The Effects of Species and Genus on Leaf Senescence

Authors

Seura Jang (seurajang@gmail.com), Dongha Kim (donghakdh@hotmail.com)

Abstract

Deciduous trees undergo leaf degradation every year through a process known as autumn leaf senescence. This integral life history stage in deciduous trees is usually signalled by harsh environmental conditions which cause the trees to store more energy to survive. As a response to the harsh winter temperatures, deciduous trees will reduce production of chlorophyll in leaves to conserve energy which leads to the browning of the leaves and the ensuing falling of leaves. The aim of this study was to determine if the species of the trees were an important factor in the rate of leaf senescence. It was hypothesized that since all deciduous trees undergo leaf senescence, there won't be a significant difference observed between the groups. We analyzed three *Prunus avium* trees and one *Salix nigra* tree everyday from October 22nd, 2020 till November 13th, 2020. The percent canopy cover of the 4 tree samples were taken daily through the use of the Canopeo phone application and were later implemented into a dataset. A decline in percent canopy cover was found in the four tree samples indicating the process of leaf senescence. The dataset of percent canopy cover was transformed into the rate of change in percent canopy cover by obtaining the difference between one canopy cover reading with the canopy cover reading of its preceding date. An ANOVA single factor statistical test was done to determine if the rate of change in the percent canopy cover of the 4 tree samples were significantly different. Given a p-value of 0.948, it was concluded that there was no significant difference in leaf senescence for the 2 tree species.

Introduction

Temperate deciduous forests are found all across the globe, mainly sequestered in the mid-latitude regions of the world. As the name suggests, these forests experience a broad range of temperatures throughout the year ("Temperate Deciduous Forest"). These regions of the world can experience cold winters with temperatures less than 0°C and hot winters of up to 35°C. Inhabitants of temperate forests must be able to adapt to the change in temperature throughout the year in order to thrive.

As temperatures decrease in temperate regions, the native vegetation undergo a massive phenological change to survive(Gill et al. 875). Deciduous trees will go through a process known as autumn leaf senescence, where the chlorophyll in leaves are degraded and leaf abscission occurs (Mariën et al. 166). The process of autumn leaf senescence has been observed in all deciduous trees, yet the complete mechanism(s) of this process are not fully explored(Kortebein). Understanding the drivers of leaf senescence can be useful for society as it can be applied to the field of agriculture as well as how global warming can impact the ecosystem of temperate deciduous forests.

Within our study, we investigated if the species of the tree play a role in leaf senescence. The data was recorded throughout the months of October and November 2020. In particular, we examined three *Prunus avium* trees as well as one *Salix nigra* tree located in Burnaby, B.C. Our null hypothesis suggests that since the main drivers of leaf senescence come from decreasing temperatures, the difference in tree species will not have a significant role in the rate of leaf senescence. With this study, assessed the percent canopy cover of the trees over a month long period and carried out an ANOVA single factor statistical test to determine if there was a significance between the trees percent canopy cover.

Methods

We found and identified the species of four tree samples by using a dichotomous key found on *gobotany.org* to obtain proper identification. Once the tree species were verified, a researcher was assigned to observe and document each tree sample. The researcher downloaded the Canopeo application on their phone in order to obtain a quantitative value of percent cover for each tree sample. The percent cover value was obtained by standing a foot away from the base of the tree and pointing the camera up to the canopy of the tree at a 45° angle. A percent canopy cover reading of the tree samples were taken everyday from mid-October until all tree samples had obtained a 0% canopy cover. A 0% canopy cover meant that the Canopeo application gave a reading of 0% canopy and meant that the tree had no more leaves attached to the canopy. In order to reduce sources of error, the assigned researcher had made sure to take the canopy cover reading at the same angle and same spot for every tree sample. When taking measurements of the percent canopy cover of the tree samples, some notes were made describing the weather to explain possible sources of variation within the dataset.

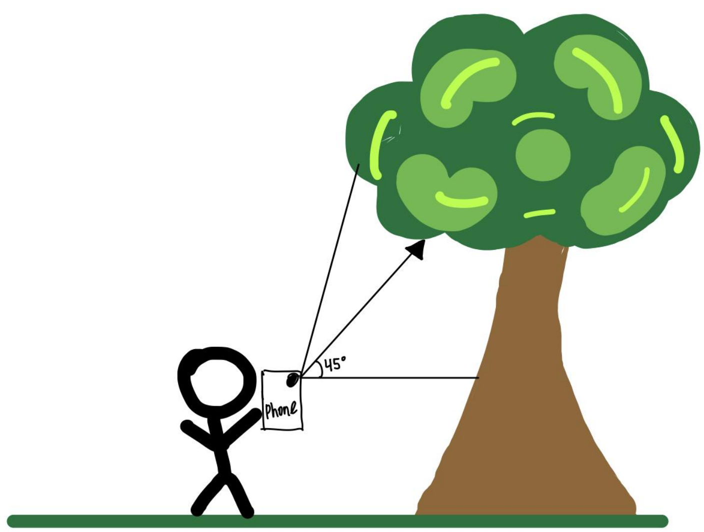

Fig. 1. An example diagram of the procedure taken to obtain the percent canopy cover readings for each tree sample

Once the data set was complete, the rate of change in percent canopy cover was obtained by calculating the difference between the percent canopy cover reading from one date with the percent canopy cover of its preceding date. The rate of change in percent canopy cover was found for all 4 tree samples. With this transformed data set, an ANOVA single factor statistical test was done to determine if there was a difference between the 4 tree samples. If the ANOVA tests concluded there was a significant difference between the 4 groups, a subsequent Tukey's test would be done to determine which groups were significantly different from each other. The 4 groups each had 21 data points for rate of change in percent canopy cover. A p-value lower than 0.05 obtained from the ANOVA analysis would be indicative that there is a significant difference in rate of change of percent canopy cover within the 4 tree samples, thus rejecting the null hypothesis. A p-value higher than 0.05 would mean that the data failed to reject the null hypothesis.

Results

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	25.43544	3	8.478481	0.120031	0.948072	2.718785
Within Groups	5650.866	80	70.63583			
Total	5676.301	83				

Table 1. An ANOVA single factor statistical test was done on Excel. The mean rate of change in percent canopy cover for the four tree samples were analyzed using ANOVA and a p-value of 0.948072 was obtained.

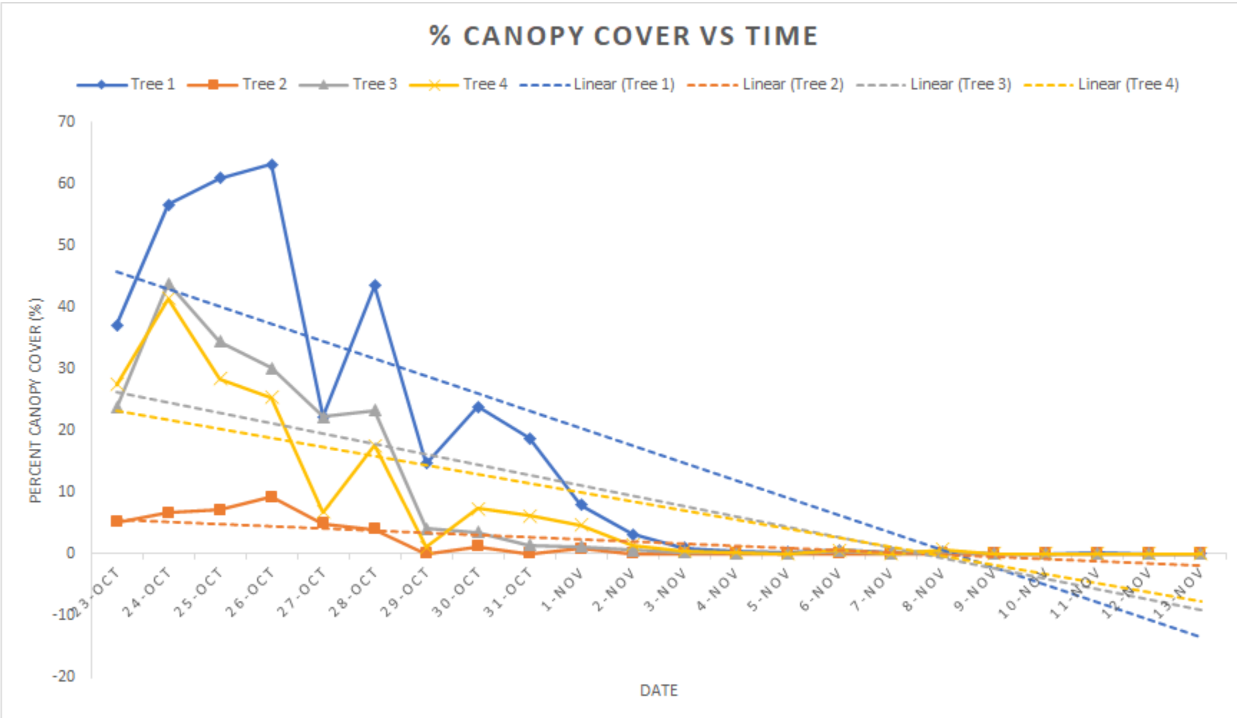

Figure 2. A line graph depicting the % canopy cover of the four tree samples in relation with time. All trees had a negative trend that was indicative of the process of leaf senescence in the trees. Positive jumps in percent canopy cover were found on Oct 23-27 and Oct 29th that arose from errors. We know these positive jumps of percent canopy cover are errors as the percent canopy cover would not regenerate, leaf senescence would not revert. The tree samples had varying initial percent canopy covers when beginning the study.

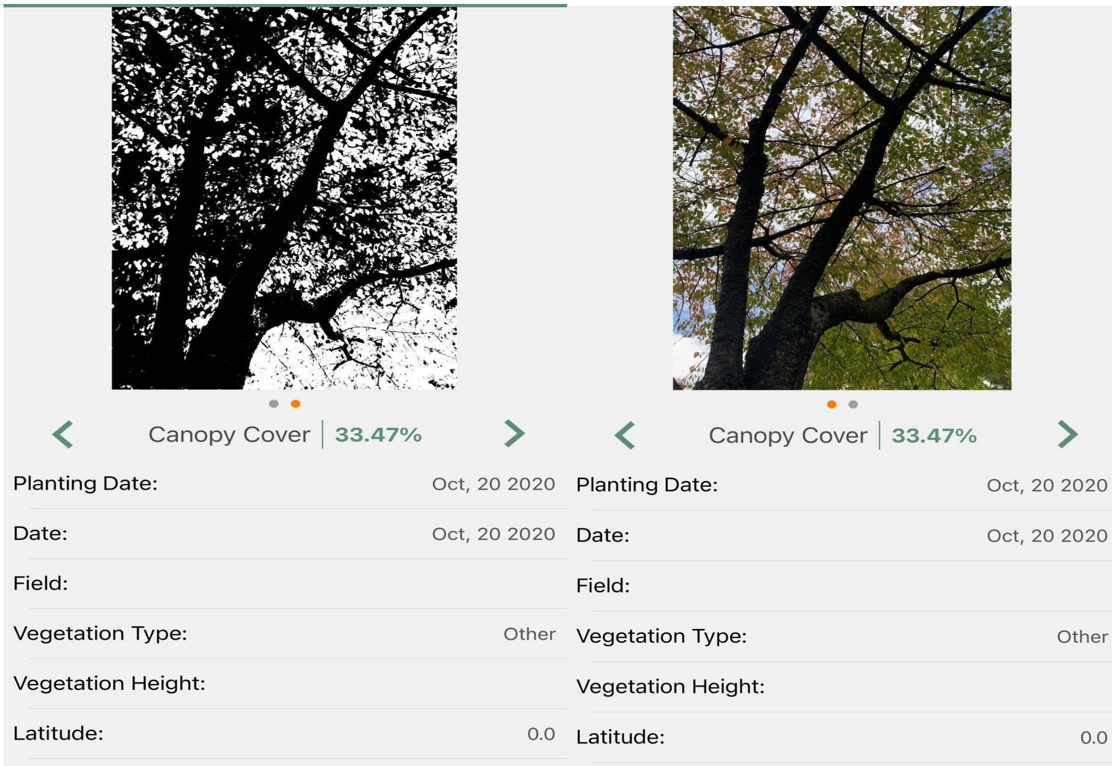

Figure 3. An example of the results obtained from the pictures taken via the Canopeo application. The percent canopy cover of the trees was detailed to the 2nd decimal place along with the date of the photographs. A black and white filter could be implemented to the photograph to further demonstrate the amount of leaves attached to the tree canopy.

Discussion

In this study, we determined if the four deciduous trees led to variation in rate of change of percent canopy cover. With the use of the statistical test, ANOVA, a p-value of 0.948 was obtained as seen in Table 1. Since the p-value was greater than 0.05, the null hypothesis had failed to be rejected, meaning that the variation in rate of change of percent cover is due to chance. An F value of 0.120 was obtained and an F critical value was determined to be 2.719. As the F value is smaller than the critical value, this is an indication that there was no significant difference in the rate of change of percent canopy cover between the four deciduous trees. In other words, the rate of change of canopy cover is similar between the trees.

It was determined that the temperatures in October were the best predictors for when the senescence occurs (Gill et al. 875). Assuming the average weekly temperature becomes colder from October to November, this drop in temperature will lead to deciduous trees undergoing leaf senescence at a similar time frame to one another. This will lead to indifference in results of the rate of change of percent canopy cover. Autumn leaf senescence is a signal which indicates that photosynthetic activities in temperate deciduous trees have ended (Liu et al. 4104). The study done by Liu et al shows that all temperate deciduous trees will roughly undergo leaf senescence in the fall and this will occur within a similar time frame to one other.

Some possible sources of error may have stemmed from having only four deciduous trees to obtain data from, and only having two different species. It was difficult to find more of the same trees around the neighbourhood. In our study, we assumed that the difference between sunny and cloudy days were negligible in percent cover but consistency errors arose due to the limits of the Canopeo application. There were fluctuations in canopy percentage based on the cloud coverage of a given day and this may have affected our results. Another assumption for this study was that other factors aside from temperature, such as wind, rain, and carbon dioxide concentration, were constant. It was described that the 45 degree angle was maintained throughout the study in the methods section, however it was challenging to obtain a strict 45 degree angle for every observation, which may lead to some error in the dataset. It was assumed that the images for canopy cover on all four trees were taken at the exact same position each time. Some other assumptions required for this study is to assume the average trend of temperature decreases with time, and as images were taken between 12 pm and 2 pm, it was assumed that the interval of 2 hours were negligible and did not affect our data.

For future studies, it would be advised to consider other factors like wind, precipitation, and carbon dioxide concentration in the atmosphere around the trees and see how those affect the rate of percent canopy cover. It would be more beneficial to acquire a data set that has been obtained for more than one year. Perhaps, obtain data for at least five to ten years and see what type of changes occur in the rate of canopy cover. A topic of consistent interest would be climate change; therefore, by looking at the long-term data, it would be helpful to study if there is a change in temperature which results in a faster or slower autumn senescence. This study shows that the senescence starts in October and all trees lost their canopy cover by November 13th, however, this date could vary each year.

Conclusion

It was found that there was no significant difference in leaf senescence between *Prunus avium* and *Salix nigra*. Through the use of an ANOVA single factor statistical test, a p-value of 0.984 was found and since the p-value was greater than the significance level of 5%, the null hypothesis failed to be rejected. The study was done to determine if the species of the tree is a critical factor for the promotion of leaf senescence. The ANOVA test concluded that since the species of the tree is not a critical factor for the promotion of leaf senescence, the two tree species had similar rate of change in percent canopy cover.

Acknowledgements

We thank our professor Dr. Celeste Leander for guidance to approaching the project as well as providing an opportunity to publish our paper. We would also like to thank the research team at Oklahoma State University for creating the Canopeo Application.

Works Cited

Gill, Allison L et al. “Changes in autumn senescence in northern hemisphere deciduous trees: a meta-analysis of autumn phenology studies.” *Annals of botany* vol. 116,6 (2015): 875-88. doi:10.1093/aob/mcv055. Accessed 23 Nov. 2020

Kortebein, P. “Why Do Some Trees Keep Their Leaves Through Winter?” *ThreeRivers Park District*, 24 Dec. 2018, https://www.threeriversparks.org/blog/why-do-some-trees-keep-their-leaves-through-winter. Accessed 23 Nov. 2020

Liu, Q., Piao, S., Campioli, M., Gao, M., Fu, Y. H., Wang, K., . . . Janssens, I. A. (2020). Modeling leaf senescence of deciduous tree species in Europe. *Global Change Biology, 26*(7), 4104-4118. doi:10.1111/gcb.15132. Accessed 24 Nov. 2020

Mariën, Bertold, et al. “Detecting the Onset of Autumn Leaf Senescence in Deciduous Forest Trees of the Temperate Zone.” *New Phytologist*, vol. 224,1(2019): 166–176., doi:10.1111/nph.15991. Accessed 24 Nov. 2020

“Temperate Deciduous Forest.” Nasa earth observatory, https://earthobservatory.nasa.gov/biome/biotemperate.php#:~:text=Temperate%20deciduous%20forests%20are%20located,area%20to%20have%20four%20seasons. Accessed 24 Nov. 2020

Appendix

ANOVA Single Factor Test

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Column 1	21	-37.05	-1.76429	177.7478		
Column 2	21	-5.21	-0.2481	2.197456		
Column 3	21	-23.77	-1.1319	46.14318		
Column 4	21	-27.5	-1.30952	56.45488		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	25.43544	3	8.478481	0.120031	0.948072	2.718785
Within Groups	5650.866	80	70.63583			
Total	5676.301	83				

Raw Data Table

Date	Temperature (°C)	Tree 1 Canopy Cover (%)	Tree 2 Canopy Cover (%)	Tree 3 Canopy Cover (%)	Salix nigra (%)	Observations	Rate of change of Tree 2 Canopy Cover	Rate of change of Tree 1 Canopy Cover	Rate of change of Tree 3 Canopy Cover	Rate of change of Tree 4 Canopy Cover
Oct 22, 2020	12	62.08	24.97	46.97		sunny day				
Oct 23, 2020	6	37.05	5.21	23.77	27.5	the weather seems to have made the results very different (rainy and cloudy)	-25.03	-19.76	-23.2	27.5
Oct 24, 2020	8	56.61	6.62	43.86	41.38	a very sunny day. The second tree seems like it had fewer trees. bright or cloudy weather seems to effect images used for canopy coverage	19.56	1.41	20.09	13.88
Oct 25, 2020	3	60.96	7.18	34.45	28.38	partly cloudy, partly sunny.	4.35	0.56	-9.41	-13
Oct 26, 2020	3	63.11	9.25	30.1	25.38	very cold day, sunny	2.15	2.07	-4.35	-3

Oct 27, 2020	8	22.18	4.94	22.18	6.8	cloudy, no sun - pictures didn't come out as bright so some of the canopy didn't get included even at the highest brightness setting.	-40.93	-4.31	-7.92	-18.58
Oct 28, 2020	11	43.51	4.03	23.28	17.64	very cloudy, grey skies	21.33	-0.91	1.1	10.84
Oct 29, 2020	13	14.73	0.08	4.07	1.06	very cloudy and drizzling rain. image was very dark in general which may have resulted in these extremely low numbers	-28.78	-3.95	-19.21	-16.58
Oct 30, 2020	13	23.88	1.23	3.52	7.38	sunny day	9.15	1.15	-0.55	6.32
Oct 31, 2020	11	18.79	0.11	1.44	6.24	Mostly sunny, very little clouds	-5.09	-1.12	-2.08	-1.14
Nov 1, 2020	13	7.95	0.82	1.27	4.72	sunny day, bright. very little trees left on tree 2	-10.84	0.71	-0.17	-1.52
Nov 2, 2020	17	3.14	0.07	0.58	1.43	partly cloudy, partly sunny. maybe the tree color is affecting the % because not all leaves are being detected by the CANOPEO app.	-4.81	-0.75	-0.69	-3.29
Nov 3, 2020	10	1	0.09	0.28	0.5	drizzling, dark, cloudy	-2.14	0.02	-0.3	-0.93

Nov 4, 2020	16	0.39	0.03	0.15	0.33	pouring, rain; 2 basically have no leaves (maybe only a few), tree 3 mostly lost all leaves except for one side at the bottom right. the salix nigra tree looks about half as full compared to when it started.	-0.61	-0.06	-0.13	-0.17
Nov 5, 2020	11	0.27	0	0.02	0.1	partly cloudy, no more leaves on tree 2,	-0.12	-0.03	-0.13	-0.23
Nov 6, 2020	9	0.64	0	0.47	0.61		0.37	0	0.45	0.51
Nov 7, 2020	8	0.26	0	0.04	0.05	sunny	-0.38	0	-0.43	-0.56
Nov 8, 2020	9	0.41	0	0.24	0.72	canopeo sometimes shows the branches as being a leaf so had to adjust to make zero since tree one has no leaves left.	0.15	0	0.2	0.67
Nov 9, 2020	3	0.1	0	0.03	0.02	tree 1,3, and salix nigra only has few leaves left now. cloudy	-0.31	0	-0.21	-0.7
Nov 10, 2020	6	0.03	0	0.02	0	leaves are almost gone on tree 1,3 and salix nigra trees have only a bit of dead brown leaves on trees. cloudy.	-0.07	0	-0.01	-0.02
Nov 11, 2020	5	0.13	0	0	0.02	no leaves on tree 2,3 and barely any on salix. cloudy day.	0.1	0	-0.02	0.02

Nov 12, 2020	6	0.07	0	0	0.01	cloudy, slight rain	-0.06	0	0	-0.01
Nov 13, 2020	9	0	0	0	0		-0.07	0	0	-0.01
Nov 14, 2020	8	0	0	0	0		0	0	0	0
Nov 15, 2020	11	0	0	0	0		0	0	0	0
Nov 16, 2020	8	0	0	0	0		0	0	0	0
Nov 17, 2020		0	0	0	0		0	0	0	0