Cloud Forest Characteristics of Khao Nan, Thailand

P. Sangarun, W. Srisang, K. Jaroensutasinee, and M. Jaroensutasinee

***Abstract*—**A better understanding of cloud forest characteristic in a tropical montane cloud forest at Khao Nan, Nakhon Si Thammarat on climatic, vegetation, soil and hydrology were studied during 18-21 April 2007. The results showed that as air temperature at Sanyen cloud forest increased, the percent relative humidity decreased. The amount of solar radiation at Sanyen cloud forest had a positive association with the amount of solar radiation at Parah forest. The amount of solar radiation at Sanyen cloud forest was very low with a range of 0-19 W/m^2. On the other hand, the amount of solar radiation at Parah forest was high with a range of 0-1000 W/m^2. There was no difference between leaf width, leaf length, leaf thickness and leaf area with increasing in elevations. As the elevations increased, bush height and tree height decreased. There was no association between bush width and bush ratio with elevation. As the elevations increased, the percent epiphyte cover and the percent soil moisture increased but water temperature, conductivity, and dissolved oxygen decreased. The percent soil moistures and organic contents were higher at elevations above 900 m than elevations below.

***Keywords*—**Cloud forest, Climate, Vegetation, Soil, Hydrology.

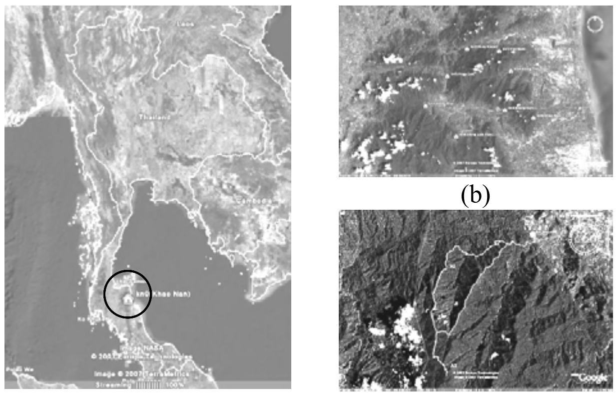
I. Introduction

TROPICAL montane cloud forest occurs in mountainous altitudinal band frequently enveloped by orographic clouds [1,2]. This forest obtains more moisture from deposited fog water in addition to bulk precipitation [3-5]. The main climatic characteristics of cloud forests include frequent cloud presence, usually high relative humidity (RH) and low irradiance [4]. At high altitude tropical mountains, the trees typically decrease in stature, and leaves become smaller, and harder. If the tropical mountain intersects the cloud cap, their effects are magnified. Twisted stunted trees are encountered and the leaves become even more akin to desert xeromorphic leaves. The dwarfed trees in the cloud cap are laden with a heavy mass of epiphytes whose roots suspend in air. Cloud forest soils are wet and frequently saturated, though rarely waterlogged. No cloud forest soil ever showed a water deficit, even during severe drought [4]. There has been one observation of cloud forest dieback in response to a drought [5].

Little has been done on climatic factors, vegetation, soil, hydrology and their effects on tropical montane cloud forest in Thailand. The lack of understanding of the cloud forest characteristics makes it difficult to predict what the impacts of climate change will be on the cloud forest. This study was the first to investigate the climate, vegetation, soil and hydrology characteristics of tropical montane cloud forest at Khao Nan, Nakhon Si Thammarat, Thailand.

II. Materials and Methods

A. Site Description



(a) (b) (c)

Fig. 1 (a) The map of Thailand, (b) Sanyen cloud forest and (c) Sanyen Nature Trail, Khao Nan

Khao Nan is situated at Noppitam sub-district, Thasala district, and Sichon district in Nakhon Si Thammarat province. The geographical characteristic of Khao Nan is a high mountainous range in North-South direction which is a part of Nakhon Si Thammarat mountain range. The forest at Khao Nan is tropical mountain forest which is an important watershed source of Nakhon Si Thammarat. The area of the Khao Nan is 406 km^2. The highest peak is Khao Yai which is 1,438 m above sea level and it is a part of Nakhon Si Thammarat mountain range.

Many valuable economical plants are found in Khao

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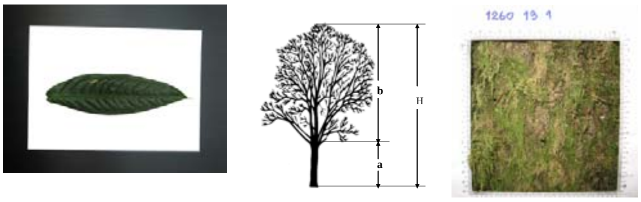
Nan, such as Dipterocarpus, *Intsia palembanica* Mig., *Hopea pierrei* Hance, *Hopea odorata* Roxb., *Parashorea stellata* Kurg. Phyllanthus, *Michelia champaca* Linn., and etc. Furthermore, in the area of Ban Tapnamtao, Ban Naprachao, Ban Huaiprik, and Ban Huaihang, there is *Elaleriospermum tapos* Bl. in large area. This type of tree with edible fruit is rarely found growing in a large area as it is in Khao Nan. The wild animals seen in this area are goat-antelope, *Tapirus indicus*, cervidae, wild pig, mouse-deer, virerridae, civet and etc. including more than 150 types of birds.

B. Climatic Characteristics

We collected climatic factors at Sanyen cloud forest, Khao Nan from 18-20 April 2007. Sanyen cloud forest was located at 1270 m above mean sea level (Fig. 1b,c). HOBO data logger was used to collect mean, maximum and minimum air temperature, relative humidity and solar radiation. We collected the same climatic data at Parah forest and Walailak University by using Davies weather station model Pro II Plus. Parah forest weather station was located at 220 m above mean sea level. Walailak Weather station was located at 8 m above mean sea level.

C. Vegetation Characteristics



(a) (b) (c)

Fig. 2 Vegetation characteristics (a) leaf photography, (b) tree height, and (c) % Epiphyte cover around tree trunk with scales

We studied vegetation characteristics from Klongkai station at 329 m in elevation to Sanyen cloud forest at 1279 m in elevation during 17-21 April 2007. We measured leaf size, tree height and the percent epiphyte cover tree trunk. For leaf size, we collected ten leaves/tree and five trees per study site. We selected leaves that were in good conditions from the first branch from the tree base. We took photographs of these leaves with a Canon A530, 5 million pixels in the laboratory against a white A4 paper (Fig. 2a). The leaves on these photographs were then measured for leaf width, length and area using Adobe Photoshop and MultiSpec Win 32. For leaf thickness, we used a vernier caliper to measure its thickness at 0.01 cm resolution. We used a simple linear regression to find the association between leaf size and elevation.

D. Soil Characteristics

We measured some soil characteristics in the field, collected some soil samples back and measured some soil characteristics in the laboratory. In the field, we used Kelway soil probe to measure soil pH and moisture. We placed this soil probe in the soil no deeper than 10 cm depth every 100 m interval starting from Klongkai station until we reached Sanyen Cloud forest with a distance of 5600 m (Fig. 1c). At each study site, we measured soil pH and moisture three times within 1 m radius and measured latitude, longitude and elevation of the study sites using GPS model 76 CSX. We also collected soil samples at these following elevations: 300, 500, 700, 900, 1100, 1200, and 1300 m (Fig. 1b) by using a soil auger. Because this soil contained a lot of rocks, we used a sieve number 10 to sieve the rocks out from our soil samples prior to weigh the soil. We weighed 550 g soil/sample, oven dried at 90 °C for 24 hrs, reweighed soil again and calculated the percent soil moisture. We weighed 50 g oven dried soil/sample, burned it at 550 °C for 1 hr, reweighed the soil and calculated for the percent soil organic content.

E. Hydrology Characteristics

We measured water quality in all water body found along Klongkai station to Sanyen cloud forest (Fig. 1c). Water quality was composed of water temperature, conductivity and dissolved oxygen (DO) using METTLER TOLEDO Portable Lab™ 300MX three times per study site.

F. Data Analysis

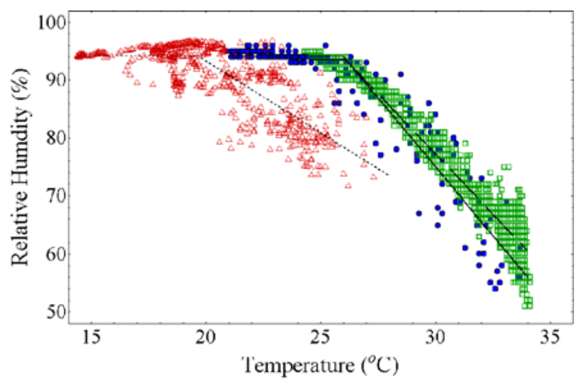
Parametric statistics were used when underlying assumptions were met, otherwise non-parametric tests were used. We compared Simple linear and non-linear regressions were used to find some association between (1) Sanyen cloud forest climatic data, Parah forest weather station and Walailak weather station on the same dates, (2) leaf size and elevation, (3) %epiphyte cover and elevation, (4) %soil moisture and % soil organic content and (5) water temperature, conductivity and DO and elevation. All significant tests were two-tailed.

III. Results and Discussion

A. Climatic Characteristics

The mean, maximum and minimum air temperature at Sanyen cloud forest were ($\overline{X} \pm SD$) = 20.12±0.89 °C; maximum temperature ($\overline{X} \pm SD$) =24.15±2.79 °C; minimum temperature ($\overline{X} \pm SD$) = 17.45±1.74 °C. As the air temperature increased, %RH decreased in all three locations (nonlinear regression: Sanyen cloud forest: $F_{3,573}$ = 1.20x10^4, P<0.001, Fig. 3a, Eq.1; Parah forest: $F_{3,255}$ = 7000, P<0.001, Fig. 3a, Eq.2; Walailak University: $F_{3,573}$ = 2.349x10^6, P<0.001, Fig. 3a., Eq. 3), where T represented air temperature. These results were clearly shown that Sanyen cloud forest was much cooler than Parah forest and Walailak University. The maximum temperature at Sanyen cloud forest was 28 °C.

(a)



(b) (c) (d)

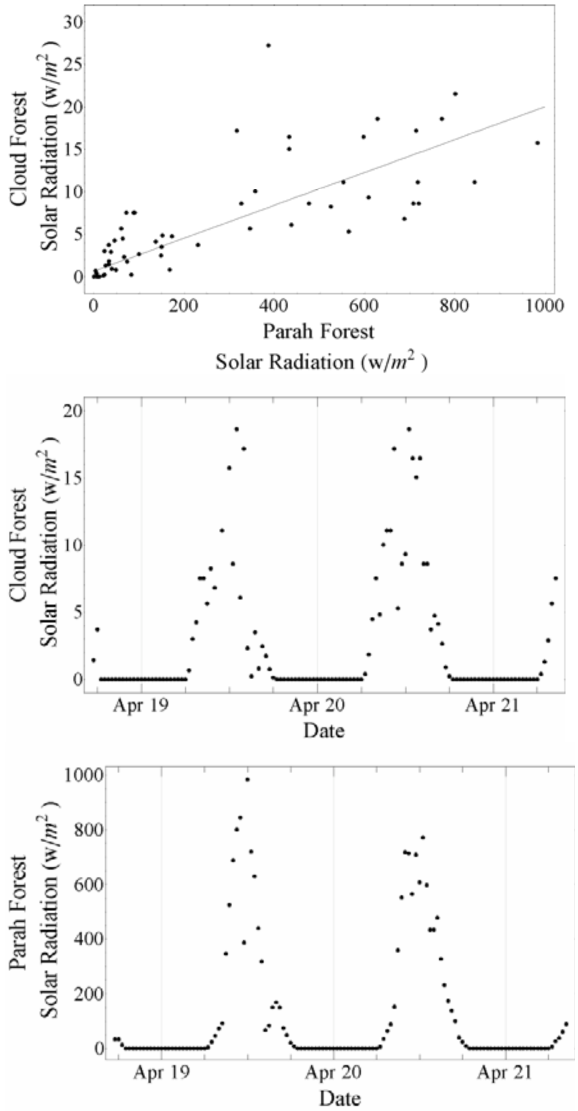


Fig. 3. Climatic characteristic of Sanyen cloud forest, Khao Nan from 18-20 April 2007. (a) relative humidity and temperature (°C): Δ (--) Sanyen cloud forest, ● (___) Parah forest and □ (__ __) Walailak University, (b) the amount of solar radiation (W/m^2) at Sanyen cloud forest and Parah forest, (c) the amount of solar radiation (W/m^2) at cloud forest, and (d) the amount of solar radiation (W/m^2) at Parah forest

On the other hand, the maximum temperature at Parah forest and Walailak University were 33 and 34 °C. %RH at Sanyen cloud forest ranged from 72-100%. This indicates that Sanyen cloud forest contains more water vapour even in the summer time than lower elevation locations. As the air temperature at Sanyen cloud forest increased, % RH decreased with a shallow slope. On the other hand, as the air temperature at Parah forest and Walailak University increased, % RH decreased with steeper slopes than at Sanyen cloud forest.

At Sanyen cloud forest,

$$RH = 94.25, T < 19.62°C \quad (1)$$
$$RH = 94.25 - 2.48(T - 19.62), T \geq 19.62°C$$

At Parah forest,

$$RH = 94.15, T < 25.97°C \quad (2)$$
$$RH = 94.15 - 4.74(T - 25.97), T \geq 25.97°C$$

At Walailak University,

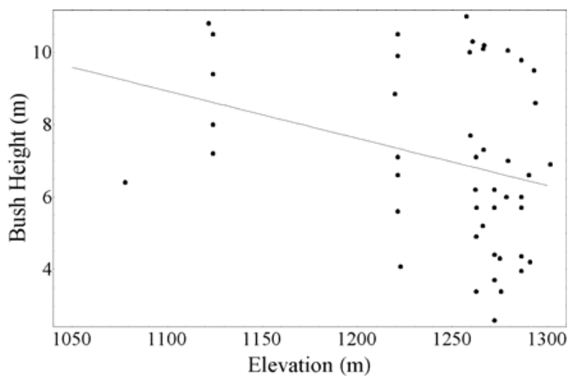
$$RH = 93.56, T < 25.97°C \quad (3)$$
$$RH = 93.56 - 4.15(T - 26.07), T \geq 26.07°C$$

The amount of solar radiation at Sanyen cloud forest was positively associated with the amount of solar radiation at Parah forest (linear regression: y = 0.0194x + 0.630, R^2 = 0.702, $F_{1,125}$ = 294.746, P< 0.001, Fig. 3b). The amount of solar radiation at Sanyen cloud forest was lower with a range of 0-19 W/m^2 than at Parah forest which was 0-1000 W/m^2 (Fig. 3c,d).

Tropical montane cloud forests have regular fogs or cloud immersion. This cloud immersion reduces a large amount of solar radiation. Our results support previous findings [2,4] that the amount of solar radiation was a lot less at Sanyen cloud forest when we compared with Parah forest and Walailak University. This large amount of reduction in solar radiation would reduce bio-productivity [6].

B. Vegetation Characteristics

There were no differences between leaf width, leaf length, leaf thickness and leaf area among different elevations (leaf width: $\overline{X} \pm SD$ = 6.26±1.35, $F_{50,229}$ = 1.290, ns; length: $\overline{X} \pm SD$ = 19.18±3.67, $F_{76,203}$ = 1.070, ns; thickness: $\overline{X} \pm SD$ = 0.007±0.0056, $F_{2,277}$ = 0.0761, ns; area: $\overline{X} \pm SD$ = 87.80±32.70, $F_{20,259}$ = 0.949, ns). As the elevations increased, bush height and tree height decreased (bush height: y = -0.013x + 23.351, R^2 = 0.091, $F_{1,44}$ = 4.429, P< 0.05, Fig. 4a; tree height: y = -0.022x + 38.604, R^2 = 0.231, $F_{1,44}$ = 13.203, P< 0.001, Fig. 4b). There was no association between bush width and bush ratio with elevations (bush width: $F_{1,44}$ = 0.323, ns; bush ratio: $F_{1,44}$ = 1.473, ns). As the elevations increased, % epiphyte cover increased (y = 0.064x + 0.147, R^2 = 0.724, $F_{1,94}$ = 246.93, P< 0.001, Fig. 4c).



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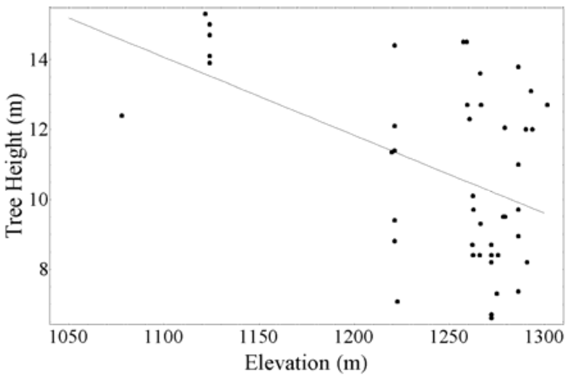

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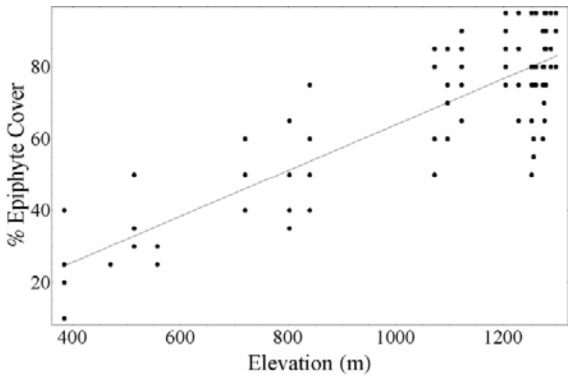
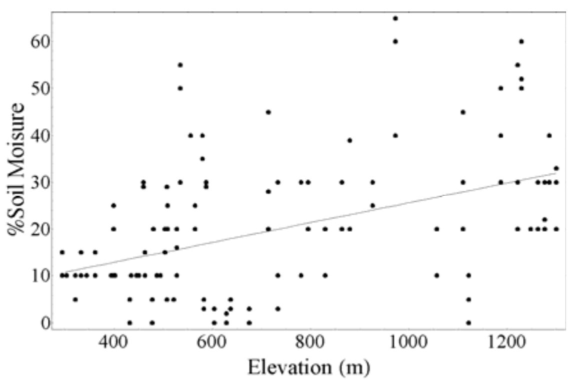


(c)

Fig. 4 Vegetation characteristics from Klongkai station to Sanyen cloud forest during 17-21 April 2007. (a) bush height (m) and elevation (m), (b) tree height (m) and elevation (m), and (c) % epiphyte cover and elevation (m)



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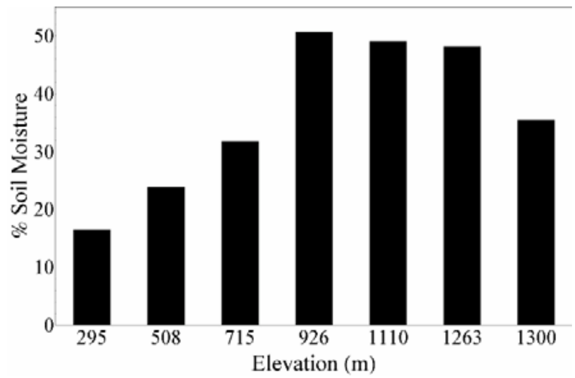

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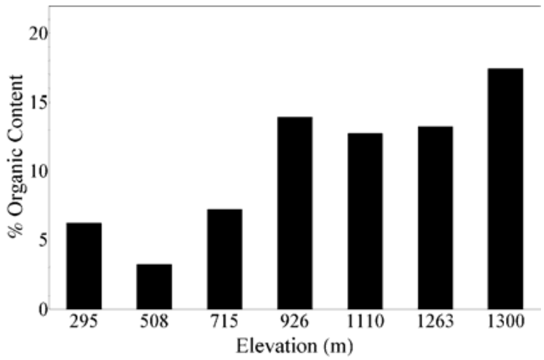


(c)

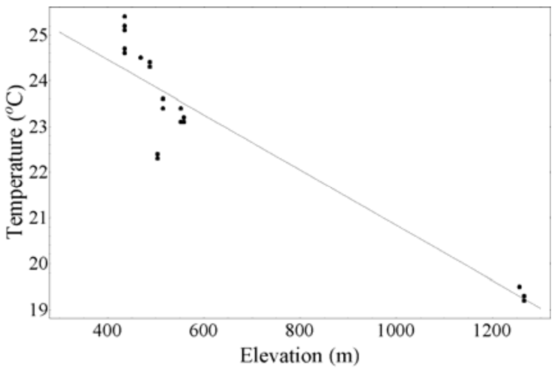
Fig. 5 Soil characteristics and elevation (m) from Klongkai station to Sanyen cloud forest during 17-21 April 2007. Soil characteristics: (a) % soil moisture from field data, (b) % soil moisture from laboratory data and (c) % organic content

With an increasing in elevations, plant species change from lowland species to montane species with tree stature, and leaf size decreases but the epiphyte load tends to increase. Cloud forest trees are twisted, gnarled and often have umbrella-like crown [3, 4]. Our results support previous findings. This high epiphyte load could have four important roles in cloud forest. First, the productivity of epiphytes in cloud forest can exceed other flora. Second, epiphytes could capture, store up to 50,000 l/ha [5] or 3000 l/ha [6] and slowly release water to canopy animals in cloud forest. Third, epiphytes capture, store and slowly release up to half the total input of NH_4^+, NO_3^- and other important ions and nutrients in cloud forests from water stripping from passing clouds. Finally, epiphytes provide home for invertebrates, amphibians, birds and even some primates [7].

C. Soil Characteristics

From the soil field data, as the elevation increased, % soil moisture increased (linear regression: y = 0.021x + 4.370, $F_{1,160}$ = 43.180, R^2 = 0.213, P<0.001, Fig. 5a). From the soil laboratory data, % soil moisture and % organic content were separated into two groups: above and below 900 m in elevation. % soil moisture and % organic content were higher in 900 m in elevation (Fig. 5b,c).

Our results support previous findings [2, 3] that cloud forest soils were high in organic contents, and soil moisture. The results were clearly shown that after 900 m in elevation, there were a large increase in % soil moisture and % soil organic content. This indicates that Sanyen cloud forest might start from 900 m in elevation and reached its peak around 1300 m. The capacity of the soil to absorb and store a great deal of water provides the important services of erosion and flood control as well as dry weather stream flow [2].



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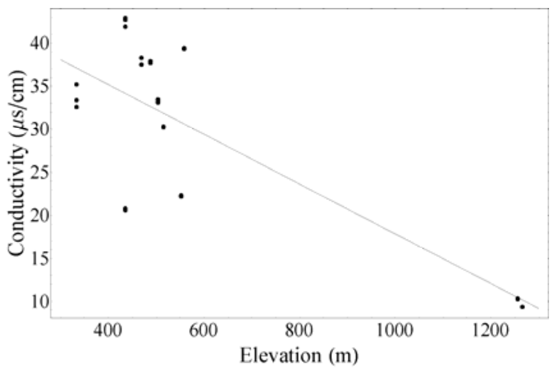

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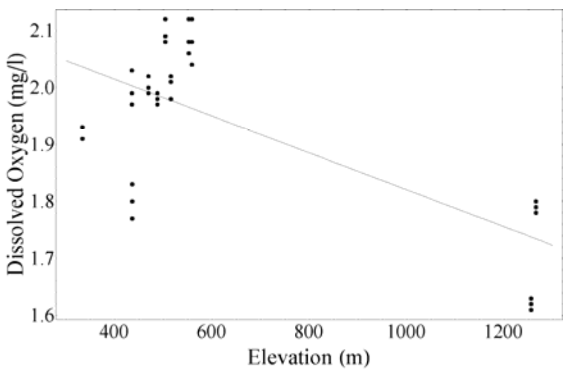

(c)

Fig. 6 Hydrology characteristics and elevation (m) from Klongkai station to Sanyen cloud forest during 17-21 April 2007 (a) water temperature (°C), (b) conductivity (µS/cm), and (c) Dissolved Oxygen (mg/l)

D. Hydrology Characteristics

As the elevations increased, water temperature, conductivity, and DO decreased (Linear regression: water temperature: y = -0.006x + 26.875, $F_{1,28}$ = 230.015, R^2 = 0.891, P<0.001, Fig. 6a; conductivity: y = -0.029 x + 46.734, $F_{1,31}$ = 58.2155, R^2 = 0.653, P<0.001, Fig. 6b; DO: y = -0.0003x + 2.14, $F_{1,31}$ = 28.947, R^2 = 0.483, P<0.001, Fig. 6c).

Our results showed that water temperature, conductivity, and DO were lower at Sanyen cloud forest than at lower elevation water bodies. Water temperature showed a similar trend with air temperature. This could be because the cloud reduced the amount of solar radiation at the cloud forest. This study showed that conductivity was very low at Sanyen cloud forest. This could be because Sanyen cloud forest is the head of watershed; therefore, there would be less ions dissolved in the water body than at lower elevation water bodies. The amount of DO at Sanyen cloud forest was very low, especially at 1250 m in elevation. This water body was very shallow with approximately 10 cm deep with lots of algae at the bottom.

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