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Drying a Standing Teak Tree using a Solar Kiln Drying Method

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Abstract

Understanding the rate of drying of standing trees dried by using a solar kiln drying method could help in predicting the change of moisture content in the tree over a period of drying time. The purpose of this study was to observe the change of moisture content profile in a standing tree during drying. A standing *Tectona grandis* tree was selected for the experiment with a diameter at breast height of 29 cm in a mixed-species plantation. The tree was girdled with 20 cm width at 20cm above ground. For the experiment, the tree was wrapped in a transparent plastic sheet and a black plastic sheet was installed at the bottom with an angle of 39 °C facing Southwest to maximize solar radiation, with the method being modified from the solar kiln method, which is known as a greenhouse type, with 2 layers of plastic cover. The black and white sheets were placed on the inner side for insulation and for collecting heat from the sun's radiation, while the outer layer was transparent, which allowed radiation to propagate unhindered in the black sheet. In this study, a sensor for temperature and relative humidity (DHT22) was attached inside the wrapped plastic and the data recorded every 6 min. The results showed that drying a standing teak tree from an initial average moisture content of 105 % to a constant point of 60 % took 80 days under the maximum of the collected temperature of 46 °C inside the wrapped plastic; this finding confirmed that the predicted model of recharge and discharge curve was likely accurate.

Key words: Solar drying, Drying a standing tree, Moisture content profile, Temperature oscillation, Arduino Uno-solar kiln

Introduction

Delivering fallen timber (green logs) from plantation sites to sawmills costs high capital, because the green timber contains lots of water. Drying timber practices, such as the air-drying method and kiln drying processes, are usually conducted at sawmills after timber is sawn. Therefore, investigating any possibility to dry timber at plantation sites before delivering to factories is considered, to reduce costs as a result of the lighter weight.

The air-drying method could be one of the available methods to address the above problem. However, logs need to be converted to lumber; otherwise, drying can be time-consuming. Alternatively, drying standing trees could possibly help reducing weight and to crack during the drying process. Traditionally, in Laos, local people collected deadwood to be used as firewood for cooking purposes. When lacking deadwood in the forest, they usually debarked/girdled standing live trees at approximately lower than 1 m above ground, with a length of 20 cm longitudinal as a circle of the horizon. After 1 to 2 months, trees were ready to be cut and used as firewood, because the wood was partially dried. The time taken for the tree to be ready to be cut would depend on climatic conditions of different regions and seasons and the diameter of the standing tree. The problem here is how can we control the drying parameters, i.e., temperature, relative humidity, and airflow, in an opened yard where the standing trees are located.

A 2 m^3 greenhouse type solar kiln (Solarkilns Pty Ltd, Kilsyth, VIC, Australia) has been used in Melbourne, Australia [1-3]. The kiln came with 2 layers of plastic cover. The black and white sheets were placed on the inner side for insulation and for collecting heat from the sun's radiation, while the outer layer was transparent, which allowed radiation to propagate unhindered in the black sheet. Adapting this technology with some modifications may offer productivity for drying standing trees, such as drying time being faster than natural drying and avoiding cracking. There are 2 main points for which it is believed to be able to make modifications. Firstly, a controller unit modification, where unnecessary parts of the original scale of kiln compartment has to be fitted with the actual size and shape of a standing tree; thus, fans for air circulation and water sprayers could be removed. Secondly, applying 2 plastic sheets for the purpose of direct heat propagation is required to fit with the size of a standing tree. This would help to reduce the costs of installation and ease the processes. However, expanding numbers of trees to be dried by this method could lead to higher costs, where the capacity of the controller unit should be improved and upgraded.

It was suggested that tropical latitude has high solar radiation [4] and the prediction of temperature in Vientiane (Laos) using a recharge and discharge curve model found that the maximum temperature could reach 47 °C at 2 pm [1]. In addition, the lowest ambient equilibrium moisture content (EMC) in Vientiane was around 11 - 12 % from December to March, and 14 % for April [5]. Thus, drying a standing tree in this region could be appropriate.

Moisture content (MC) profile is well-known as one of the vital drying parameters by drying experts. It assists in understanding the drying rate and timber quality during and at the end of drying. Therefore, understanding the effect of using the proposed technology via experimenting with drying standing trees is required at this initial stage for further improvement. The objective is to observe the change of MC profile during drying a standing tree.

Materials and methods

Samples and experimental setup

Teak is one of the timber species that is being increased by area and supply to the wood processing sector in Laos. For instance, in Luang Prabang Province, 15,000 ha of teak (*Tectona grandis* L. fil.) has been established. Teak is encouraged for domestic wood processing aiming to mobilize this teak resource as an alternative to timber from natural forests [6]. The total areas of teak plantation in Lao PDR vary, with estimates between 40,000 ha [7]. Therefore, understanding drying of this timber species could contribute to reduction in costs of the transportation of logs from plantation areas to sawmills and processing sites. Thus, a *Tectona grandis* tree was selected for this experiment, conducted at the Faculty of Forest Science, National University of Laos (NUoL), from February until June, this period offering high solar radiation, as suggested by Simpson andTschernitz [4], and SSE [8] and is also known as the dry season in Laos [9]. Also, Phonetip *et al.* [5] found that the Faculty of Forestry Sciences is one of the most suitable locations for drying timber using solar kilns. The tree was located at geographical coordinates of 18 ° 0.2 ' 21 "N and 120 ° 37 ' 45 "E, with 108 m above sea level. The diameter at the high breasts was 29 cm, and it was 18 m high.

The experimental set-up included 2 parts; a data acquisition unit (**Figure 2**) and a compartment as shown in **Figure 1**. The drying compartment used a clear plastic sheet covering the tree's stem from below the 1st branch under its canopy with a square shape (steel frame) of 60×60 cm^2, down to the bottom of the tree, with an attachment of a closed-black plastic sheet with steel frame of 300×300 cm^2 with a suggested angle of 39° where maximum solar radiation could be received between 10 am to 3 pm [10]. Each corner of the steel frame was tight with lashes that made contact with the ground to ensure it could withstand wind. The top of the wrapped plastic was open, allowing water to evaporate and then removed by an exhaust fan.

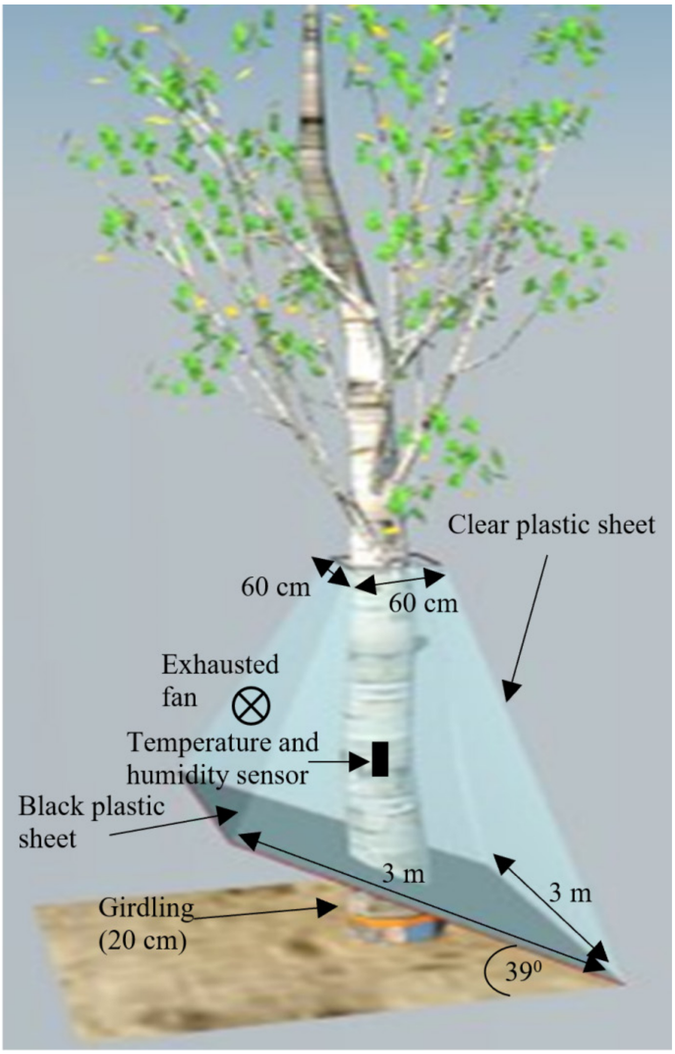

Figure 1 Drying compartment set-up.

Data acquisition unit

The data acquisition unit (**Figure 2**) was invented by Khamtan Phonetip using an Arduino Uno with a sensor of DHT22. The accuracy of the DHT22 sensor was as follows: humidity was ±2 % RH (Max ±5 % RH), and temperature was < ±0.5 Celsius [11]. An exhaust fan of 8×8 mm^2 was used for venting humidity. The temperature and relative humidity were recorded every 6 minutes and stored on an SD card. The RH was set and controlled by an exhaust fan at 25 %, which was "Off" mode, and "On" when the RH was higher than the set value from the start until the end of the experiment.

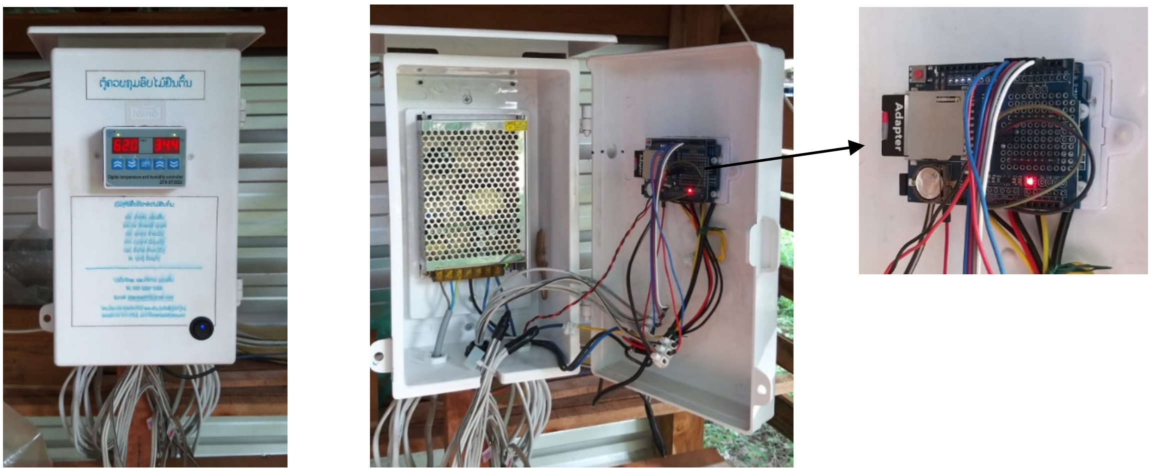

Figure 2 Data acquisition unit.

Samples collection

The girdling of the standing tree was done at 20 cm above 0 ground, with 20 cm width and 2 cm depth. The monitoring MC profile was done using an increment borer. It was used to drill into the standing *Tectona grandis* tree from 1 edge through the pith to another edge of the tree in order to take specimens. The method of taking samples was as shown in **Figure 3**. Each drill sample was split into 9 specimens for measuring the MC. Specimen Nos. 1, 2, 8, and 9 were case areas located near the bark of the tree. Specimen Nos. 4 and 5 were core areas that covered the pith and the center part of the tree. After that, MC values were calculated based on the Oven-dry Laboratory Method. Samples were taken from the bottom, then moved up to the next spot vertically at 2 cm hole distancing for every 10 days and continued until constant values of MC were reached.

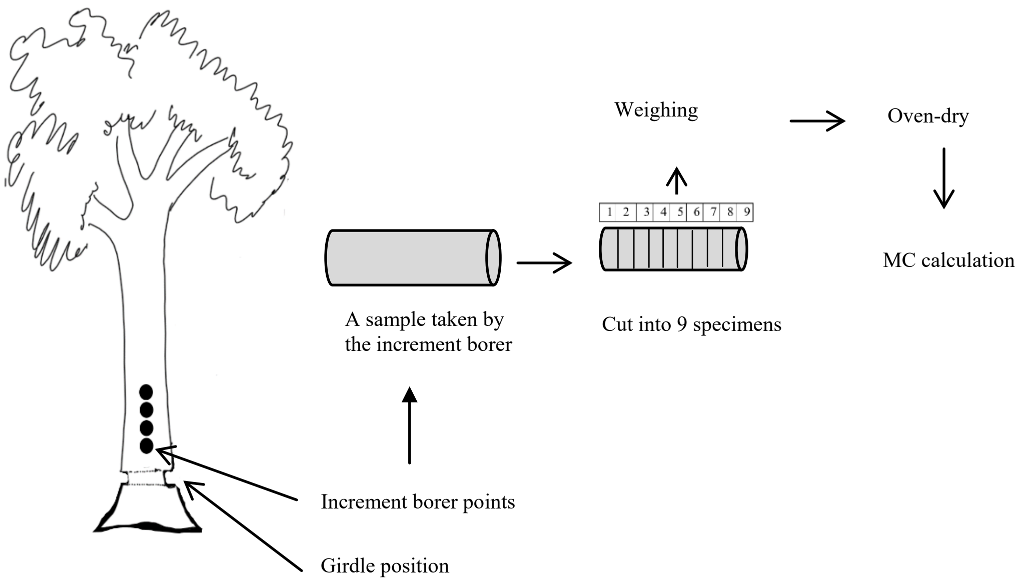

Figure 3 Measuring MC profile.

Results and discussion

Drying conditions

Figure 4 shows that the mean minimum temperature inside the drying compartment was 25 °C ±1 at 6 am, and the mean maximum temperature was 41 °C ±5 at 2 pm. This means that the maximum temperature was 46 °C, which approximately reached the results (47 °C) from a previous study that used a recharge and discharge curve model [12], while the maximum ambient temperature was found to be 35 °C [13]. Since the drying unit did not have a supplemental heating supply, the only way the heat came was from the black plastic that was stored at the bottom of the teak tree inside the compartment (**Figure 1**). The temperature fluctuated from time to time and day to day, depending on diurnal conditions; therefore, the difference in peak temperature was found to be 10 °C.

The mean lowest relative humidity was at 50 % ±25 from 1.30 to 4.30 pm, and the highest RH was 95 % ±5 at 7.00 am. The RH was able to reach the set point of 25 % from 2 to 5 pm. This value of RH inside the drying compartment was found to be lower than the ambient condition of 35 % predicted by [8].

Considering the maximum temperature of 46 °C inside the compartment with the range of relative humidity value of 25 - 50 %, the conditions could allow EMC at 4.5 - 8.5 %, as per the EMC chart [14]. The EMC values were found to be much lower than the ambient conditions (11 - 12 %) from December to March, and 14 % for April [5].

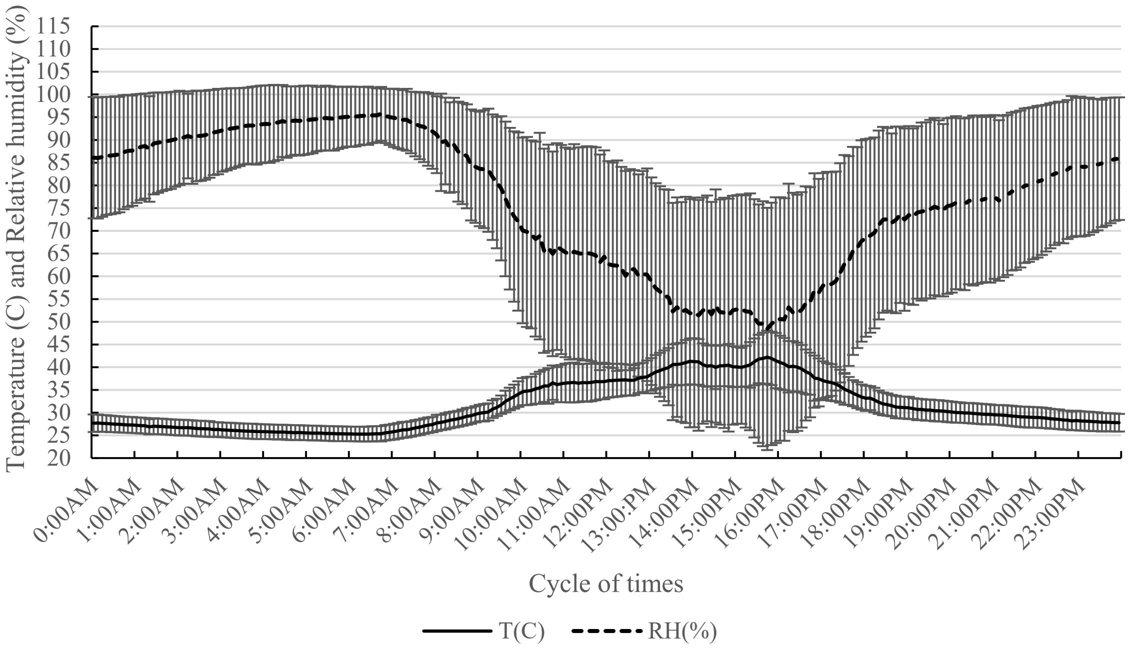

Figure 4 Oscillation of temperature and relative humidity conditions inside the drying compartment during 24 h cycles for 80 days.

Moisture content profile in the tree during drying

The variations of MC change within the standing tree (9 specimens) showed that the mean initial MC was 105 % ±7, where the case MC was 102 % and the core MC was 108 %. After that, the measurement of MC at 70 days (MC70), 80 days (MC80), 90 days (MC90), and 100 days (MC100) was calculated and plotted, as in **Figure 5**. Drying the standing *Tectona grandis* tree took 80 days from the initial average MC of 105 to 60 %, where the MC was constant.

The case MC started from 102 to 52 % and 108 to 68 % at the core of the tree (**Figure 6**). It decreased by 0.6 %/day at the case and 0.5 %/day on average at the core of the tree. The drying experiment was conducted over 100 days, but the MC was found at constant points from 80 days of 52 and 68 % for the case and core, respectively.

According to drying conditions, shown in **Figure 4**, the tree should have reached the lowest MC of 4.5 %, rather than a constant point at 60 %. Moisture content migrates from the pith to the bark of the tree and evaporates, which could be caused by 2 reasons. The bark could be acting as insulation, and the top of clear wrapped plastic was open (**Figure 1**). The insulation could stop water evaporating from sapwood, while the open plastic from the top near the canopy could receive rain (water) which could be absorbed by the tree bark. This meant that the tree could increase its MC when the rain came, so causing slow drying of the standing tree by keeping the inner at a higher MC than the outer part. In this case, the EMC of this region would not be affected by this kind of drying experiment.

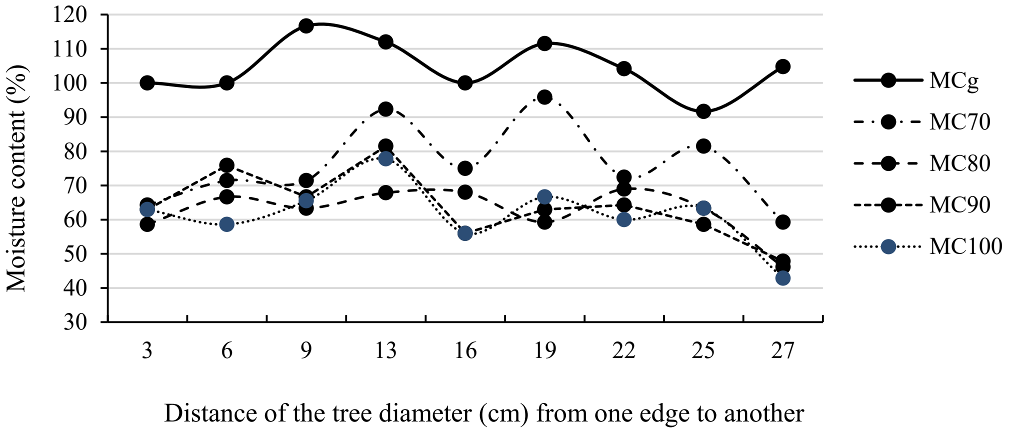

Figure 5 MC decrement by specimens against drying time.

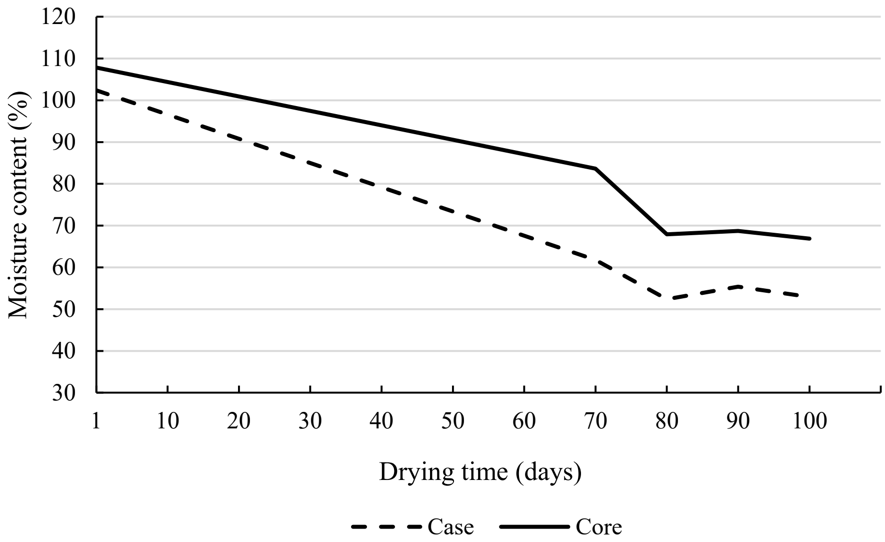

Figure 6 MC decrement by the case and core area against drying time.

Traditionally, timber is partially air-dried to 57 - 68 % [15] at the sawmill before being kiln-dried. This implied that the green weight teak tree had decreased significantly over 80 days. Thus, delivering teak logs at 60 % of MC from plantation to sawmill could help reduce the cost of transportation, with less and impact on roads and fewer carbon emissions.

Conclusions

Drying a standing teak tree from an initial average moisture content of 105 % to a constant point of 60 % took 80 days under the oscillation of temperature 25 °C ±1 at 6 am and mean maximum temperature of 41 °C ±5 at 2 pm, with fluctuating RH of 50 % ±25 from 1.30 to 4.30 pm and the highest RH of 95 % ±5 at nighttime inside wrapped plastic. The initial mean MC of the case was 102 %, decreasing to 52 %, and core 108 %, decreasing to 68 %. This finding confirmed that the predicted model of recharge and discharge curve for the temperature inside the solar kiln based on Laos' climatic conditions was likely accurate (this prediction being 47 °C).

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