THE EFFECT OF TEMPERATURE AND PRECIPITATION ON THE INTRA-ANNUAL RADIAL GROWTH OF *Fokiena Hodigsii* IN KON KA KINH NATIONAL PARK, VIETNAM

Oanh Nguyen Thi[1], Nam Le Canh[2], Hung Dinh VieT[1], Tich Vu Van[3]
[1]School of Interdisciplinary Studies, Vietnam National University, Hanoi, VietNam
[2]Forest Sciences Institute of Central Highlands and South of Central VietNam
[3]Vietnam National University, Hanoi
Corresponding author: oanhnt_91@vnu.edu.vn

Abstract: *Fokienia hodginsii* ((Dunn) A. Henry et H.H. Thomas) (known locally as *Po-mu*) is the only living species member of the Fokienia genus, the family name is Cupressaceae. *Fokienia*, an endemic species to Annamite range, is mainly distributed in the mixed broad-leaved and coniferous forests in the Central Highlands of Vietnam. The objective of this study was to identify the impacts of climatic factors and climate change on the tree ring width of *Fokienia* in Kon Ka Kinh National Park at the Central Highlands, Viet Nam. The dataset of tree-ring width was collected from 30 sampled trees by using a Haglof increment borer incorporated into the climatic dataset in 57 years (1961-2017) at Pleiku Station. Weighted Linear/Nonlinear methods were applied for modeling regressions of tree-ring width and climatic factors. As a result, *Fokienia*'s annual tree-ring width increment was negative with the average annual temperature and the average monthly temperature of from March to July (except May) and positive with the monthly rainfall (April rainfall and July rainfall). The study also indicated that there was a climate change in the Central Highlands over the past 57 years, the average annual temperature increased approximately by one degree Celsius that made the decrease in the growth of *Fokienia*.

Keywords: Climate change; tree-ring width; drought.

1. INTRODUCTION

Large-scale or regional drought and flood disasters can have significant social, economic and ecological impacts. The knowledge of past disasters could aid in the evaluation of potential regional hazards in the future and facilitate the assessment of the links between regional and worldwide disasters (Wilhite, 2000). This perspective can be achieved through the use of paleoclimatic records of droughts and floods. Gia Lai province was located mostly to the West of Truong Son Range; topographic slopes steadily decrease from the northeast to the southwest; diverse terrain with alternating hills, mountains, highlands, and valleys. Gia Lai not only has an important role in the economic development of Central Highlands but also is critical for the generation of hydroelectric power. To date, understanding undocumented historical disasters is generally dependent on climatic proxies (Nelson et al., 2011). The tree growth in the arid or semi-arid regions can provide annual or seasonal records of drought events through the study of their annual rings (Fritts, 1976). The identification of links between tree growth and documented drought events allows us to determine how accurately tree-ring records reflect drought occurrence.

Fokienia hodginsii has commercial value large trade in wood, often using wood for making objects construction materials, handicrafts and distilleries oil. The species of Fokienia is only distributed in China, Laos and Vietnam. In Vietnam, this species is widely distributed in 19 provinces: the North and Northeast (Ha Giang, Lao Cai, Tuyen Quang, Bac Kan, Bac Giang) to the Northwest (Dien Bien, Lai Chau, Son La, Hoa Binh, Thanh Hoa) from the North (Nghe An, Thanh Hoa, Quang Binh) through Central (Kon Tum, Gia Lai, Lam Dong, Dak Lak) and ends in the South (Khanh Hoa and Ninh Thuan). The conservation status of *Po-mu* in Vietnam is red book EN A1a,c,d, on the world is coming endangered_VU A2acd; B2ab(ii, iii, iv, v).

Climate is one of the important ecological factors influence on the growth of forest trees. Today, climate change has affected the growth of forest trees and quantification of the influence of climate factors and climate change on forest tree growth is a necessary issue. This study provides scientific information as a basis for the development of silvicultural strategies in the management and conservation of Fokienia in order to adapt to climate change.

2. METHODS

2.1. Collection data

The tree-ring data used for this study were derived from the increment core samples collected from old growth of Fokienia, growing in an altitude range of 1700-2000 m above sea level of Kon Ka Kinh National Park, Gia Lai province. In Gia Lai province, the wet season from April last year until October last year, and again during the dry season from November this year until March next year. Climate change in the Central Highlands records the average annual temperature increasing by about one degree Celsius over the past 57 years.

Table 1. Summary of climate information at Pleiku station, Gia Lai province

Content	Pleiku station
Average annual precipitation (P, mm/year)	2202
Number of rainy months (months)	7 - 8
Average annual temperature (T, °C)	21.9
Total annual temperature (°C)	264.6
Average annual humidity (%)	83
Number of dry months (months)	2 - 3
Dry month	12, 1, 2, 3
Average number of sunshine hours per year (hours)	210.7

Source: Averaged climate data (from 1961 to 2017 at Pleiku station).

2.2. FIELD SURVEY

The tree ring data was collected and crossdate with master chronology to 2017. Use a Haglof growth drill with a drill bit diameter of 5 mm and a drill length of 70 cm to determine the ring width (Zr) in years. We took a pair of cores from each of 30 individual trees for a total of 60 core samples at breast height (1.3 m above ground), the standard practice in dendro-chronology (Fritts, H. C., Bottorff, C. P., and Mosimann, 1969; Marvin A. Stokes and Terah L. Smiley, 1996). Criteria for selection of aubergines is a tree with normal growth, without deformities, growing in representative conditions of the stand in which it is distributed. The sampled trees were measured for diameter at chest height (D, cm) and tree height (H, m); each drill has 2 - 4 cores in the direction of East West - North South. The drill sample is dried, then the sample is glued onto a wooden tray and finally the surface is sanded/polished with coarse to fine sandpaper (200 - 600). After sufficient surfacing to clear revelation of cellular structure, all cores were visually cross-dated by using the standard methodology (Stokes and Smiley 1968; Fritts 1976) resulting in the absolute assignment of calendar years to every growth ring

2.3. Methods in the laboratory

2.3.1. Dating dendrochnology

We measured all cross-dated growth rings to an accuracy of 0.01 mm by using a sliding stage micrometer interfaced directly with a computer for measurement capture. The ring width was gauged optically under low magnification with a microscope equipped with a cross-hair reticle in one eye-piece as the sliding stage moved the sample parallel to the axis of the crosshair. Ring-width measurement series were rechecked for possible dating errors using the quality control software COFECHA (Holmes RL, 1983) by comparing individual series against a master series derived by averaging all series on the basis of correlation statistics. This procedure confirmed that our dating was correct for all cores ultimately used in this study. The ring width time series were standardized by using the software ARSTAN (Cook, 1985) in order to detrend long-term individual growth pattern due to aging, while at the same time attempting to minimize the removal of long-term climatic variance. We employed simple correlation analyses between ring-width index and monthly climate data. The most common and direct comparisons are typically made with the instrumental records of rainfall and temperature. While it is always desirable to use meteorological records from stations at only 57 years in length the observation period at the nearest meteorological station to Pleiku was too short for meaningful response analysis.

2.3.2. Growth-Climate Relationship Analysis

To determine the climatic variables that control the radial growth of Fokienia, mean monthly temperature and total monthly rainfall were compared with the local chronologies for each sampling site. The local chronologies were compared with the Pleiku meteorological station. The SPSS program was used to compute the response of tree growth to climate, by means of a multiple stepwise regression. Coeffcients were considered signifcant at *$p<0.05$ and **$p<0.01$.

Climatic factors are collected according to key indicators such as average temperature of month i (Ti), mean annual temperature (Ttb), average rainfall of month i (Pi), total annual rainfall (Ptb). Collected climate data for Kon Ka Kinh area using climate data of Pleiku Meteorological Station for 56 years (1961 - 2017).

To exclude the influence of the age factor (A) on the ring width, the standardized ring width index (Zt) was used and it was calculated using Arstan software (Cook, 1985).

$$Zt = \frac{rt}{gt} \quad (1)$$

$$g_t = \frac{\sum rt}{n} g_t \quad (2)$$

Where, Zt is the index of the ring widths normalized at year t; rt is the ring width measured at year t; gt is the average growth at year t and n is the number of years.

Now the expectation of the normalized ring width index E[Zt] = 1 for all time t and the variance δ^2 of Zt will be:

$$\delta^2 = \sum_{t=1}^{n} \frac{(Z_t - E[Z_t])^2}{n} \quad (3)$$

Zt was averaged from the drill tree samples and over the time series of the climates collected in Kon Ka Kinh of the Fokienia

Analyze the influence of key climate indicators such as average of temperature in month i (Ti: T1-T12) and rainfall in month i (Pi: P1-P12), with i from January to December; mean annual temperature (Ttb), mean annual rainfall (Ptb) to Zt, climate indicators are considered to be influential when $P < 0.05$.

Modeling the relationship Zt with the influencing climate variable Ti/Pi is detected in different linear and non-linear forms.

3. RESULTS

3.1. The temperature and precipitation in Pleiku station

The annual average of temperature (Ttb) and precipitation (Ptb) variation in Pleiku shows that the graph shows the variation of temperature and average annual precipitation with extremes, especially in some years. extremes have very unusually high or low values; This shows that there is a clear climate change manifested through sudden fluctuations in temperature and rainfall over the years.

In general, the average annual temperature has increased by 1 ^{o}C over the past 57 years, which is consistent with information about climate change due to the increase in global temperature; Meanwhile, the average annual rainfall does not have a clear pattern, where there is a clear tendency to decrease like in Kon Ka Kinh. This result confirms that the climate change phenomenon in the Central Highlands follows the global general rule that is the increase in air temperature and leads to abnormal weather such as rain and storms, making the rainfall unstable. Over the years, it has affected the forest ecosystems, the cycle and the growth rhythm of forest trees.

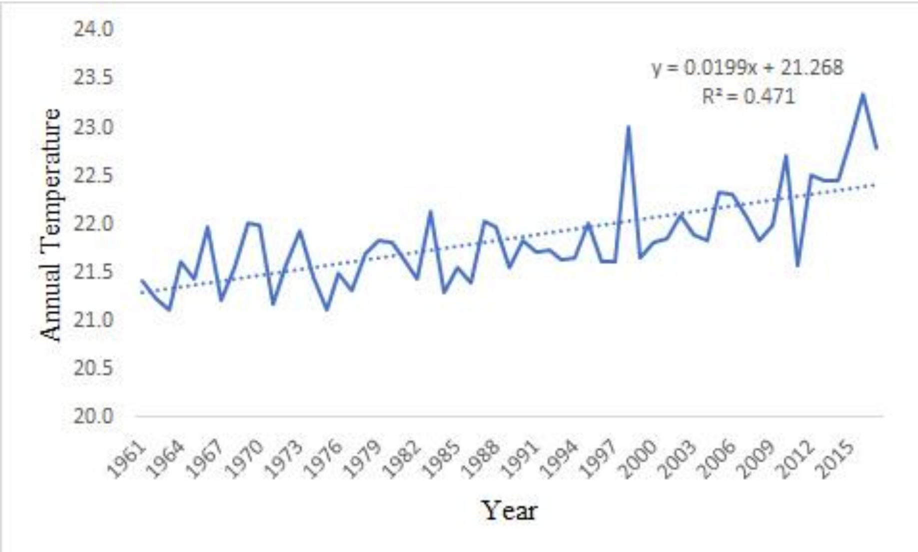

Figure 1. Variation of average temperature (Ttb) by year in Kon Ka Kinh.

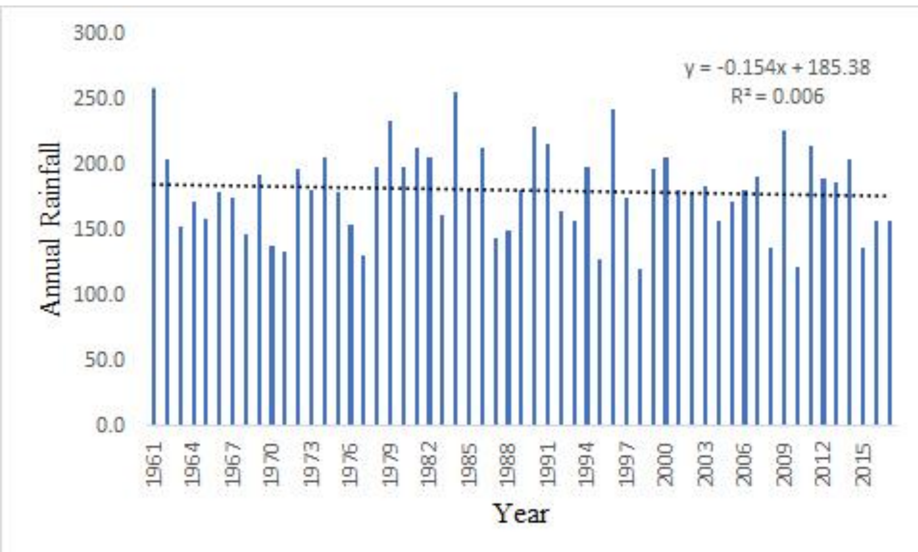

Figure 2. Variation of average rainfall (Ptb) by year in Kon Ka Kinh.

3.2. The tree ring index chocronology (Zt)

Based on ARCTAN software, a standardized year-round width series (Zt) by time series has been established at KonKa Kinh, the results of the calculation of statistical indicators are shown in Table 2 and illustrated in Figure 3.

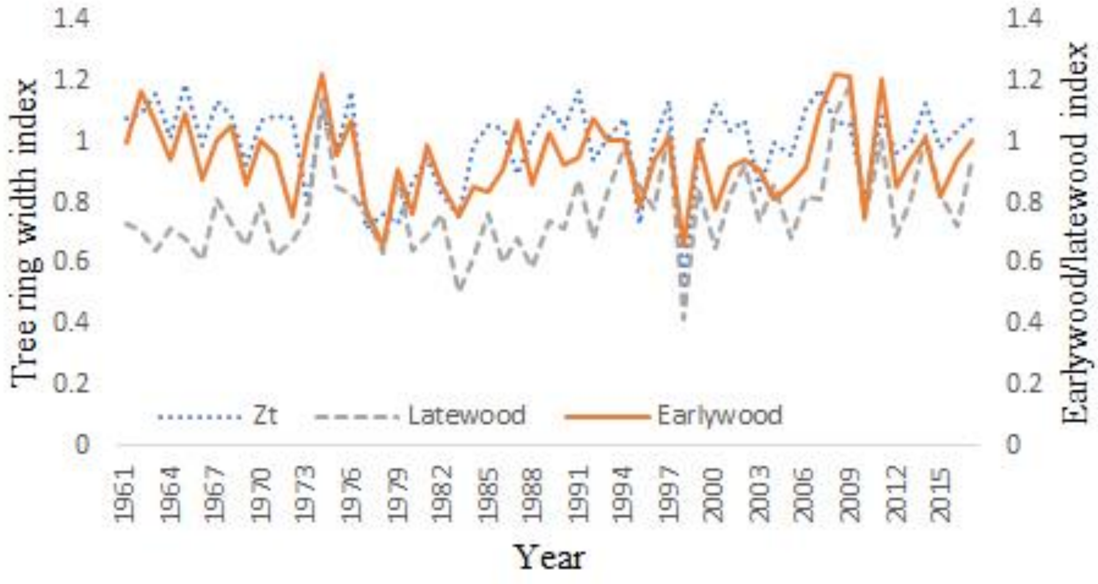

Figure 3. The tree ring index Zt (TRW), the early wood and late wood index.

Table 2. The statistic information of tree ring index (Zt), the early wood and late wood index

		Zt (TRW)	Early wood	Late wood
N	Valid	328	328	328
	Missing	0	0	0
Mean		0.994	0.922	0.724
Median		1.008	0.940	0.723
Mode		1.021[a]	0.945[a]	0.720
Std. Deviation		0.145	0.107	0.094
Skewness		-0.583	-0.354	0.693
Std. Error of Skewness		0.135	0.135	0.135
Kurtosis		0.832	0.959	4.523
Std. Error of Kurtosis		0.268	0.268	0.268
Minimum		0.464	0.532	0.420
Maximum		1.344	1.229	1.188

a. Multiple modes exist. The smallest value is shown

From the above results, it can be seen that there are large fluctuations in Fokienia growth in some stages; especially from 1997 to 2017.

Since the influence of plant age on ring width has been excluded, this indicates that environmental factors such as climate have had a significant impact on Fokienia growth. Statistical indices Zt and main climatic factors by region are distributed in the Table 3.

Table 3. Statistical index of standardized year-round width Zt and corresponding time series of climate indicator in Kon Ka Kinh

		Zt	Ttb	Ptb
N	Valid	57	57	57
	Missing	0	0	0
Mean		0.998	180.911	21.847
Std. Deviation		0.138	32.955	0.482
Variance		0.019	1086.06	0.232
Skewness		-1.148	0.230	1.030
Std. Error of Skewness		0.316	0.316	0.316
Kurtosis		1.178	-0.310	1.100
Std. Error of Kurtosis		0.623	0.623	0.623
Minimum		0.533	120.9	21.1
Maximum		1.195	258.2	23.4

3.3. The effect of climate factors with tree ring index (Zt)

The results of testing the relationship between the Zt series and the annual average climate data series such as annual mean temperature (Ttb) P-Value < 0.05 and mean annual precipitation (Ptb) have P-Value > 0.05; Thus, the annual average temperature indicator has a linear relationship with Zt, while the annual average rainfall indicator does not affect the growth of Pomu by climate change; so continue to investigate the relationship between Zt with monthly temperature (Ti) and monthly rainfall (Pi).

The annual average climate indicator in terms of temperature has a linear relationship with Zt according to the linear equation:

$$Zt= 2.711 - 0.272\ Ttb \quad (4)$$

Where: n= 57, R=0.272, P=0.041, Durbin Watson= 1.547, Std.dev= 0.991.

The equation (4) show that Zt has an inverse relationship with the average of annual temperature. This means the increase in temperature during the dry season will reduce the growth of *Po-mu*.

i) The effect of monthly temperature (Ti) with tree ring index (Zt)

The results of the relationship analysis show that Zt has an inverse relationship with the average temperature of month from February to July (T3,4,6,7) according to the selected model as follows:

$$Zt= 2.73 - 0.458\ T_3 \quad (5)$$

Where n= 57, R=0.458, P=0.000, durbin watson= 1.716, Std.dev= 0.991.

$$Zt= 2.979 - 0.437\ T_4 \tag{6}$$

Where n= 57, R=0.458, P=0.001, durbin watson= 1.345, Std.dev= 0.991.

$$Zt= 2.508 - 0.309\ T_6 \tag{7}$$

Where n= 57, R=0.309, P=0.02, durbin watson= 1.455, Std.dev= 0.991.

$$Zt= 3.598 - 0.422\ T_7 \tag{8}$$

Where n= 57, R=0.422, P=0.001, durbin watson= 1.542, Std.dev= 0.991.

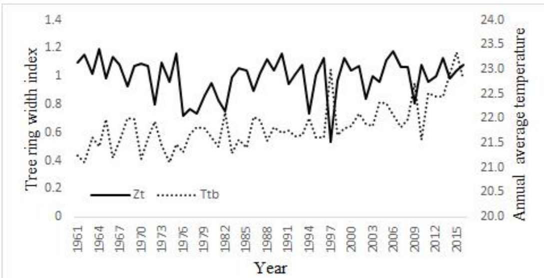

Figure 4. The relationship with the average of annual temperature with Zt.

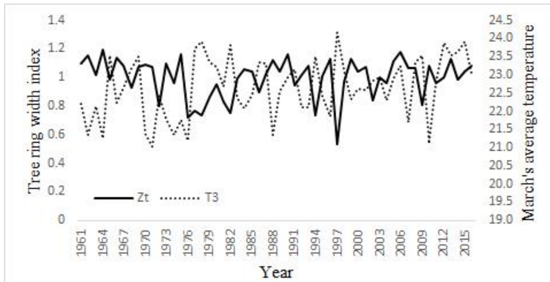

Figure 5. The relationship with the average of month temperature T3 with Zt.

Figure 5 to 8 shows that the variation in the ring width index Zt predicted by the weighted and observed model is negative relatinship with average temperature month; so it can be seen that the simulation model is good for the influence of the average temperature from February to July with Zt.

Especially, Figure 5 and Figure 6 shows that there is a very close correlation between the variation of the tree ring index (Zt) with the average temperature fluctuations in March and April (T3, T4), the time T3 has the extreme (lowest or highest), then Zt has the opposite value. This result shows that the selected model simulates the Zt fluctuations well, and at the same time confirms the influence of T3, T4 on Zt in the opposite direction, when the temperature in March and April increases, the annual ring width index Zt decreases and opposite.

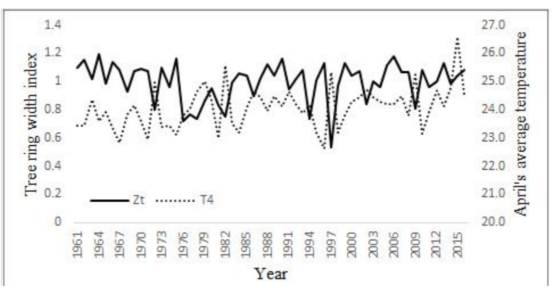

Figure 6. The relationship with the average of month temperature T4 with Zt.

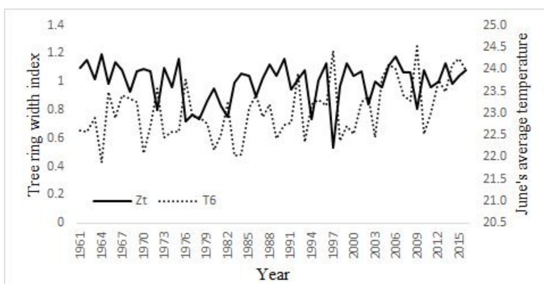

Figure 7. The relationship with the average of month temperature T6 with Zt.

ii) The effect of monthly precipitation (Pi) with tree ring index (Zt)

The results show that there is a relationship between Zt and rainfall in April (P4) and July (P7) according to the following model:

$$Zt = 0.94 + 0.293\ P4 \quad (9)$$

Where: n= 57, R=0.293, P=0.027, durbin watson= 1.618, Std.dev= 0.991.

$$Zt = 0.85 + 0.405\ P7 \quad (10)$$

Where n= 57, R=0.405, P=0.002, durbin watson= 1.815, Std.dev= 0.991.

The results from Figures 9 and 10 show that there is a clear correlation between the rainfall in April and July (P4, P7) and Zt, which is also a positive relationship; when P4, P7 increases, Zt increases, and the extremes (highest, lowest) are almost the same. In other words, the annual growth of Fokienia has a sensitive response to the change in rainfall in April and July of the previous year. The increase and prolongation of the rainy season in April and July will help increase the growth rate of Fokienia.

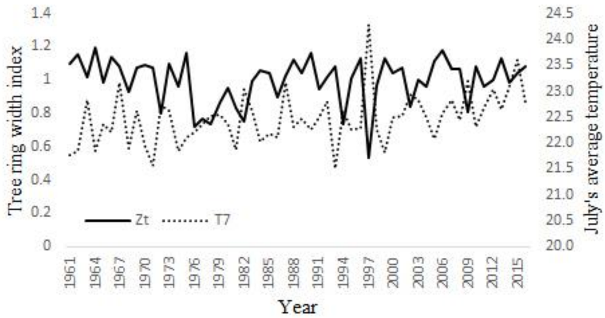

Figure 8. The relationship with the average of month temperature T7 with Zt.

Synthesized from the results of analysis of the relationship between the tree ring index Zt of Fokienia with climatic factors shows that:

In Kon Ka Kinh, the Zt index has an negative relationship with the temperatures in March and April (March and April). These are the last two months of the dry season, the air temperature is very high, so when climate change increases the temperature in these months, the growth rate of Fokienia is markedly reduced; in other words, climate change negatively affects Fokienia growth. This result coincides with Buckley et al., 2010; Sano et al., 2009 when it was determined that the growth of tropical conifers is often negatively correlated with temperature. This result is consistent with the study of Zuidema et al. (2011) when showing that drought reduces the growth rate of these species. Comparison with some other pine species shows that the growth of 3-leaf conifer in Da Lat is also negatively related to the temperature in January and June (Zuidema et al., 2011; Buckley et al., 2017); or Buckley et al. (2017; 2019); Hansen et al., 2017 showed that the growth of 5-leaf pine was inversely proportional to the temperature in April.

On the other hand, the Zt index has a positive relationship with the annual rainfall in April and July (P4, P7). This shows that increased and prolonged rainfall at the beginning of the rainy season in April and July also helps to increase plant growth.

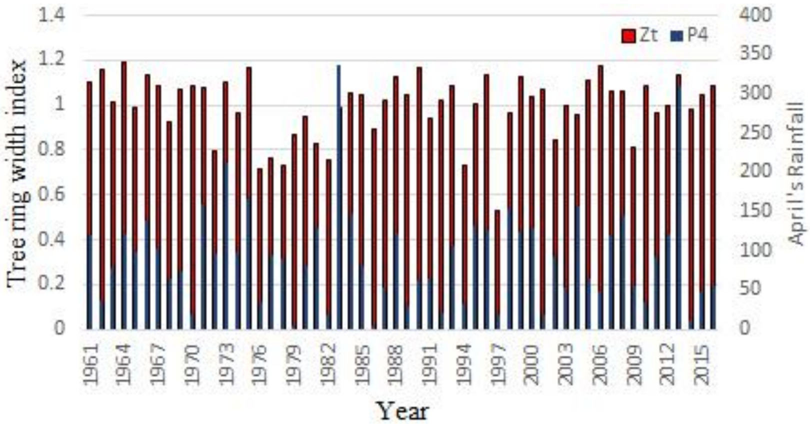

Figure 9. The relationship with the average of month rainfall P4 with Zt.

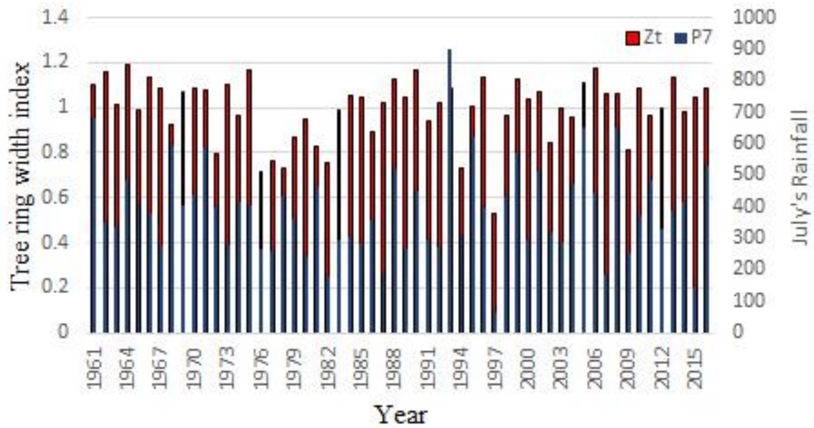

Figure 10. The relationship with the average of month rainfall P7 with Zt.

4. CONCLUSIONS

There has been climate change in the Central Highlands over the past 57 years, with the average annual temperature increasing by about one degree Celsius. Increasing temperature due to climate change reduces the growth of Fokienia diameter in the Central Highlands.

Climatic factors have an influence on the growth of the annual ring width of Fokienia species. The growth of the annual ring width Fokienia has an inverse relationship with the average annual temperature, an inverse relationship with the average temperature from February to July, especially closely with the temperature of March and April. Because in March, the temperature and dry humidity in the Central Highlands is high. Thus inhibiting the growth of Fokienia.

The growth of the Fokienia ring width has a positive relationship with the rainfall in April and July. The reason for this is that April is the beginning of the rainy season in the Central Highlands, so the growth cycle goes through a process. arid process in the dry season, rain at the beginning of the rainy season, so the greater the amount of rain, the more favorable the growth of Fokienia.

Acknowlegement: The content of this manuscript is based upon work supported by the project of Vietnam National University, grant number QG.20.69. We would like to thank the constructive feedback from an expert reviewer and the Guest Editor improved the paper.

REFERENCE

1. Buckley, B. M., Anchukaitis, K. J., Penny, D., Fletcher, R., Cook, E. R., Sano, M., Nam, L. C., Wichienkeeo, A., Minh, T. T., and Hong, T. M. (2010). “Climate as a contributing factor in the demise of Angkor, Cambodia”. *Proceedings of the National Academy of Sciences of the United States of America*, 107(15): 6748-6752.
2. Buckley, B. M., Stahle, D. K., Luu, H. T., Wang, S. Y. S., Nguyen, T. Q. T., Thomas, P., Le, C. N., Ton, T. M., Bui, T. H., and Nguyen, V. T. (2017). “Central Vietnam climate over the past five centuries from cypress tree rings”. *Climate Dynamics*, 48(11-12): 3707-3723.
3. Buckley, B. M., Ummenhofer, C. C., D’Arrigo, R. D., Hansen, K. G., Truong, L. H., Le, C. N., and Stahle, D. K. (2019). “Interdecadal Pacific Oscillation reconstructed from trans-Pacific tree rings: 1350-2004 CE”. *Climate Dynamics*, 53(5-6): 3181-3196.
4. Cook, E. R. (1985). A Time Series Analysis Approach to Tree Ring Standardization. In School of Renewable Natural Resources: Vol. PhD Thesis, 171.
5. Fritts, H. C., Bottorff, C. P., and Mosimann, E. (1969). Tree ring.
6. Fritts HC (1976). *Tree rings and climate*. Academic Press, New York.
7. Hansen, K. G., Buckley, B. M., Zottoli, B., D’Arrigo, R. D., Nam, L. C., Van Truong, V., Nguyen, D. T., and Nguyen, H. X. (2017). “Discrete seasonal hydroclimate reconstructions over northern Vietnam for the past three and a half centuries”. *Climatic Change*, 145(1-2): 177-188.
8. Holmes RL. (1983). “Computer-Assisted Quality Control in Tree-Ring Dating and Measurement”. *Tree Ring Bull*, 43: 1983, 69-78.
9. Marvin A. Stokes and Terah L. Smiley. (1996). An Introduction to Tree-Ring Dating.
10. Nelson, D. B., Abbott, M. B., Steinman, B., Polissar, P. J., Stansell, N. D., Ortiz, J. D., Rosenmeier, M. F., Finney, B. P., and Riedel, J. (2011).” Drought variability in the Pacific Northwest from a 6,000-yr lake sediment record”. *Proceedings of the National Academy of Sciences of the United States of America*, 108(10): 3870-3875.
11. Sano, M., Buckley, B. M., and Sweda, T. (2009). “Tree-ring based hydroclimate reconstruction over northern Vietnam from Fokienia hodginsi: Eighteenth century mega-drought and tropical Pacific influence”. *Climate Dynamics*, 33(2-3): 331-340.
12. Zuidema, P. A., Vlam, M., and Chien, P. D. (2011). “Ages and long-term growth patterns of four threatened Vietnamese tree species”. *Trees - Structure and Function*, 25(1): 29-38.

USING STEEL SLAG AGGREGATES: A GREEN MATERIAL AS FUNCTIONAL FILLERS IN SMART ULTRA-HIGH PERFORMANCE CONCRETE WITH SELF-SENSING ABILITY

Viet Le Huy[1,2], Hung Vo Trong[1], Dong Joo Kim[3]
[1]Faculty of Civil engineering, Hanoi University of Mining and Geology, Hanoi, Vietnam
[2]Geotechnical Engineering, Construction Materials and Sustainability research Group
[3]Faculty of Civil engineering, Sejong University, Seoul, Korea
Corresponding Author: lehuyviet@humg.edu.vn

Abstract: Steel slags are the waste products of steel manufacturing. The steel slag can be used as a mineral admixture in concrete or an aggregate in concrete. In this study, fine steel slag aggregates (manufacturing by using Slag Atomizing Technology) which contain almost no free CaO and MgO were used as a fine aggregate in ultra-high performance concrete (UHPC). In addition, the fine steel slag aggregates with high electrical conductivity was potential electrically conductive functional fillers in smart concrete with self-sensing ability. The self-sensing ability of smart UHPC containing steel slag aggregates was investigated. The UHPCs containing SSAs produced high workability (250 mm in diameter) and compressive strength (185 MPa). The addition of steel slag aggregates enhanced conductive network of functional fillers in the smart UHPCs, thus improved self-sensing ability of smart UHPCs under compressive loading. As the compressive stress increased, the electrical resistivity of smart UHPC clearly decreased. Based on change in electrical resistivity of smart UHPC, the change in compressive stress of specimens was observed and vice versa. Hence, steel slag aggregate, a green material, was potential fine aggregate for concrete as well as functional filler for enhancing self-sensing ability of smart concretes.

Keywords: Steel slag aggregate; Ultra high performance concrete; Self-sensing; Green materials.

1. INTRODUCTION

Steel slag aggregate is a waste product of steel manufacturing, which should be considered as a green resource (Jiang et al., 2018). Steel slag can be classified into basic oxygen furnace (BOF) slag or an electric arc furnace (EAF) slag based on steel manufacturing technology. During the manufacturing of carbon and stainless steels, a significant amount of by-product steel-slag is produced, accounting for about 15-20 wt.% of the total steel output (Das et al., 2007). The chemical compounds in steel slag generally include SiO_2, CaO, Fe_2O_3, Al_2O_3, and MnO (Jiang et al., 2018).

In Vietnam in 2020, (Huyen Trang and Quyen, 2020) reported that the annual production of steel is about 20 million tons while that of steel slag is about 2,2 million tons (11-12% steel production (Hien, 2016)).

Huge amount of steel slag leads to occupation of lands and potential pollution of water and soil owing to the alkaline leachates from steel slags. Thus, utilization of steel slags as a recycled material for concrete is an interested topic for environmental protection.

Researches have recently shown that steel slag would be used as a coarse or fine aggregate for concrete (Rondi et al., 2016; Saxena and Tembhurkar, 2018). Moreover, concrete containing steel slag aggregate displays satisfactory compressive strengths and