Chapter in Book

C.C.Maps

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Abstract: *Leaf pigment is one of the methods used to show trends in spectral and plant pigment contents that indicate the health and stress status of the mangrove forest. However, there are no chlorophyll concentration maps focusing on mangrove ecosystem areas, especially in the northern regions of Peninsular Malaysia. Thus, C.C.Maps generally aims to conserve and preserve mangrove ecosystems and their components to ensure their sustainability. The C.C.Maps were created by merging mangrove forest data with remote sensing (RS) technologies. The C.C.Maps is a ready-made product in the forms of paper and digital format that consists of leaf chlorophyll concentration data and vegetation indices images of mangrove forests derived from the remote sensing technologies data. These maps also are intended to meet the needs of a wide range of customers including social and economic parties as well as the local communities. In terms of the contribution, it can make, C.C.Maps can assist environmentalists in monitoring the health status of mangrove forest areas to ensure the sustainability of this ecosystem and its components. In addition, C.C.Maps also can assist in the conduct of effective mangrove monitoring and management efforts in order to promote the long-term sustainable development of mangrove ecosystems. This C.C.Maps will significantly provide a guideline to improve the management of this ecosystem and its sustainability and align with the United Nation's Sustainable Development Goals (SDG), particularly SDG 13 (climate action), SDG 14 (life below water) and SDG 15 (life on land).*

Keywords: Chlorophyll Content; Mangrove; Remote Sensing; Sustainable.

1. INTRODUCTION

Mangroves are unique ecosystem structures composed of salt-tolerant vegetation found in tropical and subtropical climate regions (Roslani et al., 2013; Roslani et al., 2014). Mangrove forest provides various valuable benefit on Earth such as help to stabilize banks and coasts while also providing habitat for a variety of species (Kamaruzaman & Kasawani, 2007) including marine and terrestrial organisms and other various importance ecologically, biologically, and economically. However, their existence is declining at an alarming rate worldwide. Pollution, hydrological changes, aquaculture, recreational activities, climate change, natural disasters, various anthropogenic activities and other factors have all contributed to global degradation of mangrove forests (Zhang et al., 2014; Flores-de Santiago et al., 2016). Marine vegetation preservation and protection should be encouraged because coastal and estuarine regions are heavily impacted by anthropogenic activities (Kamaruddin et al., 2018). Therefore, there is a great demand to gain initiatives for better inventories and conservation towards the monitoring and managing mangrove ecosystem. As a result, the monitoring and protection of the mangrove environment should be prioritized.

Furthermore, having a deeper understanding of their basic biology knowledge would help to ensure the longevity of this ecosystem. There is a need to develop mangrove condition indicators using remotely sensed data (Pastor-Guzman et al., 2015). Remote sensing is an effective method for tracking phenological changes from the regional to the global scale, such as leaf greenup and autumn colouration (Cleland et al., 2007; Motohka et al., 2010). Therefore, studying the basic biology of leaf pigment contents is crucial especially their chlorophyll contents. In addition, leaf pigment is one of the methods to show trends in spectral and plant pigment contents indicating the health and stress status in the mangrove forest areas.

Leaf chlorophyll content has traditionally been measured with high accuracy that used a plot-based field sample collection and chemical analysis approach (Ecarnot et al., 2013; Zhen et al., 2021), which is destructive, time-consuming, and difficult to scale up to large-scale accurate mapping (Asner et al., 2017, Cornelissen et al., 2003; Zhen et al., 2021). Thus, monitoring forest health and stress utilising remotely sensed images is crucial for forest management (Zhang, 2007). Therefore, C.C.Maps was generally created to ensure the sustainability of mangrove ecosystem and their components. The objectives of C.C.Maps are to conserve and preserve mangrove ecosystems by indicating the general health of mangrove vegetation by combining in-situ mangrove forest data with remote sensing data.

2. METHOD & MATERIAL

The C.C.Maps was created by combining of ground data collected and the remote sensing technologies data. The ground data used were acquired within the Pulau Tuba, Langkawi. The leaf chlorophyll concentration was determined using a handheld chlorophyll meter during sampling and spectrophotometer techniques in the laboratory. Latitude and longitude of the sampling station were recorded. The data collected were entered in a spatial database for subsequent spatial queries and analysis. The multispectral image was used to derive vegetation index images which was calculated from the specific mathematical algorithm and the final C.C.Maps were produced.

3. FINDINGS

C.C.Maps has a big potential to aid and assist wide range of customers including environmentalists, policy-makers and local communities in relation to the conserving and preserving the mangrove ecosystems and their components. C.C.Maps is also helpful in ensuring the sustainability of the mangrove's ecosystem, monitoring the changes of mangrove areas, preserving valuable resources and their components as well as increasing income for local communities, government and industry players. The C.C.Maps is a ready-made product that would offer paper and digital maps. The development of the C.C.Maps is based on the integration of remotely sensed data that includes in-situ and laboratory data on chlorophyll concentration and signature profiles for various species of mangrove vegetation, as well as vegetation index images derived from remotely sensed data, particularly in the mangrove area of Pulau Tuba, Langkawi, Kedah.

4. DISCUSSION

Mangrove forests along the coast form a unique and vital ecosystem that is known as the most productive and biologically diverse ecosystem (Roslani et al., 2013). However, mangrove areas have been declining at an alarming rate over the last decade, as these ecosystems have degraded and receded (Roslani et al., 2013; Roslani et al., 2014) due to the various kinds of direct and indirect pressure (Roslani et al., 2014). As a result, maintaining mangrove ecosystems is critical which necessitates a better understanding of physiological processes such as photosynthesis, net primary production, and plant health (Flores-de-Santiago et al., 2013; Heenkenda et al., 2015).

Chlorophyll is one of a good indicator of a plant's health and nutritional status as it grows (Zhen et al., 2021). Remote sensing provides an ideal set of techniques for estimating chlorophyll concentration (Pastor-Guzman et al., 2015). For photosynthesis, chlorophyll absorbs light strongly in the blue and red wavelength regions (Heenkenda et al., 2015). As a result, quantifying the spatial-temporal variation of leaf chlorophyll content could provide important information for understanding ecosystem responses to changes in environmental, meteorological, and ecological factors (Croft et al., 2017, Richardson et al., 2002; Zhen et al., 2021).

5. CONCLUSION

C.C.Maps was tasked with modelling the spatial distribution of mangrove canopy chlorophyll content using remotely sensed data and field samples, in accordance with the United Nations' Sustainable Development Goals (SDG), specifically SDG 13: "Climate change," SDG 14: "Life below water," and SDG 15: "Life on land."

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References

Asner, G. P., Martin, R. E., Anderson, C. B., Kryston, K., Vaughn, N., Knapp, D. E., ... & Malhi, Y. (2017). Scale dependence of canopy trait distributions along a tropical forest elevation gradient. *New Phytologist*, 214(3), 973-988.

Cleland, E. E., Chuine, I., Menzel, A., Mooney, H. A., & Schwartz, M. D. (2007). Shifting plant phenology in response to global change. *Trends in Ecology & Evolution*, 22(7), 357-365.

Cornelissen, J. H. C., Lavorel, S., Garnier, E., Díaz, S., Buchmann, N., Gurvich, D. E., ... & Poorter, H. (2003). A handbook of protocols for standardised and easy measurement of plant functional traits worldwide. *Australian Journal of Botany*, 51(4), 335-380.

Croft, H., Chen, J. M., Luo, X., Bartlett, P., Chen, B., & Staebler, R. M. (2017). Leaf chlorophyll content as a proxy for leaf photosynthetic capacity. *Global Change Biology*, 23(9), 3513-3524.

Ecarnot, M., Compan, F., & Roumet, P. (2013). Assessing leaf nitrogen content and leaf mass per unit area of wheat in the field throughout plant cycle with a portable spectrometer. *Field Crops Research*, 140, 44-50.

Flores-de-Santiago, F., Kovacs, J. M., Wang, J., Flores-Verdugo, F., Zhang, C., & González-Farías, F. (2016). Examining the influence of seasonality, condition, and species composition on mangrove leaf pigment contents and laboratory based spectroscopy data. *Remote Sensing*, 8(3), 226.

Heenkenda, M. K., Joyce, K. E., Maier, S. W., & de Bruin, S. (2015). Quantifying mangrove chlorophyll from high spatial resolution imagery. *ISPRS Journal of Photogrammetry and Remote Sensing*, 108, 234-244.

Kamaruddin, S. A., Abd Aziz, K. N., Roslani, M. A., Tajam, J., Zaınolabdın, S. N., & Razman, N. F. A. M. (2018). Mapping of salinity level using spline interpolation techniques over the water of Sungai Merbok, Kedah. *Malaysian Journal of Sustainable Environment*, 5(2), 114-130.

Kamaruzaman, J., & Kasawani, I. (2007, December). Spectral signatures of some mangrove species in Malaysia. In *The 5th WSEAS International Conference on Environment, Ecosystems and Development (EED'07), Puerto De La Cruz, Tenerife, Canary Islands, Spain.*

Motohka, T., Nasahara, K. N., Oguma, H., & Tsuchida, S. (2010). Applicability of green-red vegetation index for remote sensing of vegetation phenology. *Remote Sensing*, 2(10), 2369-2387.

Pastor-Guzman, J., Atkinson, P. M., Dash, J., & Rioja-Nieto, R. (2015). Spatiotemporal variation in mangrove chlorophyll concentration using Landsat 8. *Remote Sensing*, 7(11), 14530-14558.

Richardson, A. D., Duigan, S. P., & Berlyn, G. P. (2002). An evaluation of noninvasive methods to estimate foliar chlorophyll content. *New Phytologist*, 153(1), 185-194.

Roslani, M. A., Mustapha, M. A., Lihan, T., & Juliana, W. W. (2013, November). Classification of mangroves vegetation species using texture analysis on Rapideye satellite imagery. In *AIP Conference Proceedings*, 1571 (1), 480-486. American Institute of Physics.

Roslani, M. A., Mustapha, M. A., Lihan, T., & Wan, J. (2014). Applicability of RapidEye satellite imagery in mapping mangrove vegetation species at Matang mangrove forest reserve, Perak, Malaysia. *Journal of Environmental Science and Technology*, 7(2), 123-136.

Zhang, C., Kovacs, J. M., Liu, Y., Flores-Verdugo, F., & Flores-de-Santiago, F. (2014). Separating mangrove species and conditions using laboratory hyperspectral data: A case study of a degraded mangrove forest of the Mexican Pacific. *Remote Sensing*, 6(12), 11673-11688.

Zhang, Y. (2007). *Hyperspectral remote sensing algorithms for retrieving forest chlorophyll content*. University of Toronto.

Zhen, J., Jiang, X., Xu, Y., Miao, J., Zhao, D., Wang, J., ... & Wu, G. (2021). Mapping leaf chlorophyll content of mangrove forests with Sentinel-2 images of four periods. *International Journal of Applied Earth Observation and Geoinformation*, 102, 102387.