Data Article

Brunei Darussalam rainforest temperature and light intensity data recorded in 2017

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\textbf{ABSTRACT}

Air temperature and light intensity in the tropical rainforest of Brunei Darussalam was recorded at a 20-min interval from 2011 to 2017. Five units of the HOBO Pendant® data loggers were attached to tree trunks within a circle of 5 m radius at 2 m above the ground. Approximately once a year, data were downloaded, and the sensors serviced. The test site is in a peat swamp forest classified as a mixed dipterocarp forest. The redundancy of the sensors allows for the assessment of the relative precision of the datasets. The root means squared error (RMSE) for the temperature is 0.37 °C, below the manufacturer’s precision statement (0.53 °C). The RMSE for the light intensity data was 569.5 lux. There was no detection of systematic errors in the data. The sensors were calibrated before deployment. The data sets were captured in 2017. Ancillary data were collected in 2018, consisting of RGB orthophagery and Light Detection And Ranging (LiDAR) data collected from an airborne platform. The data is a unique source of information on the diurnal, intraannual periodic effects, as well as random weather-related and phenology-related phenomena. Multiannual datasets in the same ecosystem will be published in the future, allowing for a multidisciplinary analysis of the data in the context of climate change and the impact on the tropical rainforest ecosystems. The raw and auxiliary datasets are hosted in the Mendeley repository [1].

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Specifications Table

Subject
Specific subject area
Environmental Science (General)
Suitable for multi- and interdisciplinary studies of forest microclimate, phenology, tropical rainforests, forest canopy, secular climate trend, thermodynamics
Type of data
Table (ASCII)
Image (TIFF)
List (ASCII)
How data were acquired
Five units of the HOBO Pendant® data logger (Onset Computer Corporation, MA, USA), allowing for recording up to 64 kbytes (approx. 52,000 records) of temperature and light intensity data, were set to 20 minutes recording interval in 2017 (start on 6-Jan-2017 06:00, end on 31-Dec-17 23:40). A preliminary analysis of the downloaded data has found that 2 out of 5 sensors did not record any data (due to battery fault). The remaining three sensors provided 25,902 records each of the useful data. The data Light Detection and Ranging (LiDAR) survey was performed using an airborne instrument by Riegel Lidar Scanner LMS-Q680i at 15 pts/m² density. Aerial photography was captured using DigiCam 60 Megapixel digital RGB camera at 7 cm ground pixel resolution. The LiDAR and photography were captured simultaneously on 18/3/2018 from the altitude of 550 m above the ground.
Data format
Raw [Excel spreadsheet] (temperature, light intensity)
Georeferenced and geometrically corrected (orthorectified) mosaic of aerial photography (GeoTIFF)
Raw – LiDAR data (LAS v. 1.2)
Parameters for data collection
Sensors are located in a secluded, hard-to-access section of the forest. Sensors are attached to tree trunks on the westerly side at approx. 2 m above the terrain and facing the ground. The attachment of the sensor to the trunk does not damage the hosting tree. The sensors must be closed to each other to maintain the same or very similar environmental conditions (5 m radius was arbitrarily selected).
Description of data collection
The air temperature and light intensity have been recorded using a redundant set of 5 sensors every 20-minutes. Since Jan 2011, every year, the sensors are serviced and data extracted for in-office analysis. The LiDAR and orthophoto are auxiliary information providing a more in-depth insight into the structure vertical structure of the forest at the test site and the topography of the ground of the test site. The LiDAR and orthophoto were acquired during an unrelated experiment. A LiDAR and a camera were flown on an aircraft at approximately 550 m above the ground.
Data source location
Wroclaw University of Science and Technology
Wroclaw/Dolnoslaskie, Poland
Latitude and longitude the test site: Latitude = N4 °34’13.5”,
Longitude = E114 °25’06.5”
Data accessibility
Repository name: Mendeley Data
Data identification number: 10.17632/5vzp6svhwh.4
Direct URL to data: http://dx.doi.org/10.17632/5vzp6svhwh.4
Instructions for accessing these data: No restrictions.

Value of the Data

- The data recorded at ultra-high temporal resolution temperature and light intensity data at the bottom of the tropical rainforest are unique globally. Climate change and its impact on
the "lungs of the Earth" is at the core of this data collection project [2], [3]. The data can assist a range of multi-, inter- and interdisciplinary studies on the impact of global climate on tropical rainforest [14], forest canopy phenology [13], and the forest interior's energy and gases exchange. The data can also improve the atmosphere's knowledge, intra-annual and diurnal micro-meteorological variations, and fauna and flora interaction. These data linked to the satellite remote sensing observations will enable a more comprehensive spatial and temporal coverage of studied ecosystems.

• Forest researchers, ecologists, biologists [17], climatologists [8], meteorologists, remote sensing specialists [6], [7], [9] bio-thermodynamic modelers, forest canopy researchers [10], [11], [12], [15], [16] can benefit from these datasets.

• The light intensity temperature data recorded at the bottom of a forest, together with the sun's position on the sky, can be used to study the forest canopy, its internal structure, and phenology as a function of meteorological and climate variables. This information can be used in connection with remote sensing data captured by, for example., the Copernicus Sentinel program, and in particular, with the Sentinel 1A/B and Sentinel 2A/B missions' data. The prospect is even better as some biomass satellite remote sensing missions are currently being prepared.

• The distributed data package included a dense cloud of LiDAR points (approx. 15 pts/m²), high-resolution color, geometrically corrected aerial photography of the sensors' location. It also included a high-resolution digital terrain model of the site and neighborhood. This was in addition to the temperature and light intensity data. For interested researchers, similar data are available from the early months of 2011. Also, the data collection experiment has been in progress without a fixed conclusion date.

• A very inexpensive method and equipment captured the data provided here. The authors wish to encourage other researchers to establish similar data acquisition facilities at various locations globally to expand a body of evidence of the impact of global change on the earth's biosphere.

1. Data Description

Table 1 shows an example of three records taken from the logger named ‘S1_2017’.

Fig. 1 shows an example of the data graphs for all three loggers for 24 hours from 6 am local time (+8 GMT) of 6 January 2017 to 6 pm local time (+8 GMT) of 7 January 2017.

The repository contains the ‘Dataset_metadata.xlsx’ spreadsheet. The metadata file describes all the technical details and the overall context of the primary data file and the project (newbadas.xlsx).

| S/N | Site Code | Sensor | DT(Date/Time) | Temp.(°C) | Intens.(lux) |
|-----|-----------|--------|---------------|-----------|-------------|
| 1   | NB        | S1     | 06-01-17 06:00:00 | 23.39     | 0           |
| 2   | NB        | S1     | 06-01-17 06:20:00 | 23.39     | 0           |
| 3   | NB        | S1     | 06-01-17 06:40:00 | 23.39     | 0           |
| 4   | NB        | S1     | 06-01-17 07:00:00 | 23.39     | 32          |
| 5   | NB        | S1     | 06-01-17 07:20:00 | 23.39     | 108         |
| 6   | NB        | S1     | 06-01-17 07:40:00 | 23.48     | 226         |
| 7   | NB        | S1     | 06-01-17 08:00:00 | 23.68     | 388         |
| 8   | NB        | S1     | 06-01-17 08:20:00 | 23.97     | 452         |
| 9   | NB        | S1     | 06-01-17 08:40:00 | 24.26     | 926         |
Fig. 1. A sample plot of the temperature and light intensity captured during 24 hours from 6 am local time (+8 GMT) of 6 January 2017 to 6 am local time (+8 GMT) of 7 January 2017. Source: K. Becek – own work.

The ‘aerialphoto.zip’ file is a compressed mosaic of orthorectified images of the test site and its immediate neighborhood. The image file is in a GeoTIFF format, while the datum/map projection is WGS84/UTM50N. Fig. 3 shows the orthophoto.

The repository contains LiDAR.zip file, which holds the LiDAR data for the test site. The data are in the industry-standard las format version 1.2. The file contains 1,202,724 points (class 1) representing vegetation, and 19,785 points (class 2) representing the terrain. The datum and map projection for the dataset is WGS84/UTM 50N. The height of the LiDAR points is referenced to the local, orthometric (mean sea level) vertical datum. The LiDAR and aerial photographs were simultaneously captured on 18 March 2018 from approximately 550 m above the ground.

The SOP.docx contains a complete technical specification of the sensor and other relevant information needed to replicate the experiment.

2. Experimental Design, Materials and Methods

Fig. 2 shows a geographic context for the test site. The approximate coordinates of the site are Latitude = 4°34’13.5” N, Longitude = 114°25’06.5” E. The elevation of the site is approximately 11.1 m above mean sea level (AMSL). This map is not a part of the shared datasets.

Fig. 3 shows a geometrically corrected (orthorectified) mosaic of high resolution (0.1 m pixel) aerial photographs acquired on 18 March 2018 from an altitude of approximately 550 m above ground. The location of the test site is marked with a red circle.

A dense forest covers the central part of the AOI. In the lower right corner of the images, an area with sparse vegetation on sandy soil is visible. In this area, the forest was destroyed by fire in 1998.
Because of the forest’s extremely dense and multilayer structure, a high-resolution topography of the site was unknown until a recent high-resolution LiDAR survey was carried out on 18 March 2018. Fig. 3 shows a digital terrain model (DTM) of the site derived from the LiDAR points collected on the forest floor at an average density of 0.4 points m$^{-2}$. The pixel size of the DTM is 0.5 m. The prevailing elevation on the DTM is between 11 m and 12 m. The slightly brighter spots (elevated spots) in this part of the DTM have buttressed tree roots. Comparing the lowest topography of the DTM with the orthomosaic shown in Fig. 3, one can note that the forest is much denser and more spatially coherent species-wise. The higher areas of the DTM correlate with a highly diversified forest in terms of both species and tree height, most likely due to water availability and nutrients transported from the elevated areas.

The prevailing climate at the AOI is Tropical Rainforest Climate, according to the Köppen Climate Classification subtype. The average annual temperature at Brunei International Airport is 27.8 °C. On average, the warmest and coldest months are April (28.3 °C) and January (26.7 °C). Precipitation in Brunei varies between 2500 and 4500 mm yr$^{-1}$. The AOI receives approx. 3200 mm yr$^{-1}$. Brunei’s temperature rose at about 0.28 °C per decade, while the monthly mean rainfall has been rising at a rate of 9.8 mm per decade in the past 40 years. Dykes [4], [5] reported valuable research on climate and forest canopy throughfall. The observations fall well within a long-term meteorological data available from Brunei Darussalam Meteorological Department (BDMD) (although not online). The website of the BDMD

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Fig. 2. Location of the area of interest (AOI). Source: K. Becek – own work.
Fig. 3. A geometrically corrected mosaic of aerial images (orthomosaic) taken on 18 March 2018. Source: Courtesy of Soartech Systems Sdn. Bhd., Brunei Darussalam.

(http://www.bruneiweather.com.bn/climate) also provides a comprehensive and official description of Brunei Darussalam’s climate.

Based on the country’s forest map, the AOI’s forest cover of Brunei Darussalam is mixed species. It is mainly a freshwater peat forest dominated by Shorea albida Sym. and occasionally by the endangered Agathis borneensis Warb. species.

Fig. 5 shows the vertical cross-sections of the AOI that are intersecting at the approximate sensor’s location. These profiles were developed from the LiDAR data. The height above the ground classified the above-ground LiDAR points. The three classes of the LiDAR points represent the lowest, medium, and high vegetation strata. The arbitrary defined levels are: < 0.5 m; > 0.5 m and <= 15 m, and > 15 m, respectively.

Fig. 6 shows a glimpse of the forest canopy seen from above. The figure was prepared from the LiDAR data captured at an approximate density of 15 points/m². The circle radius was 100 m, and its center was coincidental with an approximate sensor’s position. The canopy trees can be easily recognized, with the tallest located in the lower sections of terrain (compare DTM in Fig. 4.).

The temperature and light intensity data were recorded using the HOBO® Pendant data logger (Onset, MA, USA). The sensor can store up to 64 kB of data at selectable temporal resolutions. In this case, a 20-min sampling rate was selected as a balance between data storage capacity and battery life (approximately one year). The 20-min sampling rate allows for
Fig. 4. Digital terrain model of the AOI based on the LIDAR survey. The ground resolution of the model is 0.5 m. The contour interval is 1 m. Source: K. Becek – own work.

400 days of recording. A detailed description of the logger can be found in the Standard Operating Procedure (SOP) available from the data repository (SOP.docx). To maintain a level of redundancy of data recording (e.g., in case of a faulty data logger or mechanical damage to the logger by animals and insects), five loggers were installed. The sensors were attached to tree trunks using a tree-friendly device developed for the experiment. Fig. 7(a), 7(b), and 7(c) show the sensor, the sensor attached to the deployment device, and the sensor attached to a tree, respectively.
Fig. 5. Vertical cross-sections N-S (top) and W-E (bottom) over the AOI intersecting at the sensors’ approximate location. The forest strata marked with colors are as follows: Lowest strata < 0.5 m; Medium strata > 0.5 m but <= 15 m; and High strata> 15 m. These profiles were produced from the LiDAR data. Note horizontal and vertical scale bars. Source: K. Becek – own work.
Fig. 6. AOI as seen from an above-canopy position. Colors indicate height above the ground: blue – ground surface; light brown < 0.5 m; green > 0.5 m but <= 15 m; and red > 15 m. Source: K. Becek – own work.

Fig. 7. (a) – HOBO® Pendant data logger used in the experiment; (b) – Datalogger attached to a deployment device; (c) – Datalogger attached to a tree trunk. Source: K. Becek – own work.

Three of the five installed loggers produced datasets of the air temperature and light intensity, while two failed to record any useful data. There are 25,902 records for each sensor. The data recording commenced on 6 January 2017 at 6 am local time (+8 GMT) and concluded on 31 December 2017 at noon (+8 GMT).
Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have, or could be perceived to have, influenced the work reported in this article.

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