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Analyzing Forest Foliage Cover Using MATLAB: Assessing Environmental and Wildlife Impacts in Global Forest Ecosystems

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Abstract: ***Forests are critical ecosystems that regulate climate, support biodiversity, and provide habitats for countless species. This study explores the application of MATLAB in analyzing vegetation coverage over time using satellite images, focusing on Indonesia's Leuser Ecosystem and Russia's Taiga. By converting RGB images into binary classifications of vegetation and non-vegetation, MATLAB calculates coverage percentages and tracks changes over decades. Results reveal significant declines in vegetation: Indonesia's forest cover reduced by 0.14%, and Russia's Taiga experienced a drastic 3.12% decrease. These findings highlight the severe ecological impacts of deforestation, including habitat loss and disrupted climate regulation. While MATLAB offers robust image processing tools, challenges such as image quality, computational limits, and misclassification persist. This research underscores the importance of remote sensing in informing conservation strategies and advancing foliage analysis techniques, paving the way for improved ecosystem monitoring and policy-making.***

Keywords: Forest foliage, vegetation coverage, MATLAB, deforestation, ecosystem monitoring

1.Introduction

Forests play a critical role in regulating the Earth's climate and sustaining biodiversity. These ecosystems, particularly in regions such as the Canadian Boreal Forest, temperate rainforests like the Great Bear Rainforest, Indonesia's Leuser Ecosystem, Russia's Taiga, and the forests of the Democratic Republic of Congo, act as significant carbon storehouses and provide habitats for countless species. Foliage cover, or the density of trees and vegetation, is a key metric in assessing the health of these forest ecosystems. Understanding changes in foliage cover over time is essential to evaluate the broader environmental impacts, including the correlation between deforestation, climate change, and the well-being of animal species that inhabit these regions.

The decline in tree coverage is intricately linked to rising global temperatures, changes in weather patterns, and the disruption of habitats. By assessing tree coverage in forests, researchers can gain insight into the health of these ecosystems and the potential consequences for the environment and biodiversity. Monitoring foliage cover also offers valuable data to predict long-term environmental trends, aiding in efforts to preserve these vital ecosystems.

This research seeks to explore how images of tree coverage in forest areas can be analyzed using MATLAB. Specifically, the study aims to quantify the extent of tree loss and determine how these changes impact both animals and the environment. The use of remote sensing technologies and image analysis can offer a new perspective on the state of global forests, shedding light on the relationship between foliage cover and broader ecological changes.

2.Literature Review

Overview of Foliage Cover Analysis

Historically, methods such as data extrapolation from floristic observations[1] and nadir photography[2] have been used to analyze foliage cover in natural areas to determine characteristics such as species richness and vegetation attributes. These results have added value to ecological maps, providing insights into patterns of vegetation and aiding in forest management, climate studies, and ecological research.

However, visual assessments, such as those used by McNellie, can include inherent biases and inconsistencies between observers and observation periods, making them less reliable for analyzing foliage coverage.[3] Additionally, techniques such as nadir photography are often measured against visual assessments, which introduces potential inaccuracies. This study explores a new approach to quantifying images and objectively measuring foliage coverage by utilizing MATLAB.

MATLAB in Remote Sensing and Image Analysis

[1] Megan J. McNellie, Ian Oliver, Simon Ferrier, et al., 'Extending vegetation site data and ensemble models to predict patterns of foliage cover and species richness for plant functional groups', *Landscape Ecology*, vol. 36, no. 5, May 2021, pp. 1391–1407, DOI: 10.1007/s10980-021-01221-x.

[2] Craig Macfarlane and Gary N. Ogden, 'Automated estimation of foliage cover in forest understorey from digital nadir images', *Methods in Ecology and Evolution*, vol. 3, no. 2, 5 September 2011, pp. 405–415, DOI: 10.1111/j.2041-210X.2011.00151.x.

[3] Craig Macfarlane and Gary N. Ogden, 'Automated estimation of foliage cover in forest understorey from digital nadir images', *Methods in Ecology and Evolution*, vol. 3, no. 2, 5 September 2011, pp. 405–415, DOI: 10.1111/j.2041-210X.2011.00151.x.

MATLAB offers a robust platform for analyzing images by breaking them down into pixels and building statistical models to classify them based on similarity. The user-friendly GUI enables the generation of subsets for building statistical classifiers. Additionally, MATLAB can segment images, which can be refined using spatial techniques like MRF[4].

Moreover, MATLAB utilizes filters such as Gaussian and low-pass filters, which are essential in reducing noise and improving image quality.[5] These filters help eliminate irrelevant details while preserving the essential features of the image, making them critical in foliage cover analysis. For example, Gaussian filters smooth the image by averaging neighboring pixels, while low-pass filters help remove high-frequency noise, resulting in a clearer representation of tree coverage. This technique ensures more accurate data when analyzing forest ecosystems.

Applications of MATLAB in Foliage Cover Analysis

Various studies have utilized MATLAB to process satellite or aerial imagery for analyzing foliage cover. For example, a study by Bojana Ivosevic and colleagues in 2017 analyzed tree coverage using aerial vehicle photogrammetry. They used unmanned aerial vehicles (UAVs) to create 3D models of areas. The collected images were pixelated in MATLAB, and the data showed that the 3D models were accurate and could enhance the accuracy of UAVs over time[6].

In another study, Andres Patrignani and colleagues[7] measured fractional green canopy coverage over several years. They developed a tool called Canopeo using MATLAB, which analyzed fractional green canopy coverage from images and videos over time. This demonstrated MATLAB's capability in long-term monitoring of foliage cover.

Case Studies and Methodologies

A notable study involving MATLAB in ecology is the analysis of the leaf area index (LAI) in woodland ecosystems by Sigfredo Fuentes and colleagues.[8] This study used digital imagery and MATLAB to measure the amount of leaf material in a canopy, known as LAI. The researchers applied gap fraction analysis and developed MATLAB scripts to compare LAI values across various sections of an Australian Eucalyptus woodland. The study highlighted how MATLAB could be customized to specific ecological measurements, providing critical data for understanding forest growth and water usage.

Challenges and Limitations

MATLAB has limitations when dealing with large datasets or high-resolution imagery. For example, the computer memory limits the resolution at which the images are analysed.[9] Additionally, in MATLAB, a 64 x 64 pixel image is often the upper limit of what it can efficiently process. This means that anything beyond that will lose resolution, and therefore might lose credibility[10]. Furthermore, most modern image processing, including that of the Hubble Space Telescope, uses digital signal processing (DSP). MATLAB is often used to implement and visualize processing techniques of such images as they are very computation heavy. However, images using digital signal processing (DSP) often are disregarded or regarded as incomplete due to them being distorted during the processing.[11] As of right now, these limitations will be hard to circumvent.

Future Applications of MATLAB

Further computational methods are emerging, in addition to potential advancements in MATLAB and their implications for future research in foliage cover analysis. For example, computational intelligence techniques such as neural

[4] Doan M, Barnes C, McQuin C, Caicedo JC, Goodman A, Carpenter AE, Rees P. Deepometry, a framework for applying supervised and weakly supervised deep learning to imaging cytometry. Nat Protoc. 2021 Jul;16(7):3572-3595. doi: 10.1038/s41596-021-00549-7. Epub 2021 Jun 18. PMID: 34145434; PMCID: PMC8506936.

[5] Sung Kim, 'Applications of Convolution in Image Processing with MATLAB', ed. by Riley Casper, (University of Washington, 20 August 2013), https://yunmingzhang.wordpress.com/wp-content/uploads/2015/01/applicationsofconvolutioninimageprocessingwithmatlab.pdf

[6] Bojana Ivosevic, Yong-Gu Han, Ohseok Kwon, 'Calculating coniferous tree coverage using unmanned aerial vehicle photogrammetry', *Journal of Ecology and Environment*, 41(1) (December 2017), https://doi.org/10.1186/s41610-017-0029-0

[7] Andres Patrignani and Tyson E. Ochsner, 'Canopeo: A Powerful New Tool for Measuring Fractional Green Canopy Cover', *Agronomy Journal*, (1 November 2015), https://doi.org/10.2134/agronj15.0150

[8] Sigfredo Fuentes, Anthony R. Palmer, Daniel Taylor, Melanie Zeppel, Rhys Whitley, Derek Eamus, 'An automated procedure for estimating the leaf area index (LAI) of woodland ecosystems using digital imagery, MATLAB programming and its application to an examination of the relationship between remotely sensed and field measurements of LAI', *Functional Plant Biology*, 35 (2008), 1070-1079 https://doi.org/10.1071/FP08045

[9] Leendert A. Klerk, Alexander Broersen, Ian W. Fletcher, Robert van Liere, and Ron M.A. Heeren, 'Extended Data Analysis Strategies for High Resolution Imaging MS: New Methods to Deal with Extremely Large Image Hyperspectral Datasets', *International Journal of Mass Spectrometry*, 260 (2–3 February 2007), 222–236, https://doi.org/10.1016/j.ijms.2006.11.014

[10] Shorten, C., Khoshgoftaar, T.M. A survey on Image Data Augmentation for Deep Learning. *J Big Data* 6, 60 (2019). https://doi.org/10.1186/s40537-019-0197-0

[11] Sung Kim, 'Applications of Convolution in Image Processing with MATLAB', ed. by Riley Casper, (University of Washington, 20 August 2013), https://yunmingzhang.wordpress.com/wp-content/uploads/2015/01/applicationsofconvolutioninimageprocessingwithmatlab.pdf

networks and decision trees are being applied to fuzzy-inference methods to study lang covers from satellite images. Results from a case study using land cover over three years from the Niassa province in Mozambique were taken from fuzzy-inference methods. Based on these findings, it is seen that these methods work similarly to decision trees, while not suffering from fitting limitations.[12]

Additionally, MATLAB is helping UAVs to improve their accuracy when it comes to analysing images in order to build three dimensional models. As a result, this can improve efficiency of farming in certain regions. This can be achieved using techniques such as the half Gaussian fitting.[13]

3. Aim of the Study

The primary aim of this research is to develop a MATLAB-based methodology for analyzing images to determine the percentage of tree cover and track changes in specific areas over time. In addition to this main objective, the study has several secondary aims: first, to assess the impact of changes in tree cover on local wildlife populations; second, to evaluate the implications of foliage changes on public health; and third, to compare the accuracy of image-based assessments of foliage cover with traditional methods of measuring tree cover. Through this comprehensive approach, the research seeks to enhance our understanding of the ecological and societal implications of forest cover dynamics.

Methods and Data Collection

The MATLAB code I wrote is designed to analyze two RGB images of vegetation to assess changes in vegetation coverage over time. It begins by prompting the user to select two image files, which are then read and converted to a suitable format for processing.

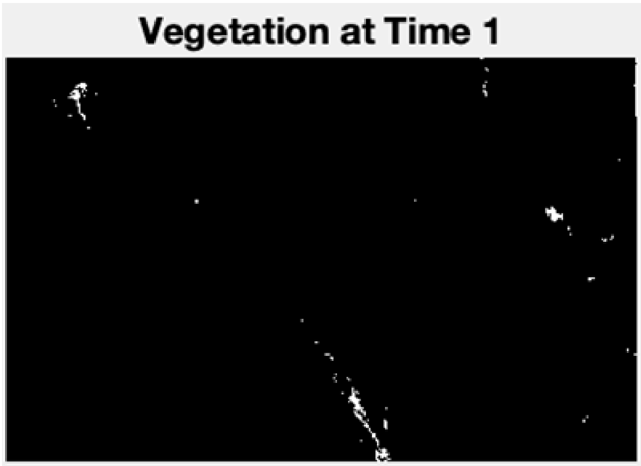
Once the images are prepared, the code applies a threshold to classify pixels as vegetation or non-vegetation based on their intensity values. This classification results in binary images that visually represent the areas of vegetation for both time points.
The code then calculates the total number of pixels in the images and counts the number of vegetation pixels for each time point. From this data, it computes the percentage of vegetation coverage and determines the change in coverage between the two images.

Finally, the results, including the area of vegetation in pixels, percentage coverage at both time points, and the overall change in vegetation coverage, are displayed in the MATLAB Command Window. This analysis allows for a clear understanding of vegetation dynamics over time.

Images were collected from the timelapse on Google Earth Engine, captured to insure an equal number of pixels in each image. Satellite and drone-captured images were collected in order to compare the regions of Indonesia's Leuser Ecosystem and Russia's Taiga from 1984, and 2022. Here are the images and the data gotten from MATLAB:

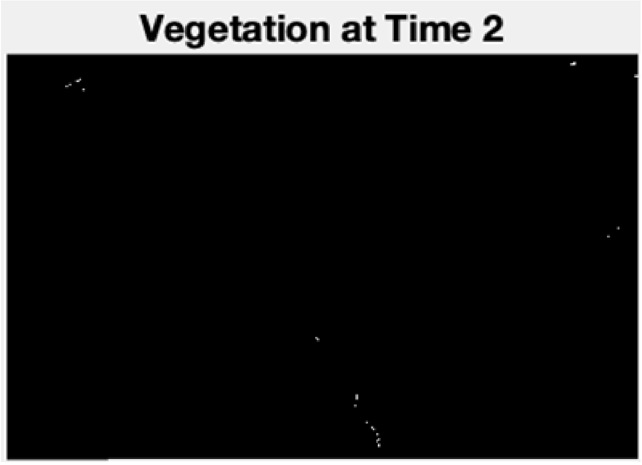
Luseur, Indonesia, 1984

Luseur, Indonesia, 2022



[12] André Mora, Tiago M. A. Santos, Szymon Łukasik, João M. N. Silva, António J. Falcão, José M. Fonseca, and Rita A. Ribeiro, 'Land Cover Classification from Multispectral Data Using Computational Intelligence Tools: A Comparative Study', *MDPI*, Multidisciplinary Digital Publishing Institute, *Information*, 8(4) (2017), 147, https://doi.org/10.3390/info8040147

[13] Linyuan Li, Jun Chen, Xihan Mu, Weihua Li, Guangjian Yan, Donghui Xie, and Wuming Zhang, 'Quantifying Understory and Overstory Vegetation Cover Using UAV-Based RGB Imagery in Forest Plantation', *MDPI*, Multidisciplinary Digital Publishing Institute, *Remote Sensing*, 12(2) (2020), 298, https://doi.org/10.3390/rs12020298



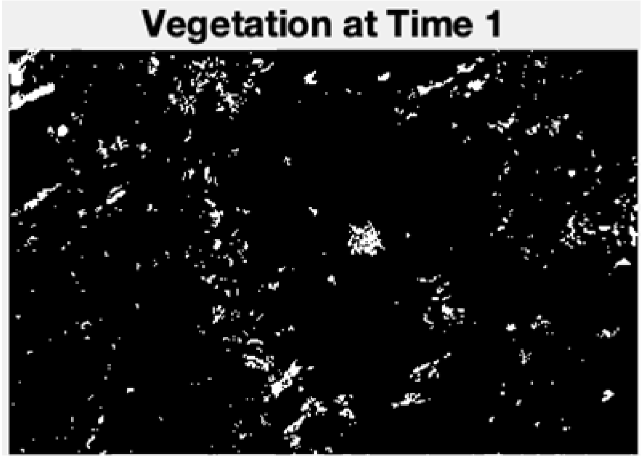
Vegetation map of Luseur over 18 years (Time 1 = 1984, Time 2 = 2022)

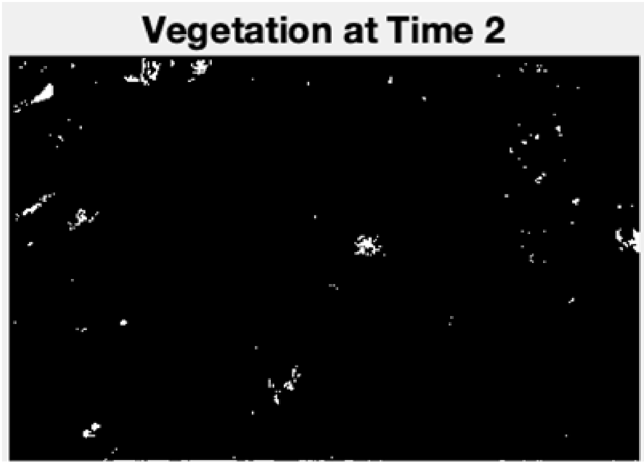
```
Vegetation Area at Time 1: 4562 pixels
Vegetation Area at Time 2: 2774 pixels
Vegetation Coverage at Time 1: 0.36001%
Vegetation Coverage at Time 2: 0.21891%
Change in Vegetation Coverage: -0.1411%
```

MATLAB's Image Pixel Analysis of Vegetation Coverage

Taiga, Kemerevo Oblast, Russia, 1984

Taiga, Kemerevo Oblast, Russia, 2022





Vegetation map of Taiga over 18 years (Time 1 = 1984, Time 2 = 2022)

```
% Display the results
disp(['Vegetation Area at Time 1: ', num2str(vegArea1), ' pixels']);
disp(['Vegetation Area at Time 2: ', num2str(vegArea2), ' pixels']);
disp(['Vegetation Coverage at Time 1: ', num2str(vegCoverage1), '%']);
disp(['Vegetation Coverage at Time 2: ', num2str(vegCoverage2), '%']);
disp(['Change in Vegetation Coverage: ', num2str(changeCoverage), '%']);
Vegetation Area at Time 1: 49304 pixels
Vegetation Area at Time 2: 9759 pixels
Vegetation Coverage at Time 1: 3.8877%
Vegetation Coverage at Time 2: 0.76951%
Change in Vegetation Coverage: -3.1182%
```

MATLAB's Image Pixel Analysis of Vegetation Coverage

4.Discussion

The analysis of vegetation coverage in the Taiga Forest of Russia and the Luseur of Indonesia reveals significant declines over the observed time periods. In the Russian Taiga, the vegetation area decreased from 49,304 pixels to 9,759 pixels, resulting in a change in coverage from approximately 3.89% to 0.77%. This represents a reduction of about 3.12%, indicating a drastic loss of forest cover, which may be attributed to factors such as logging, climate change, or increased human activity in the region.

Similarly, the forest area in Indonesia showed a decline from 4,562 pixels to 2,774 pixels, leading to a decrease in vegetation coverage from 0.36% to 0.22%. The change of approximately 0.14% indicates a concerning trend in forest loss, potentially driven by deforestation for agriculture or urban development. These results highlight the urgency for conservation efforts in both regions, as the continued decline of vegetation can have profound ecological impacts, including habitat loss, increased carbon emissions, and disruption of local climates.

Insights Gained from the Analysis of Tree Cover Trends Over Time

This analysis underscores the value of remote sensing in monitoring forest cover changes, allowing for timely interventions and policy-making. The stark differences in vegetation coverage between the two locations reflect varying environmental conditions, management practices, and levels of human impact. Tracking these changes over time provides critical insights into the health of ecosystems and the need for conservation strategies.

Moreover, the percentage changes in vegetation coverage serve as quantifiable metrics for assessing the success of preservation initiatives and inform stakeholders about the potential long-term consequences of continued deforestation.

Challenges and Limitations

Despite the insights gained, several challenges and limitations must be acknowledged. One of the primary challenges lies in the image processing stage. Errors can occur due to variations in image quality, atmospheric conditions, or misclassifications during the thresholding process, which may lead to inaccurate assessments of vegetation coverage. For example, shadows, water bodies, or other non-vegetation features could be incorrectly classified as vegetation, inflating the coverage percentages.

Additionally, assumptions made during the analysis, such as the uniformity of pixel intensity thresholds for classifying vegetation, can significantly impact the results. Different vegetation types and health states may exhibit similar spectral responses, complicating the distinction between vegetation and non-vegetation areas. As such, these assumptions can lead to either overestimation or underestimation of true vegetation coverage.

5.Conclusion

The analysis of vegetation coverage in Indonesia's Leuser Ecosystem and Russia's Taiga revealed significant declines in forest foliage over time. These findings highlight the urgent need for conservation efforts to address deforestation and its associated environmental impacts. Specifically, the Leuser Ecosystem showed a reduction in vegetation coverage from 0.36% to 0.22%, reflecting a 0.14% loss, likely driven by agricultural expansion and urban development. Similarly, the Russian Taiga experienced a more drastic decline from 3.89% to 0.77%, amounting to a 3.12% loss, which may result from logging, climate change, and increased human activities.

These changes in forest cover are critical as they directly affect biodiversity, disrupt ecosystems, and contribute to rising carbon emissions and climate instability. The decline in foliage coverage also threatens wildlife habitats, particularly for species reliant on dense forest ecosystems for survival.

This study demonstrates the utility of MATLAB in analyzing satellite imagery for monitoring vegetation dynamics over time. By processing pixelated images and applying thresholding techniques, MATLAB provided an effective means of quantifying forest cover changes. However, challenges such as misclassification errors and computational limitations highlight the need for further refinement of the methodology.

6.Future Scope

This study provides a strong foundation for understanding vegetation dynamics using satellite imagery and computational tools, but there are numerous opportunities to build upon these findings. Integrating machine learning algorithms, such as convolutional neural networks (CNNs), could significantly enhance the classification accuracy of vegetation mapping by better distinguishing between various vegetation types and minimizing errors. Additionally, extending the temporal range of analysis to include a broader set of historical satellite data could offer deeper insights into long-term trends and patterns, such as deforestation and forest recovery. Furthermore, incorporating climate data, such as temperature, precipitation, and carbon dioxide levels, could help establish links between environmental factors and changes in vegetation. Expanding this research to include a wider range of ecosystems or urban environments could also contribute to a more comprehensive understanding of how land use and climate interact to shape vegetation over time. By addressing these areas, future studies can provide even more detailed and actionable insights into ecosystem dynamics and their implications for environmental management.

References

[1] Fuentes S, Palmer AR, Taylor D, Zeppel M, Whitley R, Eamus D., 'An automated procedure for estimating the leaf area index (LAI) of woodland ecosystems using digital imagery, MATLAB programming and its application to an examination of the relationship between remotely sensed and field measurements of LAI', Functional Plant Biology, vol. 35, no. 10, Dec. 2008, pp. 1070–1079, DOI: 10.1071/FP08045.

[2] Ivosevic, B., Han, Y.-G., and Kwon, O., 'Calculating coniferous tree coverage using unmanned aerial vehicle photogrammetry', Journal of Ecology and Environment, 41(1) (December 2017), https://doi.org/10.1186/s41610-017-0029-0

[3] Kim, S., 'Applications of Convolution in Image Processing with MATLAB', ed. by Riley Casper, (University of Washington, 20 August 2013), https://yunmingzhang.wordpress.com/wp-content/uploads/2015/01/applicationsofconvolutioninimageprocessingwithmatlab.pdf

[4] Klerk, L. A., Broersen, A., Fletcher, I. W., van Liere, R., and Heeren, R. M.A., 'Extended Data Analysis Strategies for High Resolution Imaging MS: New Methods to Deal with Extremely Large Image Hyperspectral Datasets', International Journal of Mass Spectrometry, 260 (2–3 February 2007), 222–236, https://doi.org/10.1016/j.ijms.2006.11.014

[5] Li, L., Chen, J., Mu, X., Li, W., Yan, G., Xie, D., and Zhang, W., 'Quantifying Understory and Overstory Vegetation Cover Using UAV-Based RGB Imagery in Forest Plantation', MDPI, Multidisciplinary Digital Publishing Institute, Remote Sensing, 12(2) (2020), 298, https://doi.org/10.3390/rs12020298
[6] Macfarlane C, Ogden GN, 'Automated estimation of foliage cover in forest understorey from digital nadir images', Methods in Ecology and Evolution, vol. 3, no. 2, 5 September 2011, pp. 405–415, DOI: 10.1111/j.2041-210X.2011.00151.x.
[7] McNellie MJ, Oliver I, Ferrier S, et al., 'Extending vegetation site data and ensemble models to predict patterns of foliage cover and species richness for plant functional groups', Landscape Ecology, vol. 36, no. 5, May 2021, pp. 1391–1407, DOI: 10.1007/s10980-021-01221-x.
[8] Mora, A., Santos, T. M. A., Łukasik, S., Silva, J. M. N., Falcão, A. J., Fonseca, J. M., and Ribeiro, R. A., 'Land Cover Classification from Multispectral Data Using Computational Intelligence Tools: A Comparative Study', MDPI, Multidisciplinary Digital Publishing Institute, Information, 8(4) (2017), 147, https://doi.org/10.3390/info8040147
[9] Patrignani, A., and Ochsner, T. E., 'Canopeo: A Powerful New Tool for Measuring Fractional Green Canopy Cover', Agronomy Journal, (1 November 2015), https://doi.org/10.2134/agronj15.0150

Author Profile

Aarna Agarwal is one of the co-captains for Singapore American School's SpaceLab team. She's been interested in the STEM field since middle school, and has since been exploring her interests through clubs like Geek Girls and robotics. Being in Geek Girls, she advocates for more female participation in STEM classes and activities at school. In SpaceLab, she mainly worked in the electrical and experiment department. She is also an accomplished athlete, training at the Archery Academy of Singapore, and has competed at the national and international level.