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PASOH: 37 YEARS LATER

Proceedings of The Pasoh Seminar 2022

Forest Research Institute Malaysia (FRIM)

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INSTITUT PENYELIDIKAN PERHUTANAN MALAYSIA
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Foreword

Dr Wan Mohd Shukri Wan Ahmad
Advisor of the Pasoh Seminar 2022

Forest generally plays crucial roles in maintaining biodiversity maintenance and regulating the climate regulation. Besides that, a healthy forest ecosystem may provide ecological needs such as shelter, food resources, and breeding ground for wildlife and endemic plant species. To apprehend the natural forest trees population dynamics, FRIM, in collaboration with other agencies initiated a long-term research programme based in Pasoh Research Forest. Established in the early 1970s, the Pasoh Research Forest has attracted many local and foreign scientists to conduct long-term collaborative studies—, of which some are still on-going—, on biodiversity, sustainable management of tropical forests, and the role of tropical forests as carbon sinks. An area of 1,840 ha of Pasoh Forest Reserve was gazetted as a research forest by the Forestry Department Peninsular Malaysia in 1977. In 1985, the Forest Research Institute Malaysia (FRIM) in collaboration with the National Science Foundation and the Smithsonian Tropical Research Institute (STRI) successfully established a 50-ha permanent research plot amidst the lush greenery of the Pasoh Forest Reserve in Negeri Sembilan. Managed by FRIM along with the Center for Tropical Forest Science (CTFS), the plot is now one of the 74 large network of tree demographic plots located all over the world.

Since then, the plot has been the site of several other lowland dipterocarp forest research, with topics ranging from population dynamics and biodiversity to the increasingly important issue of climate change. ForestGEO (Forest Global Earth Observatory) formerly known as the Center for Tropical Forest Science (CTFS)- a centre under Smithsonian Tropical Research Institute (STRI) and Arnold Arboretum from the United States; The National Institute for Environmental Studies (NIES) and Forestry and Forest Product Research Institute (FFPRI) from Japan, and many others have made a significant contribution to these research efforts.

This year, Pasoh celebrates its 37th year of collaborative research, which includes collaborations with significant local and international institutions around the world. In regards to this, a conference which entitled "Pasoh: 37 Years Later" has been organized by FRIM on 25th May 2022. This seminar began in 2010, continued in 2013, and wrapped in 2015. The conference was originally scheduled for 2020, however it was delayed due to the COVID -19 pandemic. This seminar provided a venue for people working in Pasoh Forest Reserve to present their findings as well as to share their perspectives and experiences within interested parties in forestry sector.

This year's Pasoh Seminar 2022 has a keynote speaker as well as seven engaging sessions from experts from diverse fields. Participants will have the opportunity to explore the future of forestry in Negeri Sembilan, notably in the Pasoh Forest Reserve, as well as research opportunities. An oral presentation will be followed by a moderated question and answer session at the seminar. Several areas of forestry will be discussed during this lecture, including forest management, forest dynamics, hydrology, fauna biodiversity, and technology in the present forestry sector. In order to compile all the research findings and recent outputs of all the active projects conducted in Pasoh research plot an e-proceeding will be published. This e-proceeding will be divided into 3 parts which are; the extended abstracts by all oral presenters selected to present in this conference, the rapporteur notes and lastly the summary of the conference. The proceedings are targeted as future reference and guidance to all researchers, lecturers and students in regards to this field.

Last but not least, I believe this seminar will serve as a forum for foresters, researchers, and anybody interested in the subjects of forestry and the environment to interact and meet experts from various fields. It also is a fundamental effort to the beginning and expansion of the Pasoh 50-hectare plot as a world-class centre for lowland tropical forest research in future. I'd like to thank everyone who attended this seminar and contributed to a meaningful discussion. I am especially grateful to the members of the organizing committee for their unwavering efforts in making the seminar and e-proceedings a huge success.

Acknowledgements

We would like to express our gratitude to the Kementerian Tanah dan Sumber Asli (KeTSA) for granting permission to carry on this seminar despite the fact that it was given such a short notice. The organizing committee would like to thank Forest Research Institute Malaysia (FRIM) for their guidance and support while providing a venue and amenities on the scheduled day. Not to forget the officers from the Forest and Environment Divisions, FRIM for their time, energy, and efforts in putting this event together. The organizing committee also wishes to express its gratitude to all of the esteemed speakers for their cooperation in preparing the slides and proceedings. Special thanks to Dr Stuart J. Davies and Dr Manabu Onuma, who traveled all the way from their homeland to Malaysia for this seminar. The enthusiastic and active participation of all of the participants from various agencies has also made this seminar successful - Jabatan Perhutanan Negeri Sembilan (JPNNS), Unit Perancangan Ekonomi Negeri Sembilan, Akademi Sains Malaysia (ASM), Universiti Putra Malaysia (UPM),Universiti Malaysia Terengganu (UMT), Institut Biodiversiti Tropika dan Pembangunan Lestari (IBTPL), Universiti Sultan Zainal Abidin (UniSZA), Universiti Teknologi Malaysia (UiTM), Universiti Tun Hussein Onn (UTHM),Universiti Kebangsaan Malaysia (UKM), Universiti Teknologi Malaysia (UTM) and FRIM research officers. This seminar was aided by a grant from the Economic Planning Unit's (EPU)-RMK12: Pemantauan dan Dokumentasi Plot Penyelidikan Jangka Panjang.

Extended Abstract

CADANGAN PENUBUHAN PUSAT KECEMERLANGAN PERHUTANAN HUTAN TANAH PAMAH TROPIKA NEGARA, PASOH, NEGERI SEMBILAN

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ABSTRAK

Malaysia merupakan sebuah negara hutan tropika dan mengiktiraf sumber hutan semula jadi sebagai sumber yang penting dalam menyumbang kepada sosioekonomi negara dan kesejahteraan alam sekitar. Di Semenanjung Malaysia, sejumlah 43 peratus kawasan Hutan Simpanan Kekal masih melitupi negara, manakala di Negeri Sembilan dilitupi oleh 23 peratus dari keluasan negeri iaitu seluas 155,102 Ha. Selain itu juga Malaysia komited dalam melaksanakan pengurusan hutan secara berkekalan untuk memastikan negara terus menikmati segala faedah yang diperolehi dari sumber hutan secara berterusan. Di bawah Perkara 74 (2) Perlembagaan Persekutuan, memperuntukkan hutan di bawah bidang kuasa Kerajaan Negeri dimana setiap negeri mempunyai kuasa dan hak untuk menggubal undang-undang dan menguruskan dasar perhutanan di negeri masing-masing. Kuasa eksekutif Kerajaan Persekutuan pula terhad kepada memberi nasihat, bantuan teknikal, latihan, penyelidikan dan pembangunan dalam sektor perhutanan kepada negeri-negeri. Dalam hubungan ini, kerjasama rapat di antara Kerajaan Persekutuan dengan Kerajaan Negeri mengenai hal-hal perhutanan dapat diseiringkan bagi memaksimumkan penggunaan hutan sebagai khazanah negara. Hutan pada masa kini tidak lagi dianggap sebagai sumber untuk pengeluaran kayu-kayan semata-mata, tetapi berfungsi dalam pemeliharaan kepelbagaian biologi, kestabilan alam sekitar dan pengekalan budaya masyarakat. Pihak Kerajaan Negeri Sembilan menyedari pengurusan hutan perlu mengambil perhatian terhadap isu-isu baharu yang sedang dihadapi oleh sektor perhutanan seperti sekuriti air dan makanan, perubahan iklim, kestabilan alam sekitar dan meningkatkan taraf kehidupan rakyat. Di atas kesedaran itu, Jabatan Perhutanan Negeri Sembilan mengambil peranan bagi memantapkan pengurusan hutan negeri selari dengan kehendak dan dasar Kerajaan Persekutuan. Melalui satu kerjasama yang lebih mantap, Stesen Penyelidikan FRIM Pasoh yang sediada dan akan dinaiktaraf semasa Rancangan Malaysia ke-12 (RMK-12) dapat diberi jenama dan nafas baharu kepada Pusat Kecemerlangan Perhutanan Hutan Tanah Pamah Tropika Negara, Pasoh, Negeri Sembilan. Peranan dan fungsipusat ini tidak lagi semata-mata tertumpu kepada penyelidikan sahaja, tetapi akan lebih berkembang kepada tambahan fungsi meliputi pelancongan dan pendidikan agar dapat menghasilkan perkhidmatan hutan dengan mengambil kira kelestarian aspek sosial, ekonomi, ekologi dan alam sekitar. Fungsi pusat ini diharap akan dapat menonjolkan peranan sebenar Hutan Simpan Kekal Pasoh itu sendiri dalam kecemerlangan pengurusan hutan Malaysia di mata dunia.

Keywords: Pusat Kecemerlangan; Hutan Pamah Tropika

COMPARING THE EFFECTIVENESS OF CAMERA TRAPPING VS ENVIRONMENTAL DNA FOR BIODIVERSITY ASSESMENTS IN PASOH

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ABSTRACT

One of the characteristics of wildlife in tropical forests is the presence of several species whose activity patterns are specialized temporally (diurnal to nocturnal) and spatially (ground level to canopy). Therefore, it is difficult to evaluate biodiversity by direct observation. Therefore, camera trapping and environmental DNA analysis are very effective methods for assessing biodiversity in tropical forests. In this report, we compare the effectiveness of both methods. Camera trapping throughout the Pasoh Forest Reserve which is located 70 km southeast from Kuala Lumpur was conducted. The diversity of various wildlife has been reported in the reserve: 121 species of mammals, 235 species of birds, 49 species of reptiles, and 43 species of amphibian. Camera trap pictures were taken from 47 trap locations throughout the reserve. Bushnell TROPHYCAM (Model 119636) was used for the present survey. 47 camera traps were set in the reserved approximately 2 km interval from April 2016 to May 2018. 58 species were observed in 119,383 photos and the most common species was Wild boar (*Sus scrofa*). Apart from that,12 species of IUCN threatened species were observed. Subsequently, environmental DNA analysis was applied to evaluate species diversity using surface runoff collected at nine locations in the reserve. The result of the analysis showed that the sequences from 86 species were definitely from the environmental DNA. Of the 86 species, 7 species were common to the species detected by the camera trap. Meanwhile, the sequences of bats and small birds were detected from the environmental DNA. The results show that environmental DNA from surface runoff can be used to obtain distribution information on species that cannot be captured by camera trapping. However, reliable sequence database is essential.

Keywords: Camera trapping; Environmental DNA; Surface Runoff

CHANGES IN STAND STRUCTURE AND DYNAMICS OF TREES IN PASOH FOREST RESERVE OVER 25 YEARS

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ABSTRACT

Southeast Asian forests are experiencing environmental changes, but how forests are responding to these drivers through time has not been quantified. Using 25 years of census data (1986 to 2010) from the 50 ha plot in the Pasoh Forest Reserve (FR), we examined changes in stand structure and dynamics of trees in relation to habitats in Pasoh FR, Negeri Sembilan, Peninsular Malaysia. We found that the abundance of trees decreased by 19.33%, with the greatest declines seen in trees <2 cm in dbh, which decreased by 43%. There were no significant changes in aboveground biomass, with a mean across years of 332.59 t/ha. Mortality rates ranged from 1.16% to 2.46% per year while recruitment rates ranged from 0.59% to 2.32%, with the highest rates recorded from 2000 to 2005. Growth rates decreased in the first 15 years from 1.46 mm/year to 0.56 mm/year and increased from 2000 to 2010. Several severe droughts in mid-2004 and early 2005 were likely contributed to the high mortality rate in 2005 and contributed to more open canopy that allowed seedlings to grow and reach 1.0 cm to be recruited in 2005 and also promotes growth of trees. Big trees (dbh ≥ 30 cm) had the highest mortality rate in swamp in 2000 census and alluvial in 2005 census. Big trees are more vulnerable to environmental changes such as drought that caused dropped in soil moisture because they are taller and have higher probability of hydraulic failure and caused them to die. They are also more vulnerable to wind throw due to decrement in stability. The forest within the Pasoh 50 ha plot is often considered to be homogenous. However, our analysis shows that there is considerable heterogeneity in demographic dynamics that may be attributable to interspecific and size-related variation in the responses of trees to interactions between climate and habitat, which may produce directional changes in forest processes.

Keywords: Forest dynamics; Tree demography; Forest structure; Pasoh

1.0 INTRODUCTION

Tropical rainforests are extremely valuable. Besides being a habitat to thousands of species of flora and fauna, tropical rainforests also provide many ecosystem services. They play a very important role in combating climate change by absorbing carbon from atmosphere through photosynthesis and pooling them in their biomass. However, we still have a limited understanding of their dynamics and their capacity to adapt to the environmental changes caused by natural or non-natural disturbances.

In order to understand this, a large scale and long-term monitoring approaches is required. In this paper, using the long term demographic data that we obtained from Pasoh 50 ha plot, we aimed to quantify long-term trends in the demographic dynamics of the forest to discover whether they are related to environmental drivers like climate change which is operating at present or they may be just a stochastic variation.

2.0 MATERIALS AND METHODS

2.1 Plot and census

The study was conducted using a 25-year data derived from the Pasoh 50 ha Plot. This plot is located within the 600 ha of pristine Pasoh Research Forest, Negeri Sembilan, Peninsular Malaysia. It was established in 1985 by FRIM in collaboration with Smithsonian Tropical Research Institute (STRI), United States and Arnold Arboretum of Harvard University. The first census of the plot was conducted in 1986 right after its establishment recorded 335,347 trees from 814 species. The recensus then being conducted in a 5-year interval in 1990, 1995, 2000, 2005, 2010, 2015 and 2022. The data used for this study is from the first census in 1986 until the sixth census in 2010.

The establishment and enumeration of this plot adhere to the standard protocol developed by Forest Global Earth Observatory (ForestGEO) where all stems with the diameter at breast height (DBH) 1.0 cm and above were tagged, mapped, measured and identified to species level. The detail of the protocol was recounted in Manokaran et al. (1990).

2.2 Habitat

The Pasoh 50 ha Plot has a very restricted topographic variation with the difference in elevation of only 25.5 m (Marryanna et al. 2012). This plot has four predefined discreet habitats described based on soil series properties (Wan Juliana, 2001; Yamashita & Takeda, 2003) and drainage conditions (Marryanna et al. 2012) which are swamp, alluvial, slope and ridge as illustrated in Figure 1. About 50% of the plot is covered by alluvial habitat. This habitat is relatively well drained but some part of this habitat will be flooded during rainy season. Swamp habitat is constantly damp.. Slopes and ridges are relatively poorer in soil nutrient.

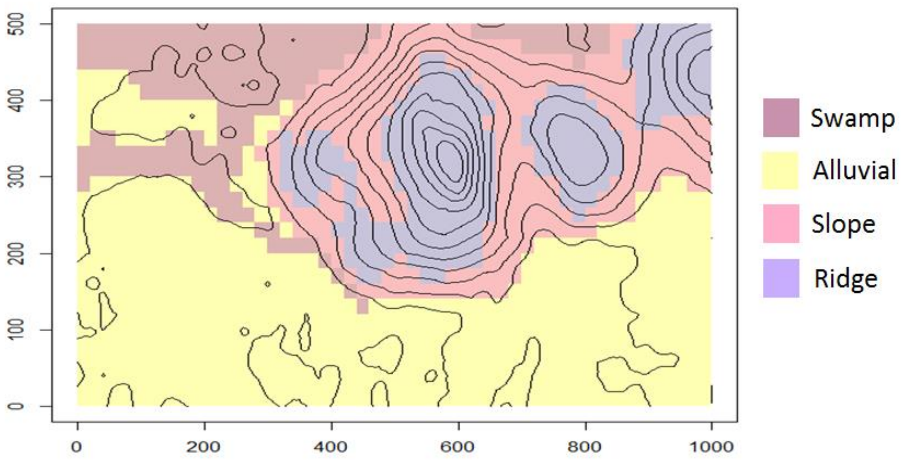

Figure 1. Topographic and habitat distribution map of Pasoh 50 ha plot.

2.3 Climate

Pasoh FR also experienced variation in climate condition namely temperature and rainfall which were monitored above the forest canopy at 52 m height of observation tower located about 2 km from the 50 ha plot (Kosugi et al. 2012). The plot generally receives mean annual rainfall of 1,804 mm (Kosugi et al. 2012). There were several severe droughts recorded in between Mac 1995 until December 2010 as shown in Figure 2. Drought signals calculated as the total rainfall over 30 days subtracted from 40 mm. If the value is negative, it will set to zero (Chen at al. 2017).

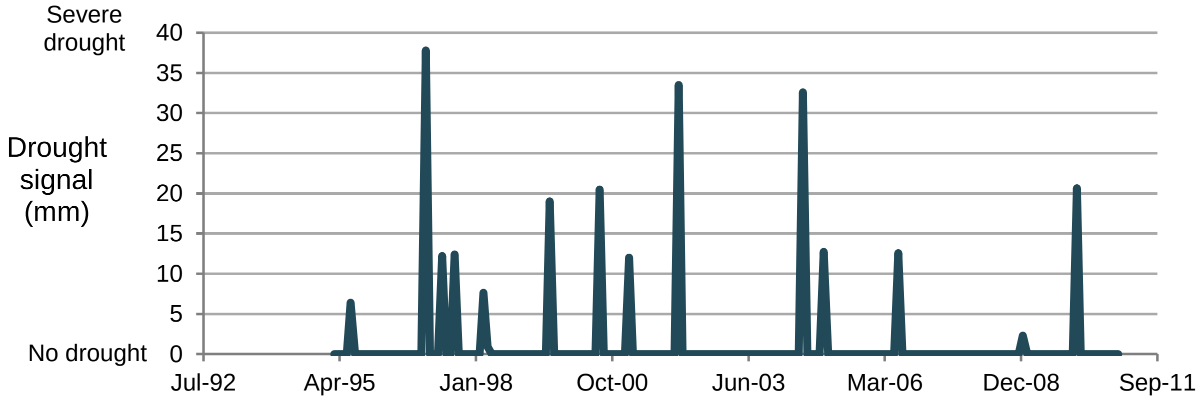

Figure 2. Drought signal graph of Pasoh FR.

This forest also experienced variation in wind speed. Being an isolated forest surrounded by oil palm plantation, the formation of large forest gaps by wind throw is a common feature at Pasoh. One catastrophic wind throw has been recorded in the south –west part of the plot in September 2004 which caused a 9.5% loss in basal area at 15 ha stand of the Pasoh 50 ha plot (Yoneda et al. 2005)

2.4 Demographic analysis

All the analysis was conducted using statistical program R version 1.1.456. The biomass was calculated using equation developed by Chave et al. (2014) where the wood density data was automatically obtained from the CTFS wood-density table (http://ctfs.arnarb.harvard.edu/Public/Datasets). The calculation of mortality, recruitment and growth rates were done using CTFSRPackage (http://ctfs.si.edu/Public/CTFSRPackage/#). The annual rates are the mean of total change within the duration between censuses.

3.0 RESULTS AND DISCUSSION

3.1 Stem abundance and above ground biomass

The abundance of all stems in the plot decreased significantly by 19.33% from 335,347 stems in 1986 to 270,539 stems in 2010. Greatest declines observed in small stems with DBH < 2 cm which decreased by 43%. No significant changes were observed in other DBH classes. The significant decreased in abundance of small stems are assumed to be related to the wild boar (*Sus scrofa*) population in the forest. This species has been recorded as the most common megafaunal species in Pasoh FR since the early 1990s due to the supplemental food from the surrounding oil palm plantation and lack of hunting activities by human (Luskin et al., 2017).

Wild boars built their birthing nest from tree sapling and each nest contains an average of 267 tree saplings. Their harvesting for birthing nests may exceed 170,000 trees and saplings per year over an area of 2 km² (Ickes, Paciorek & Thomas, 2005) and this will definitely affect the dynamics of tree sapling in the forest.

The above ground biomass calculated in the 50 ha plot shows no directional change. The value ranged from 324.14 t/ha to 346.98 t/ha with the value of 332.59 t/ha which corresponded to the amount estimated for lowland tropical rainforests.

3.2 Demographic rates

At plot level, mortality rates ranged from 1.16% to 2.46% per year while recruitment rates ranged from 0.59% to 2.32%, with the highest rate recorded in 2005 census. Mortality rate increased in the first 15 years while the growth rates decreased significantly in the first 10 years but increased from 2000 to 2010. The recruitment rate fluctuated over the study period. In between 2000 and 2005, there were several severe droughts recorded in this forest that might have contributed to the high mortality rate recorded in 2005 census. The mortality, especially of big trees attributed to more opened canopy which allowed seedlings to grow up to 1.0 cm in diameter to be recruited in 2005 census. This condition also promotes growth of trees.

The mortality and growth of trees in the Pasoh 50 ha plot was not habitat-specific because the trees in all four habitats showed a similar pattern of mortality and growth throughout the study period. But the mortality was significantly higher for big trees with DBH $\geq$ 30 cm in swamp (2000 census) and alluvial (2005 census). Swamp habitat in the plot is constantly damp. During droughts, the soil moisture in this habitat will drop tremendously. Therefore, making specialized trees in this habitat which is known to be less adaptative to poor soil moisture affected by this condition. Big trees will be affected because they are taller and need more energy to pump water all the way up to the top. And they also have a higher probability of hydraulic failure and cause them to die. Alluvial habitat consists of wet soil. Tall trees especially when they are rooted in wet soil, are more vulnerable to wind throw due to their stability. Plus, the trees are thought to be shallowly rooted thus it increased their vulnerability to wind throw.

4.0 CONCLUSION

Tropical rainforests within the Pasoh 50 ha plot is often considered to be homogenous. However, this study shows that there is considerable heterogeneity in demographic dynamics that may be attributable to interspecific and size-related variation in the responses of trees to interactions between climate and habitat, which may produce directional changes in forest processes.

REFERENCES

1. Chave, J., Réjou-Méchain, M., Burquez, A., Chidumayo, E., Colgan, M., Delitti, W., Duque, A., Eid, T., Fearnside, P., Goodman, R., Henry, M., Martinez-Yrizar, A., Mugasha, W., Muller-Landau, H., Mencuccini, M., Nelson, B., Ngomanda, A., Nogueira, E., Ortiz, E. & Vieilledent, G. (2014). Improved allometric models to estimate the aboveground biomass of tropical trees. *Global Change Biology*. 20. 3177-3190. 10.1111/gcb.12629.
2. Chen, Y-Y., Satake, A., Sun, I., Kosugi, Y., Tani, M., Numata, S., Hubbell, S.P, Fletcher, C., Nur Supardi, M.N. & Wright, S.J. (2017). Species-specific flowering cues among general flowering *Shorea* species at the Pasoh Research Forest, Malaysia. *Journal of Ecology*, 1-13. https://doi.org/10.1111/1365-2745.12836
3. Ickes, K., Paciorek, C.J.,& Thomas, S.C. (2005). Impacts of nest construction by native pigs (*Sus scrofa*) on lowland Malysian rain forest saplings. *Ecology*, 86(6), 1540-1547. https://doi.org/10.1890/04-0867
4. Kosugi, Y., Takanashi, S., Tani, M., Ohkubo, S., Matsuo, N., Itoh, M., Noguchi, S., & Nik, A. R. (2012). Effect of inter-annual climate variability on evapotranspiration and canopy CO 2 exchange of a tropical rainforest in Peninsular Malaysia. *Journal of Forest Research*, *17*(3), 227–240. https://doi.org/10.1007/s10310-010-0235-4
5. Luskin, M.S., Brashares, J.S., Ickes, K., Sun, I-F., Fletcher, C., Wringht, S.J. & Potts, M.D. (2017). Cross-boundary subsidy cascades from oil palm degrade distant tropical forests. *Nature Communications*, 8(1), 2231. https://doi.org/10.1038/s41467-017-01920-7
6. Manokaran, N., LaFrankie, J.V., Kochummen, K.M., Quah, E.S., Klahn, J.E., Ashton, P.S. & Hubbell, S.P. 1990. Methoddology for the fifty-hectare research plot at Pasoh Forest Reserve. Research Pamphlet No. 104. Forest Research Institute Malaysia, Kepong.
7. Marryanna, L., Siti Aisah, A. K., & Mohd, M. S. (2012). Association between soil mosisture gradient and tree distribution in lowland dipterocarp forest at Pasoh, Malaysia. *Malaysian Journal of Soil Science*, *16*(1), 23–42.
8. Wan Juliana, W. A. (2001). Habitat specialisation of tree species in a Malaysian tropical rain forest. University of Aberdeen.
9. Yamashita, T., & Takeda, H. (2003). Soil nutrient flux in relation to trenching effects under two dipterocarp forest sites. In T. Okuda, N. Manokaran, Y. Matsumoto, K. Niiyama, S. C. Thomas, & P. S. Ashton (Eds.), *Pasoh: Ecology of a Lowland Rain Forest in Southeast Asia* (pp. 59–72). Springer-Verlag.
10. Yoneda, T., Mizunaga, H., Tashiro, Y., Okuda, T. & Kadir, W.R.W. 2005. Effects of a storm on NEP in a tropical rainforest, Pasoh Forset Reserve. Progress report Joint Research Project on Tropical Forest Ecology and Biodiversity 2005. 17-23. Organizing committee of the NIES/FRIM/UPM joint research project.

GAS EXCHANGE OF SOUTHEAST ASIAN TROPICAL FOREST: WATER SOURCES FOR EVAPOTRANSPIRATION DEMAND IN PASOH FOREST RESERVE PENINSULAR MALAYSIA

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ABSTRACT

Tropical rainforests are one of the most important ecosystems for regulating the effects of climate change. In tropical rainforests, the amount of rainfall and changes in rainfall patterns are of great importance. Shifts in rainfall patterns can subsequently affect soil moisture, evapotranspiration (ET), stand dynamics and many other forest functions. It is well known that the tropics are rich in large amounts of annual rainfall. However, there are also areas with low rainfall. Soil water content is one of the regulators of the forest ecosystem that receives less attention but plays an important role in regulating the hydrological cycle in tropical forests. The stability of ET in dry periods and in the dry season can be observed in tropical rainforests. The stability of ET should be due to stable water sources in the soil throughout the seasons. However, less research has been done on the water sources and soil moisture conditions that support the stability of ET. Therefore, in this study, we investigated the water sources and soil water status that maintain the stability of ET in lowland dipterocarp forests in Pasoh, Malaysia. Stable isotope analysis of water sources was obtained from trees, soils, rivers and rainfall. The results of the study show that under normal climatic conditions and during the rainy season, most forest trees tend to use the water content of the soil at the surface. If there is a drought for several months, the water from this surface dries up due to water consumption by the trees and evaporation. Therefore, the tree absorbs water that is firmly connected to the soil. At least more than four months of rainfall added to groundwater must meet the tree's evapotranspiration needs during the long dry season. Tropical rainforests contain abundant moisture. However, after studying the water sources for ET in a Southeast Asian tropical rainforest in Peninsular Malaysia, it can be assumed that this tropical rainforest is under water stress, especially during dry seasons. The temporal and spatial distribution of soil moisture affects ET, water sources and stand dynamics differently, suggest that a simple model or simulation of the impacts of future climate change on tropical rainforests without field-collected data will result in poor estimates. This study will contribute to our understanding of tropical rainforest hydrology and provide baseline data describing the stable isotope signatures of precipitation, soil, plants and river water for further research at this study site. The stable isotope information obtained from this study is new information for the Pasoh Forest Reserve and possibly also for the forests in Peninsular Malaysia. The baseline data obtained in this study is important in environmental modelling for various applications, including water use and forest conservation.

Keywords: Eddy Covariance, Vapour Pressure Deficit, Stable Isotope, Drought, Forest

1.0 INTRODUCTION

The terrestrial hydrological cycle is strongly influenced by forest evapotranspiration (ET) and is vulnerable to the impact of increasing droughts (Diao et al., 2020). The tropical forest ecosystem exhibits remarkable characteristics of ET, with a strong constancy of ET during dry seasons in tropical climates (Tani et al., 2003). This feature has been consistently demonstrated by flux studies in the tropical rainforests of the Amazon and Malaysia, and in seasonal forests in Thailand and Cambodia (e.g. Tani et al., 2003). This highlights the need to understand the interactions between forests ET and drought. Extensive studies have been conducted on water and energy exchange with the atmosphere in the area, using both traditional hydro-meteorological and micrometeorological techniques (Calder et al., 1986; Tani et al., 2003) and the eddy covariance method (EC) (Takanashi et al., 2010; Kosugi et al., 2012).

The studies on the rates of ET in the Amazon rainforest found that they change depending on drought conditions (da Rocha et al., 2004 and Negrón Juárez et al., 2007). Observations in Manaus and Santarem, Brazil, showed that ET increased in the dry season with 1,307 mm (Manaus) and 1,274 mm (Santarem) (da Costa et al., 2010). In the Amazon rainforest, there are distinct dry and wet periods, which is not the case in the equatorial Southeast Asian rainforests, although there are dry and wet periods as part of the seasonal variations, which vary considerably from year to year (Tani et al., 2003; Kosugi et al., 2008). The lower magnitudes and short-term droughts generally increased forest ET, and in some cases, ET even exceeded rainfall during droughts (Diao et al., 2020).

In tropical forests, water supply is mainly derived from rainfall. Therefore, the extent and duration of droughts are crucial for forest ET responses to drought. Hence, to understand the soil water balance in tropical forests, we need to assess ET by estimating forest water use. This study aims to determine the forest water sources used by the forest ET during normal and severe drought in a dipterocarp lowland forest, using a stable isotope signature.

2.0 MATERIALS AND METHODS

2.1 Site description

The study was conducted in a lowland dipterocarp forest within the 6 hectares of Pasoh FR at 2° 58' N and 102° 18' E at an elevation of 75 to 150 metres above sea level (m.a.s.l.). The maximum depth of the taproots was about 4 m (Niiyama et al., 2010); most of the fine roots were in the A horizon (Amir Husni, 1989). Canopy height ranges from 30 to 40 m, with emergent trees ~45 m tall. The rainfall distribution in Pasoh FR is of short duration and high intensity, with an average annual rainfall of 1,805 mm (1995-2015) and an average annual air temperature of 25.4°C (1997-2011) (Noguchi et al., 2016; Marryanna et al., 2017).

2.2 Soil water content and evapotranspiration

Volumetric soil water content (VSWC) was measured with Time Domain Reflectometry (TDR) sensors (CS615 or CS616, Campbell Scientific) at 0.1, 0.2 and 0.3 m depths at three points around the tower and recorded at 30-min intervals (Noguchi et al., 2016). Eddy covariance fluxes (EC) of sensible heat and water vapour were measured at a height of 54 m on the flux tower. ET measured from the flux tower included transpiration, interception evaporation and soil evaporation. Four years of data from 1 January 2012 to 31 December 2015 were used in this study, which is consistent with the water samples used for isotope analysis. The pre-precipitation index (API60) is also used as the wetness index for the study area.

2.3 Precipitation, stream, plants, and soil sampling

Rainwater samples for isotope analysis were collected daily between 8:00and 9:00 am from September 2012 to December 2015 from a storage rain gauge installed at the monitoring station. Stream water samples were collected on 19 occasions between January 2013 and December 2015 from the main stream between the 6-ha plot and the 50-ha plot (approximately 2000 m from the flux tower). Soil and plant samples were collected from the flux tower area in Pasoh FR. Four sampling sessions were conducted for eight plant species of different sizes and soils at different depths.

2.4 Stable Isotope analysis

We use hydrogen and oxygen isotopes to determine the compartmentalisation of water in the forest. Hydrogen and oxygen isotopes (δ2H and δ18O) are powerful tools to determine the water resources of plants under different environmental conditions (Evaristo et al., 2015). Water extraction was performed using a cryogenic vacuum distillation system (West et al., 2006), which is the most commonly used method for extracting plant and soil water (Orlowski et al., 2013). A cavity ring-down spectrometer (CRDS) (L2120-i, Picarro, CA, USA) was used to analyse the isotopic composition of the samples. The notation delta (δ) indicates the value of the isotope ratio of a water sample in relation to the Vienna Standard Mean Ocean Water (VSMOW).

3.0 RESULTS AND DISCUSSION

3.1 Rainfall characteristics in Pasoh FR

Pasoh FR is subject to seasonal rainfall due to monsoonal events. These conditions form a bimodal rainfall pattern that usually peaks in April and November (Figure 1). Sometimes rainfall patterns change due to annual variations, for example in the case of ENSO. The average annual rainfall for 4 years (2012 - 2015) was 1720 mm/year. Compared to other tropical forests in Lambir, Malaysia and Manaus, Brazil, Pasoh has recorded the lowest annual rainfall of 1855 mm/year in nine years. If a monthly rainfall of less than 100 mm is considered a dry month (lack of water), Manaus, is drier in terms of length of dry spell. Meanwhile in terms of annual rainfall, Pasoh is considered a drier place. The daily rainfall ranged from 1 to 5 mm per day for the northeast and southeast monsoons. Most of the rainfall occurred in the late afternoon with a duration of 1 to 2 hours. The maximum intensity is mostly 1 to 3 mm per 30 minutes and can occasionally reach 20 mm per 30 minutes.

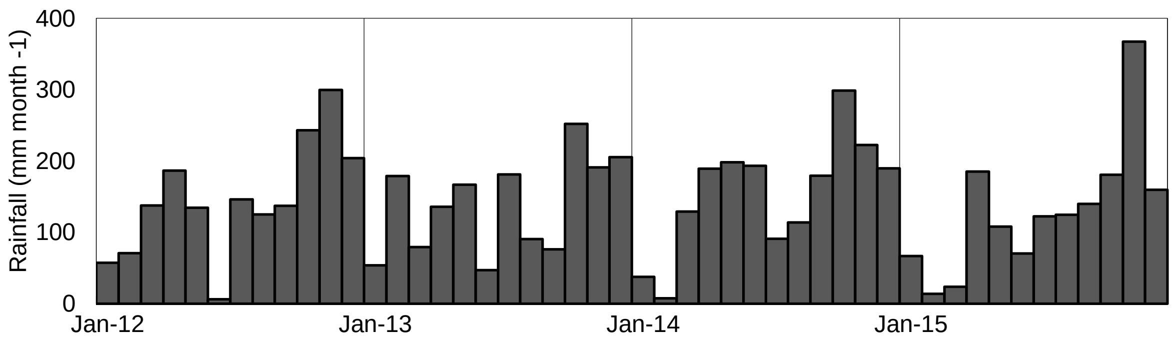

Figure 1. Monthly rainfall from 2012 to 2015 for Pasoh Forest Reserve

3.2 The influence of soil moisture on evapotranspiration and water source

VSWC at 0.5 m declined in February and March of 2014 and 2015, coinciding with very low monthly rainfall. The lowest rainfall in these months was 7.7 mm per month with API60 of 0.2 mm and VSWC of 0.288 m3 m-3. The ET is believed to decrease during the dry season due to low water inflow, but it did not decrease significantly during the dry season either. The percentage ratio of ET to rainfall varied from 62% in 2014 to 74% in 2015 (Figure 2). The annual average of ET for four years was 1182 mm per year. In general, ET shows a stable trend, although there are some declining values in the rainy season at the end of the year. Even in the driest period, the water evaporated daily from the forests with an average of 3 mm (sd 0.86) per day. The running average is calculated by adding up all the data points and then dividing the sum by the number of data points. This is a repeatable calculation. The temporal isotope signature of rainwater, stream water and soil water give an overview of how the water is partitioned for the different uses in the forest ecosystem (Figure 3). The stream water shows a similar fluctuation as the rainwater, indicating that the proportion of newly draining water in this forest is large due to the intense and short-lived rainfall as well as the clay soil with low permeability. This situation indicates the presence of overland flow, which is consistent with the earlier findings of Peh and Leigh (1978).

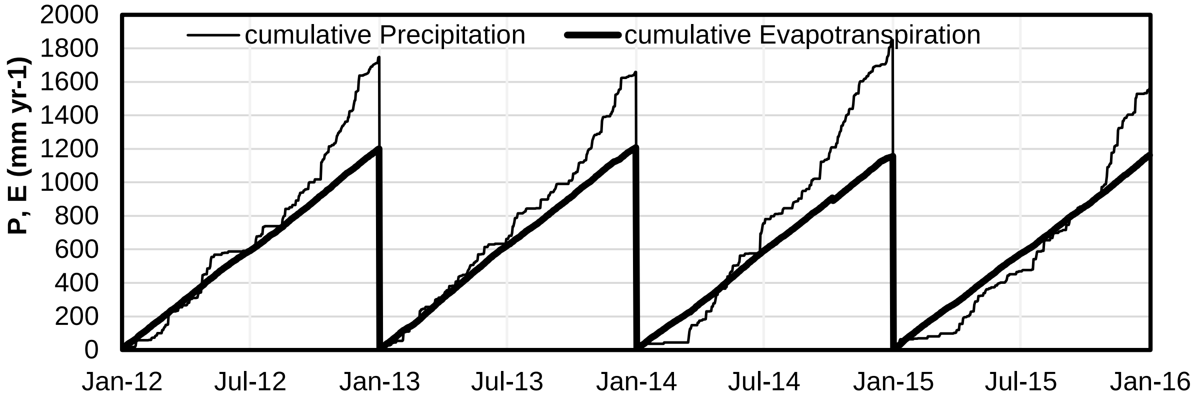

Figure 2. The cumulative evapotranspiration to rainfall in Pasoh FR from 2012 to 2015.

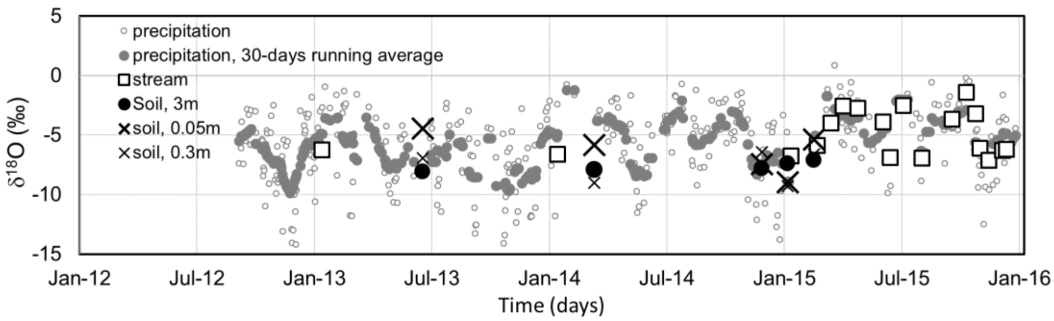

Figure 3. The isotopic signature of rainwater, soil water and stream water for Pasoh FR (2012-2015).

The estimation of possible water sources for ET needs was analysed using the previous rainfall and ET from 2012 to 2015. Two dry spells were noted from 2012 to 2015, which occurred in June 2012 and March 2014. The temporal source of water demand from ET was assessed by comparing the previous, antecedent rainfall with the demand from ET. It was found that the addition of the previous one month of rainfall was not sufficient to meet the ET demand in this forest. Even an additional water supply of two months in advance is not enough to meet the needs of the plants during the dry and very dry periods. An additional water supply for four months was still not enough to meet the needs of the plant ET during the severe dry periods in this forest. This means that the plants in this forest need a longer water supply during the severe drought, considering the rapid runoff component in this area.

4. CONCLUSION

Tropical rainforests contain abundant moisture; however, the study found that part of the tropical rainforest in Peninsular Malaysia suffers from water stress during the dry season. In Pasoh FR, the monthly ET is not only dependent on VPD and available energy but is also strongly influenced by soil moisture. In conclusion, the interaction between soil moisture and ET is very important in dry tropical forests to meet the stable ET demand. This study initiates a stable isotope approach for assessing future climate change impacts and provides new data and insights for future research development

ACKNOWLEDGEMENT

We would like to acknowledge support from the RONPAKU Fellowship grant, the Japan Society for the Promotion of Science (JSPS), JSPS KAKENHI grant number 24255014, 17H01477, and the Coca-Cola Foundation. We thank the Forestry Department Peninsular Malaysia (FDPM) and the Forest Research Institute Malaysia (FRIM) for allowing us to conduct the study in Pasoh FR.

REFERENCES

1. Diao H, Wang A, Yang H, Yuan F, Guan D, & Wu J. 2020. Responses of evapotranspiration to droughts across global forests: a systematic assessment. Can. J. For. Res. 51: 1–9 (2021) dx.doi.org/10.1139/cjfr-2019-0436
2. Calder IR, Wright IR, & Murdiyarso D. 1986. A study of evaporation from tropical rain forest-West Java. *J. Hydrol*. 89:13–31
3. Negrón Juárez RI, Hodnett MG, Fu R, Goulden ML, & Von Randow C. 2007. Control of dry season evapotranspiration over the Amazonian Forest as inferred observations at a southern Amazon Forest site. *Journal of Climate* 20: 2827–2839
4. Kosugi Y, Takanashi S, Tani M, Ohkubo S, Matsuo N, Mitani T, Tsutsumi D, & Abdul Rahim N. 2008. CO_2 exchange of tropical rainforest in Peninsular Malaysia. *Agric. For Meteorol.* 148:439–452
5. Amir Husni, M. S. 1989. Site fertility and carrying capacity in two Malaysian tropical forest reserves. University of Aberdeen. PhD Thesis. 391 pgs
6. Costa, M.H., Marcia, C.B., Sanches, L., Ana, C.M.M., Hutyra, L.R., da Rocha, H.R., Aguiar, R.G. & Araujo A.C. 2010. Atmospheric versus vegetation controls of Amazonian tropical rain forest evapotranspiration: Are the wet and seasonally dry rain forest any different? Journal of Geophysical Research, 115, G04021, https://doi.org/10.1029/2009JG001179
7. Da Rocha, H. R., Goulden, M.L., Miller, S.D., Menton, M.C., Pinto, L.D.V.O., Freitas, H.C. & Figueira, A.M.S. 2004. Seasonality of water and heat fluxes over a tropical forest in eastern Amazonia. *Ecological Application,* 14, S22–S32, https://doi.org/ 10.1890/02-6001
8. Evaristo, J., Jasechko, S. & Mcdonnell, J. J. 2015. Global separation of plant transpiration from groundwater and streamflow. *Nature*, 525, 91–94, https://doi.org/10.1038/nature14983
9. Kosugi, Y., Mitani, T., Itoh, M., Noguchi, S., Tani, M., Matsuo, N., Takanashi, S., Ohkubo, S. & Abdul Rahim, N. 2007. Spatial and temporal variation in soil respiration in a Southeast Asian tropical rainforest. *Agricultural and Forest Meteorology* 147, 35–47, https://doi.org/ 10.1016/j.agrformet.2007.06.005
10. Kosugi, Y., Takanashi, S., Tani, M., Ohkubo, S., Matsuo, N., Itoh, M., Noguchi, S. & Abdul Rahim, N. 2012a. Effect of inter-annual climate variability on evapotranspiration and canopy CO_2 exchange of a tropical rainforest in Peninsular Malaysia. *Journal of Forest Research,* 17, 227-240, https:// doi.org/10.1007/s10310–010–0235–4
11. Marryanna, L., Kosugi, Y., Itoh, M., Noguchi, S., Takanashi, S., Katsuyama, M., Tani, M. & Siti Aisah, S. 2017. Temporal variation in stable isotopes in precipitation related with

rainfall pattern in a tropical rainforest in peninsular Malaysia. *Journal of Tropical Forest Sciences* 29(3), *349–362.* https://doi.org/10.26525/jtfs2017.29.3.349362

12. Niiyama, K., Kajimoto, T., Matsuura, Y., Yamashita, T., Matsuo, N., Yashiro, Y., Azizi, R., Abd Rahman, K. & Nur Supardi, N. 2010. Estimation of root biomass based on excavation of individual root systems in a primary dipterocarp forest in Pasoh Forest Reserve, Peninsular Malaysia. *Journal of Tropical Ecology*, 26,271–284, https://doi.org/10.1017/S0266467410000040
13. Noguchi, S., Kosugi, Y., Takanashi, S., Tani, M., Niiyama, K., Siti Aisah, S. & Marryanna, L. 2016. Long term variation in soil moisture in the Pasoh Forest Reserve, a lowland tropical rain forest in Malaysia. *Journal of Tropical Forest Science*, 28, 324–333
14. Orlowski, N., Frede, H.G., Brüggemann, N. & Breuer, L. 2013. Validation and application of a cryogenic vacuum extraction system for soil and plant water extraction for isotope analysis. *Journal of Sensor and Sensor System*, 2, 179–193, https://doi.org/10.5194/jsss-2-179-2013
15. Tani, M., Abdul Rahim, N., Ohtani, Y., Yasuda, Y., Sahat, M.M., Baharuddin, K., Takanashi, S., Noguchi, S., Zulkifli, Y. & Watanabe, T. 2003. Characteristics of energy exchange and surface conductance of a tropical rain forest in Peninsular Malaysia. In: Okuda T, Manokaran N, Matsumoto Y, Niiyama K, Thomas SC, Ashton PS (eds) *Pasoh: ecology of a lowland rain forest in southeast Asia* (pp 73–88), Springer, Tokyo
16. West, A.G., Patrickson, S.J. & Ehleringer, J.R. 2006. Water extraction times for plant and soil materials used in stable isotope analysis, *Rapid Communication in Mass Spectrometry*, 20, 1317–1321, https://doi.org/10.1002/rcm.2456
17. Peh CH. (1978). Rates of sediment transport by surface wash in three forested areas of Peninsular Malaysia. Occasional paper no.3. Department of Geography, University of Malaya, Kuala Lumpur. 104 pp.
18. Takanashi S, Kosugi Y, Ohkubo S, Matsuo N, Tani M, & Abdul Rahim N. (2010). Water and heat fluxes above a lowland dipterocarp forest in Peninsular Malaysia. *Hydrological Process* 24:472–480.

HABITAT-RELATED TREE SPECIES DISTRIBUTIONS AND DIVERSITY IN PASOH LONG-TERM FOREST DYNAMICS PLOTS

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ABSTRACT

Previous studies have concluded that a majority of woody plant species demonstrate spatial aggregation, often associating with contrasting habitats defined by variation in topography, soil properties, and insolation. In a permanent 50-ha forest plot located in Pasoh Forest Reserve, Peninsular Malaysia, habitat preferences of tree species and species groups have been qualitatively described. However, plot-wide species-habitat association of Pasoh has not been statistically characterised. The present study used torus translation test to determine associations for all tree species with more than 50 stems with four discrete habitat classes defined by soil attributes. We found strong indications of species diversity being driven by niche differentiation.

Keywords: alpha diversity; beta diversity; long-term demographic plot; habitat heterogeneity; niche specialization

1.0 INTRODUCTION

Many investigations in tropical tree communities have focused on whether they are assembled by more stochastic (neutral) or deterministic (niche-based) processes. The 50-ha Barro Colarado Island (BCI) forest dynamics plot was in part created to test these alternative hypotheses of community assembly, and the location of the plot was chosen to be as homogeneous as possible for optimal tests of the neutral theory of Hubbell (2011). Likewise, the 50–ha forest dynamics plot at Pasoh Forest Reserve in Malaysia was chosen as a paleotropic analogue to BCI on the same grounds. Pasoh forest is viewed as homogeneous due to its uniformity in topographic relief and dominance of red meranti-keruing trees in the overstorey (Wong & Whitmore, 1970). Wong and Whitmore (1970) concluded that tree species distributions at Pasoh are not related to soil properties but due to dispersal limitation. Subsequent work at BCI, however, showed that despite its relatively uniform relief (Condit, 2000), environmental variation still affects the spatial distributions of tree species (Harms et al., 2001). This raises the question of whether tree distributions in the apparently homogeneous Pasoh plot also correlated with environmental variation.

We investigated how tree diversity is structured in the apparently homogeneous landscape of the Pasoh 50-ha plot and evaluated which environmental variables shape those patterns of diversity. We first defined spatially explicit habitat maps. Second, using locations of individual trees of 535 species combined with the habitat map. Third, we evaluated the relative strength of these habitats in filtering tree species by quantifying habitat-related variation in alpha and beta diversity.

2.0 MATERIALS AND METHODS

We studied the habitat-related tree species distributions and diversity in Pasoh Research Forest, Negeri Sembilan, Malaysia. In 1986, a 50-ha plot (hereafter Pasoh) was established in the south-west corner of the Forest Reserve to monitor the long-term demographic dynamic of woody plants ≥ 10 mm in diameter at breast height (DBH). The methods for this project are described by Manokaran et al. (1990). All individual stems were tagged, mapped, identified and their diameters measured to the nearest 1 mm. The plot consists of 78 families, 290 genera and 814 species.

All 1250 20 × 20 m-quadrats in the plot were assigned to one of the four discrete habitat types defined by soil series properties (Yamashita et al., 2003). The habitats are highly congruent with the topographic features and thus from the lowest to highest elevation in sequence are named here as swamp, alluvial, slope and ridge. The swamp (alluvial sandy loam) is seasonally inundated in rainy season. The alluvial (alluvial sandy), which is relatively well-drained made-up half of the total area. The slope and ridge (colluvial lateritic) are relatively poor in soil nutrients.

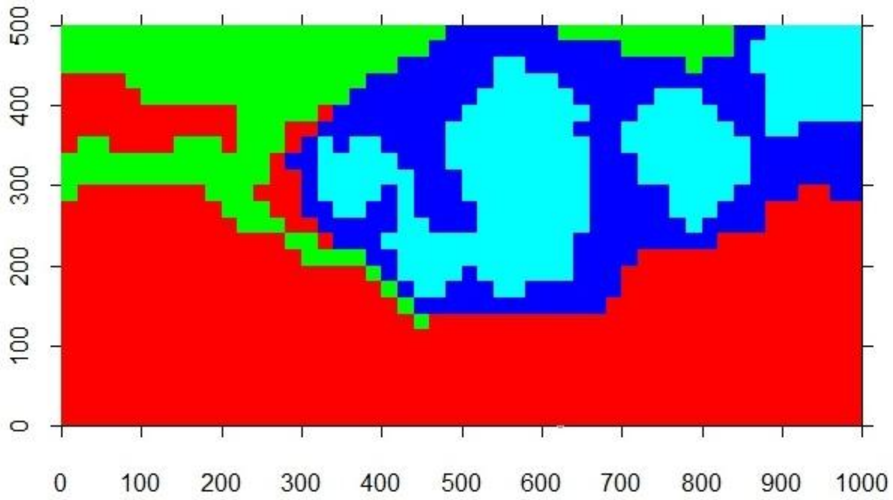

Figure 1. The habitat map of Pasoh plot. Green denotes swamp, red denotes alluvial, blue denotes slope and cyan denotes ridge. Scale in meter.

We subjected 535 species with more than 50 individuals within the plot to Torus Translation Test (Harms, 2001) in order to determine their habitat-association. First Pasoh census data was used for tree distribution.

3.0 RESULTS AND DISCUSSION

The patterns of species specialisation are summarised in **Figure 2**. Three quarters of the species tested were either positively (aggregate) or negatively (repel) associated with certain habitat(s). The highlight here is one fifth of the species are aggregated in seasonal swamp. The disproportionately high aggregation in seasonal swamp might attribute to greater water availability of this habitat.

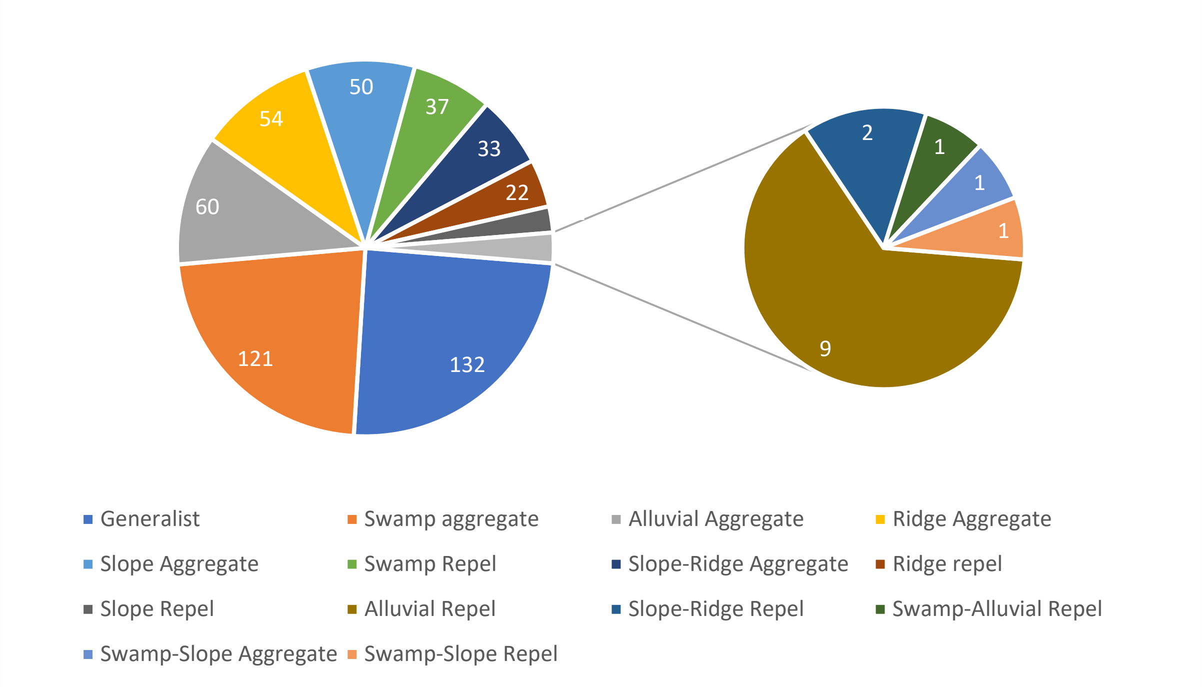

Figure 2. Pattern of species-habitat specialization.

We compared alpha diversity in different habitats rarefied species richness. The alpha diversity is highest in slope and significantly lower in alluvial.

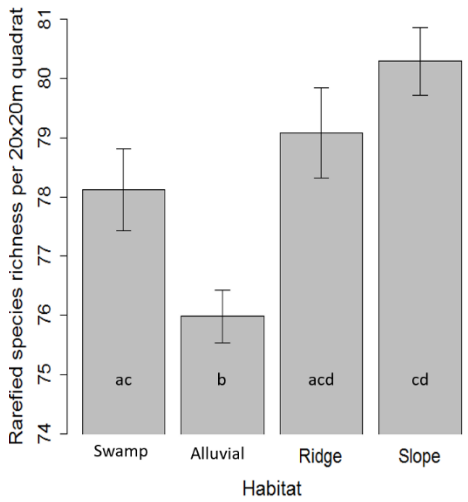

Figure 3. Rarefied species richness according to the habitats.

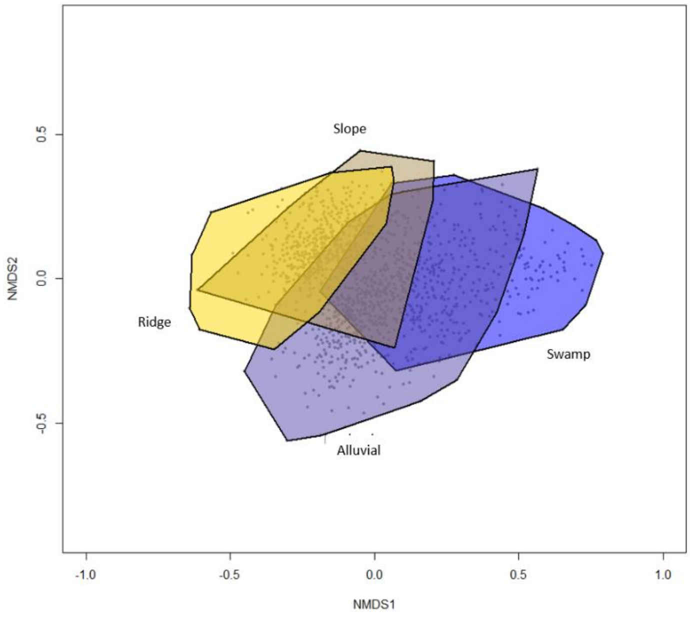

Figure 4. The variation beta diversity is visualized here in Non-metric Multi-Dimensional scaling plot.

4.0 CONCLUSION

We found strong indications of species diversity being driven by niche differentiation. More than three quarters of species tested are either positively or negatively associated to certain habitat(s). Alpha diversity varies considerably in different habitats while beta diversity is highly attributed to significant different species compositions among the habitats.

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REFERENCES

1. Condit, R. (2000). Spatial Patterns in the Distribution of Tropical Tree Species. *Science*, *288*(5470), 1414–1418.
2. Harms, K. E., Condit, R., Hubbell, S. P., & Foster, R. B. (2001). Habitat associations of trees and shrubs in a 50-ha neotropical forest plot: *Habitat associations of trees and shrubs*. *Journal of Ecology*, *89*(6), 947–959.
3. Hubbell, S. P. (2011). *The Unified Neutral Theory of Biodiversity and Biogeography (MPB-32)*. Princeton University Press.
4. Manokaran, N., LaFrankie, J. V., Kochummen, K. M., Quah, E. S., Klahn, J., Ashton, P. S., & Hubbell, S. P. (1990). *Methodology for 50-ha research plot at Pasoh Forest Reserve*.

5. Wong, Y. K., & Whitmore, T. C. (1970). On the influence of soil properties on species distribution in a Malayan lowland dipterocarp rainforest. *The Malayan Forester*, *33*, 42–54.
6. Yamashita, T., Kasuya, N., Kadir, W. R., Chik, S. W., Seng, Q. E., & Okuda, T. (2003). Soil and Belowground Characteristics of Pasoh Forest Reserve. In T. Okuda, N. Manokaran, Y. Matsumoto, K. Niiyama, S. C. Thomas, & P. S. Ashton (Eds.), *Pasoh* (pp. 89–109). Springer Japan.

ASSESSING BIOMASS OF LOWLAND DIPTEROCARP FOREST IN PASOH 50-HA PLOT USING AIRBORNE LIDAR DATA

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ABSTRACT

Airborne light detection and ranging (LiDAR) instruments has been widely used for quantification of forest biomass. This study investigated the relationships between LiDAR data and aboveground biomass (AGB). The study area is located at the 50-ha dynamic plot in a primary forest area of the Pasoh Forest Reserve, a lowland dipterocarp forest, a type of evergreen tropical moist forest. Several variables have been produced from the LiDAR metrics. These variables were correlated with AGB that were derived from census data. The study found that the CHM and a few matrices are the best predictors for AGB and therefore used for the estimation of AGB in the entire study area. The estimated AGB ranged from 52 to 718 Mg ha^{-1}, with a root mean square error (RMSE) of about 59 Mg ha^{-1}. The study suggests that the AGB estimates produced by this study is the most accurate - with an accuracy of 83% based on the mean absolute percentage error (MAPE) - as compared to other remotely sensed based estimates in the study area.

Keywords: Center for Tropical Forest Science (CTFS); 50-ha dynamic plot; LiDAR; Biomass

1.0 INTRODUCTION

Light Detection and Ranging (LiDAR) has become a primary source of data for assessing aboveground biomass (AGB) in various climatic regions and types of forests. LiDAR emits laser pulses and measures the return time of scattered returns to estimate the height and vertical structure of forests directly (Drake et al., 2002).

LiDAR can be acquired at high sampling density with excellent geometric accuracy and reveal AGB variation at spatial scales (Reutebuch et al., 2010; Mallet and Bretar, 2009). LiDAR is currently used to bridge the gap between field measurements and remotely sensed data. Therefore, LiDAR has emerged as the most promising technology for biomass estimation, especially over tropical forests when biomass density is high (Chen, 2013).

Estimating AGB using LiDAR can be carried out using two approaches (Dong and Chen, 201): (i) area-based and (ii) individual tree-based methods. Due to the structural complexity of Malaysia's tropical rainforests, these two methods offer different capability in estimating AGB in terms of accuracies and require different levels of skills to process the LiDAR point-cloud. Therefore, comprehensive research is needed to identify the relationship between AGB measured in the field and LiDAR metrics, and to determine how these relationships impact the accuracy of predictive models. This study integrates tree level census data with LiDAR variables to predict AGB in lowland dipterocarp forest. The goal of this study was to model AGB based on trees that were measured and mapped in the field, with the intention that the model could later be applied to a wider area. The immediate objectives were to: (1) develop AGB models based on census data and LiDAR data and (2) validate the model in terms of accuracy and precision. This study concentrated in the area-based method as the other methods has been investigated previously at the same study area (Wan Shafrina et al., 2018).

It appears that area-based method is commonly used for large areas as compared to individual-tree method. This usually involves five (5) major steps, which are: (i) a sample of forest plots are set up in the field, where forest attributes are measured at the tree level and summarized at the plot level; (ii) LiDAR metrics are extracted within these field plots; (iii) LiDAR metrics are extracted for the whole study area by partitioning the study area into grid cells of equivalent size to field plots and calculating LiDAR metrics within each grid cell; (iv) statistical models are developed to predict forest attributes using LiDAR metrics using the data at the plot level; and (v) the developed plot-level models are applied to each grid cell to predict and map forest attributes for the whole study area.

This study focuses on the development of LiDAR point-cloud based models for estimating AGB in the 50-ha Forest Dynamic Plot (FDP). The study also attempts to produce estimates at the highest accuracy since the census was carried out at 100% accuracy, where all trees with ≥ 1 cm diameter were measured, and the locations are well mapped. Therefore, the distribution of the sample plots can be placed anywhere within the 50-ha plot. This is one of the advantages of having 100% census data. Figure 1 shows an overall methodology that was adopted in this study.

2.1. The Study Area

Pasoh Forest Reserve (FR) is located in Jelebu District of Negeri Sembilan, Peninsular Malaysia (Figure 1). The FR resides in a rain-shadow valley (Ashton et al. 2003) with annual rainfall record varies between 1200–2400 mm. The forest is classified as south-central red *meranti-keruing* forest (Wyatt-Smith, 1987) characterized by the domination of Dipterocarpaceae family at the upper canopy. The main canopy formed at around 35 m height and the emergent trees reach 50–60 m tall (Manokaran et al., 2003). An area totaled 1813 ha at the south-west corner of the forest reserve is designated as Pasoh Research Forest, where Pasoh 50-ha FDP lies. The plot is located in lowland primary tropical rain forest nested within Pasoh Research Forest. The FDP was established between 1985 and 1988 to monitor long-term population and structural dynamics of primary forest (Kochummen et al., 1990) and re-census at five-year intervals ever since. To date, the plot sampled 435,591 trees (≥ 1 cm dbh) representing 819 species.

2.2. Census Approach

The FDP measured 1000 m length by 500 m width. Census of trees is based on protocols (Manokaran and LaFrankie, 1990; Condit, 1998). All free-standing trees with stem diameter at breast height (DBH) measured 1 cm or greater are tagged with unique number, measured at DBH, mapped and identified to species. Tree height is not measured. The census data that was used in this study was the seventh (7th) census. The census activity started in 2015 and completed in 2018.

2.3. LiDAR Dataset

The flight mission was conducted on 26 April 2018. LiDAR data for study area were obtained with a Riegl LMS-Q680i LiDAR system onboard EC120 Helicopter at 600 m flying altitude. The sensor scanning at ±30° scan angle at nadir with an average point density of 8.8 points per

m^2 and a vertical accuracy of ±15 cm RMSE.

2.4. Census-Based Variables

The 50-ha plot was divided into square plots measuring 50 × 50 m, which has made the total number of 200 plots. These plots served two purposes, i.e., one for sampling and another for validation. In this case, 140 plots were used as samples and the remaining 60 plots were used for validating the results (Figure 1-c). The AGB within each sample plot has been estimated based on the census data. The estimation was further divided into several diameter classes of trees, i.e., ≥ 5 cm, ≥ 10 cm, ≥ 15 cm, ≥ 20 cm, ≥ 25 cm, and ≥ 30 cm. Trees with dbh smaller than 5 cm were not considered in this study. These have produced 6 independent variables for AGB. The AGB for each tree was estimated based on allometric equation as found in (Chave et al., 2014).

2.5. LiDAR-Based Variables

LiDAR metrics have been derived based on the point-cloud by using R program (McGaughey, 2009). Generally, LiDAR metrics are categorized into three categories, which are (i) related to height (a percentile variable), (ii) related to canopy cover and, (iii) describing the variation in the return's intensity (standard deviation or variance). Altogether, 82 LiDAR metrics have been derived from the LiDAR point-cloud, and these were used as predictor variables for the AGB.

3.0 RESULTS AND DISCUSSION

3.1. Summary of the Census Data

Each standing trees with dbh measuring ≥ 1cm was tagged as a unique ID in the census. Information such as tag number, dbh, species and position i.e., *x* and *y* coordinates were recorded in the census datasheet. It was obvious that, although the number of small trees (dbh = 5.0 – 29.9) were abundant, the AGB within these trees were not significant. However, larger trees (dbh ≥ 30 cm) indicated that although they were small in numbers, the AGB was substantially high. It implied that the AGB within this forest is stored predominantly in large trees. Altogether 74,910 trees (with dbh ≥ 5.0 cm) were considered for this study. Based on the census records, the remaining smaller trees (dbh ≤ 5.0 cm) was 167,451 stands, which is more than 2 folds greater that of trees ≥ 5.0 cm. However, these were not considered in this study. It can be concluded that the average number of trees and AGB within FDP were about 1498 trees ha^{-1} and 280 Mg ha^{-1}, respectively for trees ≥ 5.0 cm.

3.2. Estimation Models

The first screening indicated that only few LiDAR metrics have linear correlation with AGB. Variables related to height and canopy relief, especially canopy height model (CHM) (Figure 2-b) are the best predictor for AGB in the study area. The study found that the total AGB within the entire study area ranged from 52 to 718 Mg ha^{-1} with an average of 284 Mg ha^{-1}. A spatially distributed map of AGB with a cell size of 50 m has been produced (Figure 4-c) and the total AGB was estimated at 14,018 Mg for the entire FDP. The mean absolute percentage error (MAPE) of the estimates was about 26.74%, which produced an accuracy 0f 83.36%, with a root mean square error (RMSE) of about 59.01 Mg ha^{-1}.

LiDAR metrics at plot scale are commonly calculated based on either laser points or rasterized cells. The metrics based on points could be sensitive to the flight conditions and the sensor setting (Roussel et al., 2017). In contrast, cell-based metrics can reduce such variations by focusing on only the canopy surface heights, which, however, missed the structural variations within canopy. Some researchers found that the different ways of generating metrics have small impacts on the performance of predicting forest attributes (Chirici et al., 2016).

4.0 CONCLUSION

This study has shown the potential use of waveform data in predicting structural and biophysical parameters of low land dipterocarp forest in Malaysia at high accuracy. The final models developed for AGB performed well with the adjusted R^2 ranging from 0.7 to 0.5. The lowest RMSE was at 59 Mg ha^{-1} for AGB of all trees ≥ 15 cm in dbh. However, the most accurate estimate, i.e., 83% was from the model that was used to estimate AGB for trees ≥ 10 cm.

The study demonstrated that estimating AGB in tropical forest by using waveform LiDAR improved the accuracy by reducing RMSE as compared to the satellite-based data. Although limitations still existed, the information provided by the study can be a useful reference for other studies especially the ones that are related to the applications of remotely sensed data for AGB estimations in lowland dipterocarp tropical forest.

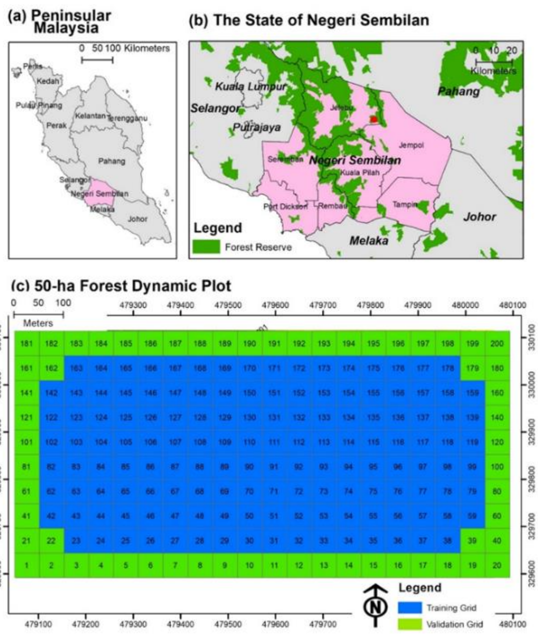

Figure 1. The location of the FDP, which is in Negeri Sembilan, Peninsular Malaysia. The FDP measures 1000 × 500 m

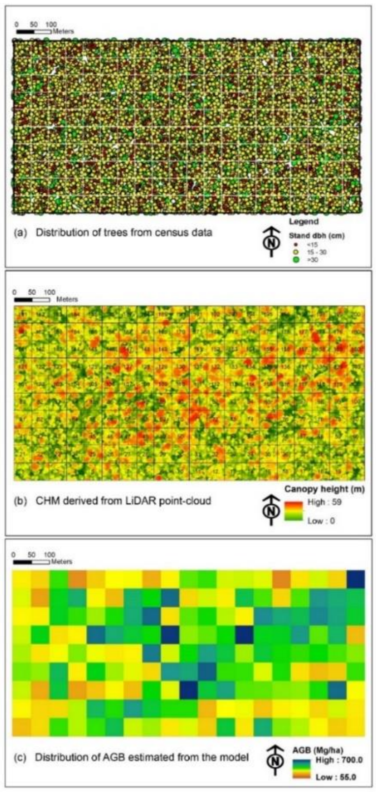

Figure 2. Spatially distributed map of census trees (a), canopy height model (b), and the estimated AGB (c).

REFERENCES

1. Ashton, P.S., Okuda, T. and Manokaran, N. 2003. Pasoh Reserch, Past and Present. In Pasoh: Ecology and natural history of a Southeast Asian lowland tropical rain forest; Okuda, T., Manokaran, N., Matsumoto, Y., Niiyama, K., Thomas, S.C., Ashton, P.S., Eds.; Springer: Tokyo, Japan. pp. 1–13.
2. Chave, J., Rejou-Mechain, M., Burquez, A., Chidumayo, E., Colgan, M.S., Delitti, W.B.C., Duque, A., Eid, T., Fearnside, P.M., Goodman, R.C., Henry, M., Martinez-Yrizar, A., Mugasha, W.A., Muller-Landau, H.C., Mencuccini, M., Nelson, B.W., Ngomanda, A., Nogueira, E.M., Ortiz-Malavassi, E., Pelissier, R., Ploton, P., Ryan, C.M., Saldariagga, J.G. and Vielledent, G. 2014. Improved allometric models to estimate the aboveground biomass of tropical trees. *Global Change Biology* 20(10): 3177-3190.
3. Chen, Q., 2013. Lidar remote sensing of vegetation biomass. Remote Sensing of Natural Resources (Eds.: Weng, Q. and Wang, G.): 399–420.
4. Chirici, G., McRoberts, R.E., Fattorini, L., Mura, M. and Marchetti, M. 2016. Comparing echo-based and canopy height model-based metrics for enhancing estimation of forest aboveground biomass in a model-assisted framework. *Remote Sensing of Environment* 174: 1–9.
5. Drake, J.B., Dubayah, R.O., Knox, R.G., Clark, D.B. and Blair, J.B. 2002. Sensitivity of large-footprint LiDAR to canopy structure and biomass in a neotropical rainforest. *Remote Sensing of Environment* 81: 378–392.
6. Kochummen, K.M., LaFrankie, J.V. and Manokaran, N. 1990. Floristic Composition of Pasoh Forest Reserve a lowland rainforest in Peninsular Malaysia. J*ournal of Tropical Forest Science* 3: 1–13.
7. Manokaran, N., Quah, E.S., Ashton, P.S., LaFrankie, J.V., Nur Supardi, M.N., Wan Shukri, W.A. and Okuda, T. 2003. Pasoh Forest Dynamic Plot, Peninsular Malaysia. In Tropical Forest Diversity and Dynamism, findings from a Large-Scale Plot Network (Eds. Losos, E.C. and Leigh, Jr. E.G.). The University of Chicago Press: Chicago, USA. pp. 585–598.
8. McGaughey, R. 2009. FUSION/LDV: Software for LiDAR Data Analysis and Visualization. US Department of Agriculture, Forest Service, Pacific Nortwest Research Station.
9. Roussel, J.R., Caspersen, J., Béland, M., Thomas, S. and Achim, A. 2017. Removing bias from LiDAR-based estimates of canopy height: Accounting for the effects of pulse density and footprint size. *Remote Sensing of Environment* 198: 1–16.
10. Wan Shafrina, W.M.J., Woodhouse, I.H., Silva, C.A., Omar, H., Khairul Nizam, A.M., Hudak, A.T., Klauberg, C., Cardil, A. and Mohan, M. 2018. Improving Individual Tree Crown Delineation and Attributes Estimation of Tropical Forests Using Airborne LiDAR Data. *Forests* 9(759): doi:10.3390/f9120759
11. Wyatt-Smith, J. 1987. Manual of Malayan silviculture for inland forest, Part 3-Chapter 8. Red meranti-keruing forest. FRIM Research Pamphlet No. 101; FRIM: Kepong, Malaysia. 89 pp.

DIGITALISATION AND INTERNET OF THINGS (IOT) PROGRAMME FOR BIODIVERSITY IN PASOH FOREST RESERVE

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ABSTRACT

Biodiversity is important to all life on earth, playing an important role in stabilizing the climate as well as preventing and reducing the effects of natural disasters. Therefore, proactive approaches for long-term biodiversity management are needed to maintain its balance in ensuring that these biodiversity treasures can be enjoyed by future generations. This paper presents a digitalization program and precision biodiversity development initiated by Akademi Sains Malaysia (ASM) under Precision Biodiversity Task Force to support data-driven biodiversity maintenance and conservation using emerging digital twin technologies encompassing internet-of-things (IoT), artificial intelligence (AI), robotics, drones and cloud computing. The expected outcomes will transform the forest management routine to a precise and data-driven biodiversity and its ecosystems insights including a holistic knowledge on the biodiversity of the forest, increased biodiversity census and surveillance efficiency, and more accurate insights on the value of biodiversity in Malaysia's forests. It starts with a pilot study at the 50-ha plot in Pasoh Forest.

Keywords: Precision biodiversity; Internet-of-Things (IoT); Artificial Intelligence (AI); Robotics, Drones, Pasoh Forest; Digital Twin.

1.0 INTRODUCTION

Malaysia is ranked as the 12th most biodiverse country in the world but registers an alarmingly poor biodiversity status [1]. Its Ecological Footprint Consumption is between 3.5 - 5.25 global hectares. The Sumatran rhino is already extinct and the Malayan tiger, gaur and ambar deer are in peril while the deforestation rate has reached 14.4% from 2000 to 2012. A strategic and transformative approach is required by Malaysia to improve its biodiversity conservation, preservation, and management. Therefore, Precision Biodiversity is the key for Malaysia to better conserve, monitor and manage local biological resources. The digitalisation and IoT programme for biodiversity is part of a bigger project that aims to achieve this vision.

The National Biodiversity Policy 2016-2025 [2] emphasizes the importance of sustainable conservation, consistent use of resources as well as sharing the benefits of biodiversity. Strengthening sustainable forest management (Target 4) and development of a Knowledge and Science Base for biological diversity as well as increased knowledge about the relationship between climate change and biological diversity (Goal 5 Target 6); are among the focus of the policy. Based on the current issues and the aspiration towards the implementation of the policy, the requirements for PBD are a) Efficient monitoring of the development of biological diversity, b) Uniformity and centralization of knowledge base; and c) Insightful PBD reporting.

Since the last decade, high-end and advanced technologies of artificial intelligence (AI), machine learning (ML), robots, drones as well as genomic information have begun to be utilized in a few key fields like precision agriculture, precision medicine and precision conservation. Therefore, it is timely for this approach to be extended and leveraged for biodiversity. Digital twin for Precision Biodiversity (PBD) is a complementary next-generation technological approach to conserve, monitor and manage biological resources using advanced technology platforms for protection of the planet as well as for socio-economic returns. Digital twin systems are technologies that allow the benefits of precise biodiversity knowledge gathered by the IoT, robotics and drones to be processed in real time and interact with data visualization through AI and ML to predict patterns of biodiversity development. By adopting PBD, Malaysia will show the world how this first-time-ever approach, can more effectively protect the planet and simultaneously deliver socio-economic returns.

2.0 MATERIALS AND METHODS

This programme aims to develop and provide a comprehensive system and facilities for the precise management of biodiversity and its ecosystems that will benefit both human socio-economy and biodiversity conservation. The PBD programme will be implemented through two phases between year 2022 until 2025 and will focus on a pilot implementation at Pasoh Forest Reserve before it could be feasibly deployed throughout the country.

Pasoh is a 2,450-ha reserve forest that is gazetted as a Research Forest and monitored by the Forest Research Institute Malaysia (FRIM) [3-4]. FRIM is the main strategic partner that jointly implement the programme with the Academy of Sciences Malaysia (ASM) for a 4-year duration (2022-2025) under the 12th Malaysia Plan (RMK-12). From this programme, FRIM is planned to be engaged to continue the effort under the Ministry of Energy and Natural Resources (KeTSA) in mainstreaming and implementing PBD strategies, programmes and interventions at national level under RMK-13 and beyond. The aspiration of the initiative is to improve the sustainability of forest management, in line with Targets 4 and 16 in the 2016 National Biodiversity Policy [2].

Several activities involving the developers and stakeholders will take place namely interviews, focus group discussions, technology development, platform migration and testing, as well as change management. The framework of the PBD initiative which consists of five scopes as illustrated in Figure 1.

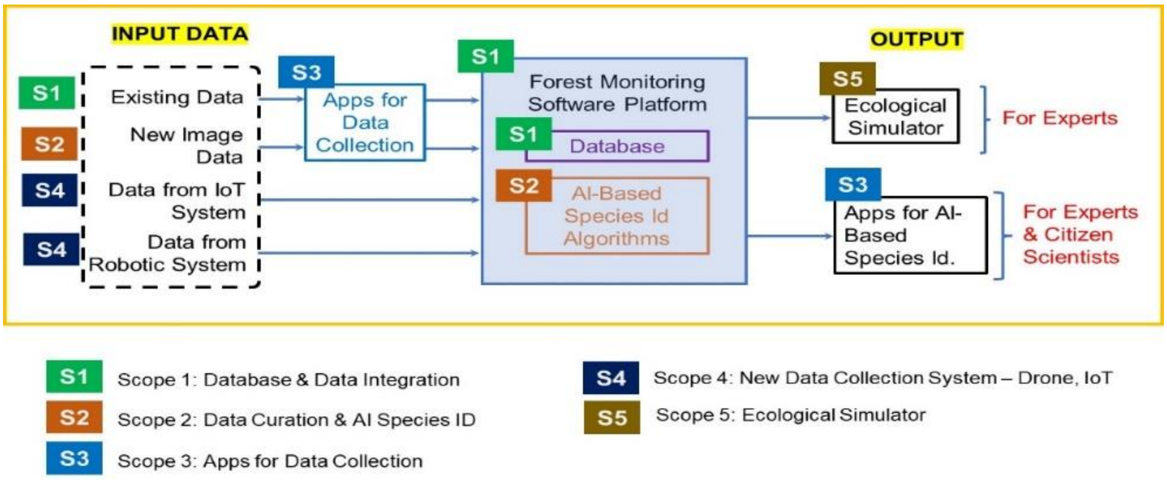

Figure 1: PBD Programme framework

2.1. Scope 1: Database set-up and data integration for the Pasoh Forest

A cloud-centralized database system for biodiversity big data lake will be developed by integrating a variety of data from heterogeneous sources through scheduled and on-demand data transfer:

i. Images and videos of flora and fauna species collected from various sources including smartphones, drones, and robots;
ii. Parameters representing the flora (tree vigor, flowering, masting, carbon, biomass) and environments (weather) collected in websites and internal databases, sensors and robots; and
iii. Forest topological information.

The process of developing this cloud-based database will be divided into three parts which are; Part 1: Developing cloud computing with databases, Part 2: Integrating data from multiple sources and Part 3: Data collection and recording. The flora and fauna species in the ecosystem will be identified and connected through their spatiotemporal information (metadata by the geolocation and time the data is collected). The database system will be used by other components in the platform and the data history will be visualized through a dashboard.

2.2. Scope 2: Data curation and AI-based species identification

Plant and animal species identification will be developed using artificial intelligence (AI) techniques. This work involves the digitization of plant and animal specimen data by storing digital images of the specimens in a specialized database. These images will be processed, labelled, annotated, and augmented before being used in the development of AI algorithms. Emphasis will be given to developing systems that can assist FRIM taxonomists in identifying species as accurately as possible and therefore require high-definition specimen images as well as based on standard protocols that are in the identification process. Species identification systems for other less critical purposes such as for science promotion activities, biodiversity tourism and other related activities will also be developed. The development of species identification algorithms can be based on images captured using low-definition devices such as mobile phone cameras. The process of data collection and development of species identification algorithms will be divided into three parts:

i. Part 1: Focus on species for one tree family from specimens in the FRIM Herbarium and one insect order from the specimen collection at the Insect Systematic Centre, Universiti Kebangsaan Malaysia (CIS UKM).
ii. Part 2: Focus on species for two tree families from specimens in FRIM Herbarium and two insect orders from specimen collection in UKM CIS.
iii. Part 3: Development of an AI-based species identification algorithm for animals from video camera traps installed on a 50-hectare plot in Pasoh Forest.

2.3. Scope 3: Development of apps for data collection

A mobile app for data collection will be developed for plant and animal specimen by two parties, either the researcher (researcher) or from the public (citizen science). This mobile application will be developed using ODK (Open Data Kit). This open-source device can upload data from mobile phones to a dedicated database (Scope 2) faster, once there is communication access. Since ODK is a device that uses a small memory capacity, its use in Pasoh where the communication network in the forest is minimal, is very appropriate. This mobile application encourages citizen science through the involvement of the public to upload their captured data, while the researchers/experts of the species will annotate and endorse the data addition/update into the database. The database in Pasoh will mature once there are at least 80-90% of the species that have been identified. Once this process takes place, the public can be given permission to add data into the database.

2.4. Scope 4: Development of data collection system and facilities

Robotics and IoT technologies will be used for data collection system and facilities which involve five components:

i. Portable and automatic drone control system for robot movement above canopy. It involves the development of an algorithm for automated drone control, performing the drone flights on a regular basis in a simple way and data collection in the form of images and multispectral MSS data, which will then be compared and analyzed.
ii. Automatic Control System using drone for the movement between trees. It involves development of an algorithm for automated drone control, performing drone flights on a regular basis and data collection for trees around the 1-ha plot using LiDAR sensor for DBH measurements.
iii. Development of weather observation system through IoT via the development of infra at the aluminium tower area, installation of temperature sensors, rainwater, etc. and the construction of the dashboard using Grafana software.
iv. Development of camera trap systems for animals involving the infrared preparation for camera traps in some of the identified areas, periodic data collection and development of AI system under S2 system to identify animal types for easier reporting.
v. A four-legged robot system with laser sensors where the implementation of forest mapping using laser cloud data in 1-ha site plot area and producing accurate 3D maps of forests in the form of cloud data using LiDAR sensors.

The technologies will transform the forest surveillance routine by the forest rangers. The drone implementation will complement the forest topological mapping and be useful for ad-hoc surveillance especially in the time of hazardous situations in the forest as the remote observation offers safer and quicker monitoring. It is anticipated that the efficiency of the trees census and mortality monitoring will be improved assisted by the robots. The role of the forest rangers will be redefined to be robots' supervisors and to evaluate the accuracy of the predicted tree growth and other census parameters. The collected data will complement the populated database system which will be enriched through S1, S2 and S3. The content of the database system will be used by the digital twin.

2.5. Scope 5: Development of ecological simulator for Pasoh Forest

The ecological simulator comprises of five modules namely data integration (S1), data analytics, reporting, recommendation, and data export. Several metrics for biodiversity sustainability risk monitoring will be leveraged such as species richness, dense, vigor, biomass and offset to measure the current achievements of biodiversity, as well as identify improvements that need to be implemented.

The descriptive analytics function in the ecological simulator will visualize the trends of the biodiversity. Diagnostics analytics will be performed to analyze the relationship between environmental disruptions and the forest biodiversity vigour (or mortality) while the predictive analytics will enable the forest ranger, analyst, researcher and forest manager to be precisely informed in-advance of the growth or decline of each biodiversity metrics. These insights will be useful to generate a dynamic work schedule and costing planning for forest management such as conservation activities. The simulator will also provide reminders (notifications) and lists actions that need to be taken based on data analysis and forecasts. This increased optimisation will increase productivity and reduce repetitive works.

3.0 RESULTS AND DISCUSSION

Forest biodiversity management have been based on a routine tied to the requirements for reporting to higher management. However, this method is limited to the scope required by the stakeholder resulting in the analytics performed not being comprehensive. Short-term and long-term decision-making through precise biological diversity reporting covering descriptive analytics, diagnostic analytics, predictive analytics and prescriptive analytics was not implemented. The transformation offered by the AI and IoT for work digitalisation and efficient forest management will enable work processes, costing estimation and time management to be more optimized. The experts and people with experience in forest management will have a role redefined; to focus more on quality output compared to just routine work. The analysis of the data collected over the years can be their benchmark and availability of the system will make the knowledge inherited biodiversity values more reliable and used for forest sustainability intervention strategies.

4.0 CONCLUSION

A sustainable biodiversity management system needs to have clear policies to address the long-term problems of biodiversity well and to be able to make effective forecasting actions. To help policymakers produce clear and effective biodiversity policies, a variety of methods, theories and tools can be developed and used. Due to these problems, good data collection, centralized information sharing system and the development of the latest innovations can improve the methods of conservation and dissemination of information to educate the public. All of this requires support for the decision-making process to a more effective digital transformation and even this solution is much needed in situations faced with the significant effects of climate change. It is hoped that the close cooperation and sharing of expertise from local universities, agencies involved, and local authorities will bring benefits to all communities to maintain the function of biodiversity in the Pasoh Forest Reserve.

ACKNOWLEDGEMENT

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REFERENCES

1. Strategic Paper on Precision Biodiversity, 2020, Academy of Sciences Malaysia https://www.akademisains.gov.my/asmpub/?smd_process_download=1&download_id=456
2. National Policy on Biological Diversity 2016 – 2025, https://www.ketsa.gov.my/ms-my/pustakamedia/Penerbitan/National%20Policy%20on%20Biological%20Diversity%202016-2025.pdf
3. Ashton, P.S., Okuda, T., Manokaran, N. (2003). Pasoh Research, Past and Present. In: Okuda, T., Manokaran, N., Matsumoto, Y., Niiyama, K., Thomas, S.C., Ashton, P.S. (eds) Pasoh. Springer, Tokyo. https://doi.org/10.1007/978-4-431-67008-7_1
4. Musalmah, 2022, “R&D di Hutan Penyelidikan Pasoh

Rapporteur Notes

	Presenter	Key Highlight	Questions
1.	***Keynote Speech*** ***Dr Stuart J. Davies*** ***Forest Global Earth Observatory (ForestGEO)*** "Years 37-50 at Pasoh: Why Maintaining Long-Term Ecological Observations Remains Critical for Science and Society"	• Changes in number of trees throughout 30 years – 43% mortality • Dramatic decline in the stem density, diameter growth, number of trees • Negative correlation between wild boar populations and oil palms • Huge impacts of wild boar on reductions of small stems • Relative abundance of lianas increased in unfenced open forests (wild boar prefers small trees compared to lianas) • DNA sequence approaches to understanding tropical diversity; herbivore diets, fungal symbiosis – mycorrhizae and neighbourhood interactions. • Factors that control ECM and No-ECM in TRF • Relations of ECM distributions to soil nutrients in quadrat plots – the biomass of ECM does not affect the soil fertility • Fate of anthropogenic CO2 emissions – forests are important • Annual Mortality Survey (AMS) is done thoroughly- AGB losses from dead trees vs damaged but living trees are very significant • Drones and laser images are new techniques which are relevant	-none-

<table>
<tr><td></td><td></td><td><u>GOALS: </u>When Pasoh 50-ha turns 50
Science
• Carbon and Biomass – benchmarks and future predictive modelling (important for policymakers)
• Allocation of biomass and carbon – An index of forest health
• Reproduction - the origin and maintenance of diversity
Engagement
• Students, faculty and RI's
Collaboration
• Bring new skills & expertise (national and international)
Policy
• Deliver real-time information to inform policy makers and support management</td><td></td></tr>
<tr><td>2.</td><td>Saleh Awaludin
Negeri Sembilan State Forestry Department (JPNNS)

"Cadangan Penubuhan Pusat Kecemerlangan Perhutanan Hutan Tanah Pamah Tropika Negara, Pasoh, Negeri Sembilan"</td><td>• In Negeri Sembilan there are 22 Permanent Forest Reserve covering 155,102 ha (23%) of state area
• Collaboration between Federal and State is crucial in maximizing national forest treasure
• Jelebu – zoned as Biodiversity Green area
• Infrastructural development is limited – focus more on eco-tourism, forest resources and environmental promotion

Way forward
• The establishment of Pusat Kecemerlangan Perhutanan Hutan Tanah Pamah Tropika Negara
eco-tourism</td><td>-none-</td></tr>
</table>

		▪ R&D ▪ Education and referral centre **Issues** • Management scope • Minimal forest resources **Recommendations** • Re-branding • Green lung to Jelebu district • Eco-tourism spot • Collaborations between FRIM and JPNS	
3.	***Musalmah Nasardin*** ***Forest Research Institute Malaysia*** ***(FRIM)*** "Changes in Stand Structure and Dynamics of Trees in Pasoh Forest Reserves Over 25 years"	• Declined in small stem by 43% - size structure • Dramatic decline in the stem density, diameter growth, number of trees • Negative correlation between wild boar populations and oil palms – dynamic • Huge impacts of wild boar on small stems(reduction) • Nest building by pig was the main driver of a decline in tree sapling density • Recruitment fluctuated throughout the years • Severe droughts in 2002-2004 contributed to the higher mortality measured • Topography wasn't significant in mortality, growth and survival rate except for in 2004 where alluvial topographic gave the highest rate for all • Changes in demographic rate in response to climate and environmental changes	**Question:** What are the definition of Homogeneity and heterogeneity of biodiversity? **Answer:** Definition - More variations in species composition and distribution. Pasoh used to be homogenous, and it changed to heterogeneous due to forest variation **Question:** In 2000-2003, there is a decrease in wild boar populations, however stem abundance does not increase but constantly declining. Is there any changes in climate change that contributed to the decline of wild boar populations? (Dr Lillian Chua) **Answer:** Pig abundance affected the small stems declining and also the wind throws events during the years Small stems need longer time to the increment of small stem. By the time

			the pigs rebound, the small stem didn't have time to grow at least to 1 cm. **Question:** What have been done by the project to tackle issues on wild boar and the forest changes **Answer:** As for now we only produce reports and papers to stakeholders. After all, this is natural disaster. Wild boar is there naturally and they have their own functions in the forest eco-system.
4.	***Dr Manabu Onuma National Institute of Environmental Studies (NIES)*** "Comparing the Effectiveness of Camera Trapping vs Environmental DNA for Biodiversity Assesments in Pasoh".	• Wild boar, macaque, tapir and monitor lizard – highest number • 58 species caught by camera trapping • By NGS sequence data – 7 species were identified • Wild boar, tapir, monitor lizard • No of species detected – CT – 58 • eDNA – 86 species • 7 species were common • CT costlier USD 30,000 • eDNA is only 3,200 USD Must have reliable database – but can't be used to evaluate the reproduction and population estimation. Must avoid contamination • CT is easier and easy to detect animals. Method can estimate population dynamics. To pursue more research and put more camera traps to collect fauna data	**Question:** Would you also consider sampling outside 50 ha using eDNA? (Dr Lillian Chua) **Answer:** Yes, we can do that. Can change the primer to detect other groups of species or locate camera trap on the other area. **Question:** What is the method used for sample collection to maximise the number of species? **Answer:** Location of the camera trap, primer of PCR used. More universal primer means more species can be detected for identification purpose.

5.	***Dr Marryanna Lion*** ***Forest Research Institute Malaysia (FRIM)*** "Gas Exchange of Southeast Asian Tropical Forest: Water Sources for Evapotranspiration Demand in Pasoh Forest Reserve, Peninsular Malaysia"	• Two drought seasons in 2014 and 2015 • ET didn't decline much in dry period • Pasoh Forest Reserve need several months' precipitation to supply for its ET demand during severe drought • In the wet period, water for ET was supplied from surface soil layer whereas in dry period, supplied from deeper soil layer precipitated several months previously at this forest • Isotope signature in rainwater, stream water and soil water result indicate large portion of new water runoff due to an intense and short time duration • Isotope signature of plant, soil and rainwater demonstrated that the water sources of the soil and plant were all different • Plant – deviated from rainwater local meteoric waterline • Plant use water with the longest residence time and bound tightly to soil particles to supply for ET demand during dry period in Pasoh Forest Reserve • Plant has no preference of soil water with regards to their height or soil depth • The ET in Pasoh Forest Reserve is balanced and maintained using the most available water resources • This study introduces the stable isotope approach for determining details hydrological parameters and provides new data and insights for this research in the future	**Question:** What is the depth of the water table around the tower? And is the consistency of ET being because of supply of the water table? (Dr Stuart J. Davies) **Answer:** The water table were not measured. Only the soil water was measured at 3 m depth. We could not identify the water table, but the soil water was sufficient.

6.	***Yao Tze Leong*** ***Forest Research Institute Malaysia*** **(FRIM)** "Habitat-Related Tree Species Distributions and Diversity in Pasoh Long-Term Forest Dynamics Plots"	• No correlation between species distributions and soil types [Wong& Whitamore (1970)] • Ashton 1976: strong correlation which is a contrast with the previous statement above • Thomas 2003: strong generalist • 76% of total species tested are positively or negatively associated with habitats • Anoxic soil condition intolerance filtering out the non-specialist • Practical implication: matching trees species to the planting site is very crucial	**Question:** Are the topography and soil play a big role in affecting species distribution? (Dr. Wan Mohd Shukri Wan Ahmad) **Answer:** Topography and soil somehow are co-related to the species distribution.
7.	***Dr Hamdan Omar*** ***Forest Research Institute Malaysia (FRIM)*** "Assessing Carbon Stock of Forest in Pasoh 50-ha Plot using Airborne LiDAR Data"	• There are many methods in remote sensing technologies. • Each and every one of the methods have advantages and limitations. • The method used for the AGB estimation of Pasoh Forest Reserve is LiDAR. • Number of small stem is high but the AGB is low and vice versa • Biomass is stored in large trees • The LiDAR can estimate biomass only 20 cm and above with highest accuracy (best model – trees with >20cm) Accuracy 83% and RMSE 59mg/ha • This kind of study can be conducted to project and stimulate AGB estimation from satellite image making Pasoh Forest Reserve as control plot • Although there limitations, information from this study can provide essential information on AGB estimation in Forest Reserve in Malaysia	**Question:** Is the peak swing flight at 600m height (Prof. Ir. Ts. Dr Ahmad 'Athif Mohd Faudzi) **Answer:** Flying altitude can be varied but, in this case, we try to minimise mission hour because the flight also covers other areas other than the 50ha area. For single observation, 2-3 flight path is enough to cover the area **Question:** How many alterations or flight were carried out? **Answer:** It takes 5 flight paths to complete the whole area. Single observation needs 2-3 flight path. The mission covered bigger area. **Recommendation:** To produce a canopy flight map. Canopy height map which consists canopy gap and see the

			regeneration rate that can relate canopy map and ecological study. (Dr Stuart J. Davies) **Question:** It was mentioned in the slide that smaller trees have higher accuracy compared to bigger trees. However, there would be limitation to have return point since there are many layers in the forest. How smaller trees have higher accuracy compared to bigger trees? (Dr. Wan Mohd Shukri Wan Ahmad) **Answer:** Accuracy is measured in two ways. Absolute accuracy based on the percentage RMSE. There are number of factors before getting the accuracy percentage. In dense forest, LiDAR unable to reach the smallest trees. So there are limited number of return from the ground. Most of it comes from top. So we try to separate DBH classes to see the variation.
8.	***Prof. Ir. Ts. Dr. Ahmad 'Athif Mohd Faudzi*** ***Centre for Artificial Intelligence and Robotics (CAIRO), UTM*** "Digitalisation and Internet of Things (IoT) Programme for	Focuses on 7 scopes of work: - Database setup and data integration for Pasoh. - Data curation & AI-based species identification - Development of mobile apps for data collection - Development of data collection system - Development of ecological simulator	**Question:** The Tree ID apps plan to identify the tree to family level or species level? **Answer:** First part on family level and the second part is genus and lastly to species level. As for now, identification will be on the family level.

	Biodiversity in Pasoh Forest Reserve”	- Transfer of technology	**Question:** Negeri Sembilan are looking forward on carbon trading especially on identifying the mechanism and guidelines of carbon trading. Using AI to identify carbon stocks, is there any measurements for carbon stocks and carbon absorptions. How to manage carbon offset? **Answer:** As for now, depend mostly on the data available especially above ground biomass data and correlation studies. Even though work on carbon trading is very active at the moment, it is still in early stage. **Recommendation:** Should consider developing tools with high resolution especially for biophysical measurement using AI, it would be beneficial to science and also helps scientist to collect a lot more data. Looking forward on how to take the IoT into the forest. (Dr Stuart J. Davies)

**Thank you to Dr Farah Shahanim and Nurcahaya Khairany, the seminar's rapporteur, who wrote and shared this report on June 15, 2022*

Summary

Pasoh Seminar 2022 was organized by Forest Research Institute Malaysia (FRIM) on 25th May 2022. The seminar was attended by stakeholders, researchers, lecturers and students from different government agencies, as well as local and foreign universities. This seminar highlighted results from research activities conducted in Pasoh Forest Reserve through FRIM's collaboration with international agencies namely Forest Global Earth Observatory (ForestGEO) and National Institute for Environmental Studies (NIES).
The main objectives of this seminar were as follow:

1. Sharing research activities conducted in Pasoh Forest Reserve
2. Discussing ecological aspect of Pasoh Forest Reserve
3. Promoting SPF Pasoh as research and tourism centre for environmental education
4. Strengthening collaboration between FRIM and research agencies/universities both local and overseas.

Keynote speech was given by Dr Stuart J. Davies from ForestGEO, emphasizing on the importance of maintaining long-term ecological observations for science and society. Keynote speaker also highlighted the future goals for Pasoh Forest Reserve in term of science, engagement and collaboration as well as delivering real-time information to policy makers and support management. A total of 8 papers were presented during this seminar. Topics on; i) future physical development, ii) changes in stand structures and dynamics of trees, iii) effectiveness of camera trapping vs environmental DNA for biodiversity assessments, iv) water sources for evapotranspiration demand, v) habitat related tree species distribution and diversity, vi) assessing biomass using Airborne LiDAR data and vii) digitalization and Internet of Things (IoT) for biodiversity were presented. Throughout the seminar, wide range of suggestions regarding current studies and opportunities were discussed. A question and answer (Q&A) session was held at the end of every paper presentation. This enabled the participants to raise any burning questions or any inquiries regarding the topics presented. The seminar has provided relevant and significant insights on future R&D regarding ecological and biodiversity aspects. The initiatives on addressing important issues were also highlighted. New technologies mainly related to IoT and geographic information system (GIS) as well as remote sensing were thoroughly discussed and these would definitely enhance the R&D outputs in the future. Nonetheless, the seminar constituted a good opportunity to foster networking among researchers and the sharing of knowledge on ecological aspect of tropical forest as well as the future of digitalization in the context of scientific studies in the tropical forest. In conclusion, this seminar has successfully achieved the targeted objectives and it is hoped that this kind of seminar will be held from time to time to ensure the continuity and sustainability of R&D in Pasoh Forest Reserve.

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