							Total
		Dipt-Ig	Dipt- Sed	Dipt- Al	Limestone	Man- Ig	Man- Sed	Man- Al	
1	Belungkor		0.08			145	248	750	1,143.08
2	Bukit Hantu	748							748
3	Gunong Pulai	2,104	771						2,875
4	Kuala Sedili							293	293
5	Lenggor Tengah		0.0025						0.0025
6	Panti	7,807	4,493	334					12,634
7	Pulau Kukup							460	460
8	Sedenak	583							583
9	Sungai Johor					222	233	2,511	2,966
10	Sungai Lebam					328	0.4	1,078	1,406.4
11	Sungai Pendas						74	418	492
12	Sungai Pulai						93	7,067	7,160
13	Sungai Santi	340	953	156		105	481	1050	3,085
14	Hulu Sedili	7,725	10,826		74				18,625
15	Kluang		0.2				0.2		0.4
Total		19,307	17,043.28	490	74	800	1,129.6	13,627	52,470.88

B. Species dominancy identification

Species dominancy identification in a new forest classes were carried out at three compartments of Hulu Sedili Forest Reserve, namely 67, 101 and 103 based on available data from post-F inventory. In Hulu Sedili three new class were identified such as Dipterocarp Igneous (7,800 ha), Limestones forest (74.0 ha) and Dipterocarp Sedimentary (18,700 ha), as shown in Fig. 5. Meanwhile Table 3 presented the new forest class, species, dbh class and total number of tree per hectare in compartment 67,101 and 103.

Syzygium spp. were found to be the most dominant species exist in both Dipt-Sed and Dipt-Ig forest with 1301 trees (19.61%) and 538 trees (20.38%), respectively. The second dominant species identified was *Elateriospermum tapos* in Dipt-Sed forest class with total of 658 trees (9.92%). This followed by family of Lauraceae and Sapotaceae with the total number of tress more than 5 %. The other species which can be found dominantly in the new forest class are *Canarium* spp., family of Annonaceae, *Dryobalanops sumatrensis*, and *Castanopsis* spp.The total number of trees per hectare for Dipt-Sed forest is about 15.64 trees. Observation found that, in Dipt-Ig forest, *Macaranga* spp. and *Elateriopsermum tapos* was quite abundant by a total of 296 trees (1.13 tree/ha) and 291 trees (1.11 tree/ha), respectively**.** Family of Lauraceae, *Canarium* spp., *Artocarpus* spp., *Gymnacranthera* spp. family of Sapotaceae, *Gluta elegans* and others were also found dominantly in these newly generated forest classes.

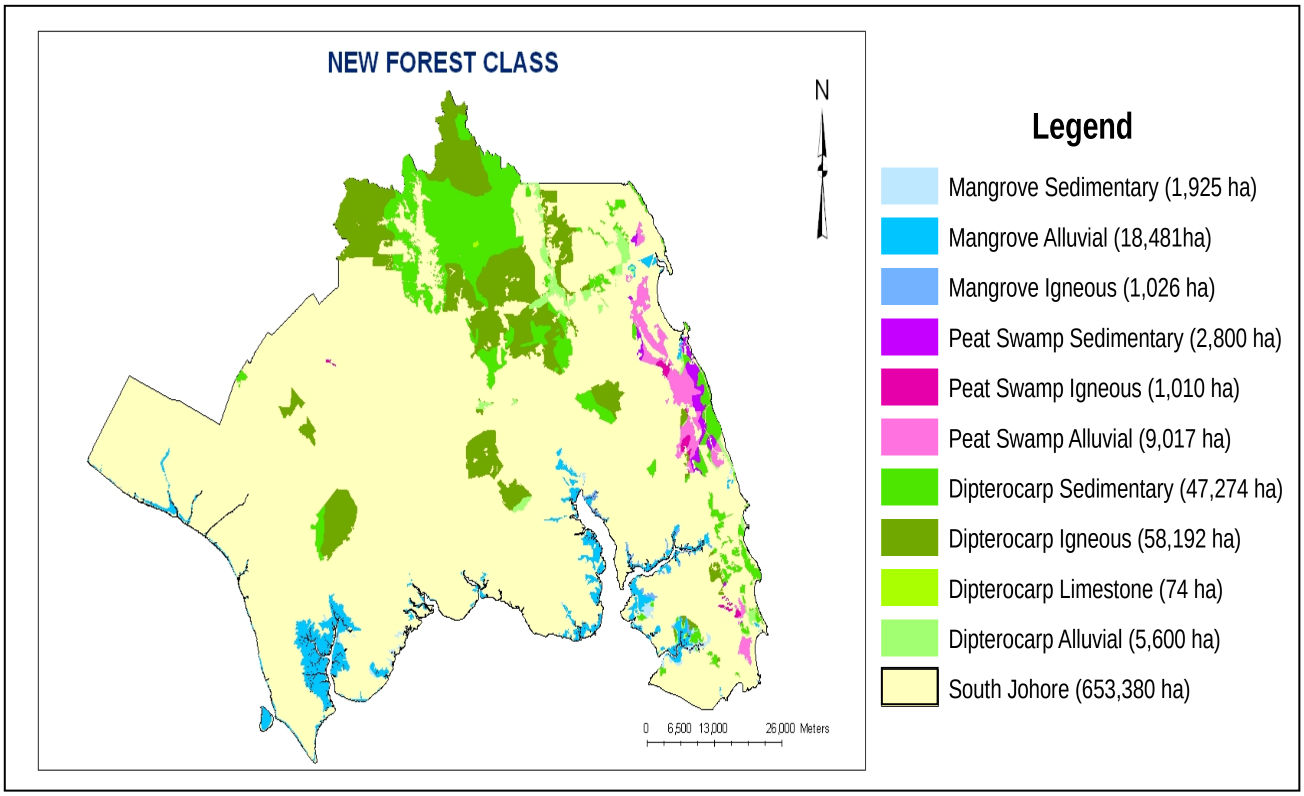

Fig. 4. The new forest type map generated from overlaying lithology and forest type of Southern Johore

The others common species found dominantly were *Syzygium* spp. (Kelat), *Elateriospermum tapos* (Perah), Lauraceae (Medang), *Canarium* spp. (Kedondong), and Sapotaceae (Nyatoh).However, four species were found abundantly in only Dipt-Sed forest; namely Annonaceae (Mempisang), *Dryobalanops sumatrensis* (Kapur), *Castanopsis spp.* (Berangan), and *Cotylelobium spp.* (Resak).

In Dipt-Ig forest there are four species identified such as Artocarpus *spp.* (Keledang bangkong), *Macaranga spp.* (Mahang), *Gymnacranthera spp.* (Penarahan), and *Gluta elegans* (Rengas). However the most abundant species found in both new forest class were *Syzygium* spp. (Kelat) with 19.61% and 20.38% respectively. Sapotaceae (Nyatoh) was found more dominant in Dipt-Sed forest with 333 trees (5.02%) rather than only 70 trees (2.65%) at Dipt-Ig forest. Lauraceae (Medang) and *Canarium spp.* (Kedondong) is more abundance at Dipt-Sed forest; 479 (7.22%) and 317 (4.78%) respectively. There are only 4.55% *Canarium spp.* can be found at Dipt-Ig forest, whereas there are about 124 trees (4.7%) Lauraceae.

Analysis from post-F data showed that the commercial value trees group were presence in these new classes, where 26 species from Dipterocarpaceae family (1382 trees), dbh ranging from 15.0 cm to 90.0 cm and above. Specifically, Dipterocarp were identified more abundance in Dipt-Sed forest compared to Dipt-Ig forest with 1,069 trees (16%) and 313 (12%) respectively. However, two dipterocarp species were found only in Dipt-Ig forests namely *Neobalanocarpus hemii* (Chengal) and *Shorea resinosa* (Meranti belang). Another non-dipterocarp family identified from heavy hardwood group in Dipt-Ig forests was *Instsia palembanica species.*

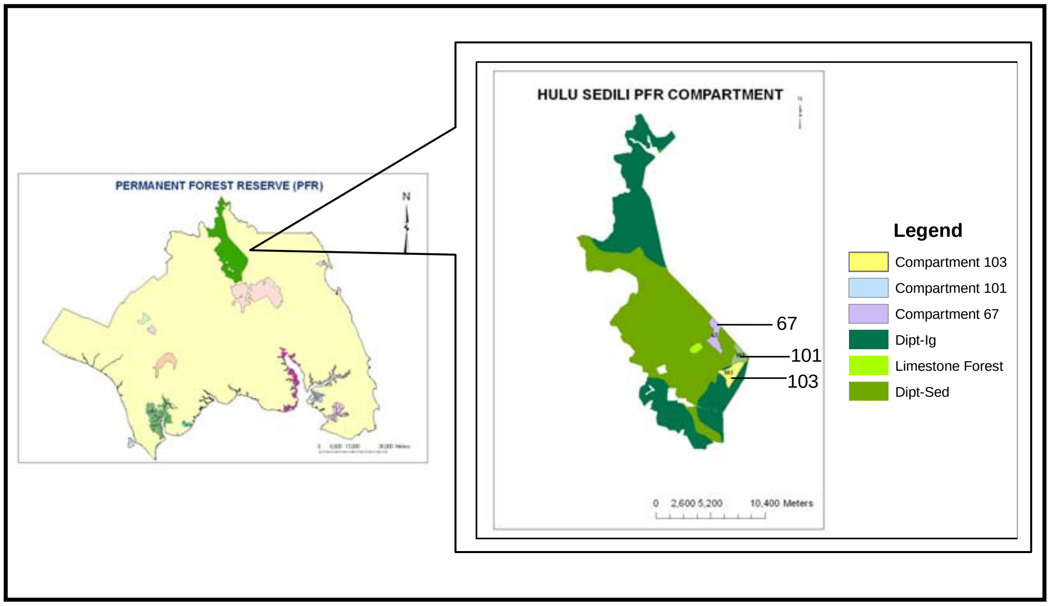

Fig. 5: The compartments of new forest classes for Hulu Sedili Permanent Forest Reserve

Table 3 The species dominancy in a new forest class with the total number of trees according to dbh class

Forest Class	Species	Vernacular Name	Total of dbh Class (tree no.) 15.00 - 29.99	30.00 - 44.99	> 50.00	Total	%
	Syzygium spp.	Kelat	817	374	110	1301	19.6
	Elateriospermum tapos	Perah	272	296	88	658	9.92
	Lauraceae	Medang	238	172	64	479	7.2
	Sapotaceae	Nyatoh	158	138	37	333	5.02
Dipt-Sed Forest	*Canarium* spp.	Kedondong	163	105	49	317	4.78
Compt.67 and 101	Annonaceae	Mempisang	152	37	10	199	3.00
(424.4 ha)	*Dryobalanops sumatrensis*	Kapur	50	52	45	147	2.22
	Cotylelobium spp.	Resak	79	56	5	140	2.11
	Castanopsis spp.	Berangan	33	67	23	123	1.85
	Others		965	753	353	2939	44.29
		Grand Total				6636	100.00
	Syzygium spp.	Kelat	301	178	59	538	20.38
	Macaranga spp.	Mahang	262	12	2	296	11.21
	Elateriospermum tapos	Perah	105	129	57	291	11.02
Dipt-Ig Forest	Lauraceae	Medang	72	36	16	124	4.70
Compt.103	*Canarium* spp.	Kedondong	58	48	14	120	4.55
(262 ha)	*Artocarpus* spp.	Keledang bangkong	80	2	0	82	3.11
	Gymnacranthera spp.	Penarahan	55	22	5	82	3.11
	Sapotaceae	Nyatoh	34	25	11	70	2.65
	Gluta elegans	Rengas	24	24	8	56	2.12
	Others		516	347	118	981	37.16
		Grand Total				2640	100.00

IV. CONCLUSION

Distribution of vegetation for the both of these two new forest classes developed shows several similarities because of igneous rocks is a primary mineral and under the suitable environment condition, igneous rocks can change into sedimentary/ metamorphic rocks (Richard, 1992). GIS has proven the capability to create new forest class by fusing vegetation and lithology characteristics from three forest classes into ten forest classes. This study observed that there are certain species dominancy differences between Dipterocarp Sedimentary and Dipterocarp Igneous forest even though from same forest type areas. This indicates that lithology has impact of species presence in an area. This finding is similar to Taylor and Warrel (1991) where they found out that growth response to application of phosphate was also influenced by lithology. Further study need to be carried out to verify the dominancy species over the study area and it is possible to increase the reliability of species dominancy identification by using airborne hyperspectral data technique for precision forestry approach.

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