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MICROCLIMATE EFFECT OF AGROFORESTRY PLANTATIONS ON ATMOSPHERIC TEMPERATURE IN ABIA AND EBONYI STATES, SOUTHEAST NIGERIA

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ABSTRACT

A two-year field study was conducted to determine the microclimate effect of agroforestry plantations on atmospheric temperature at Okwuta, Umuahia, Abia State and Ishiagu, Ebonyi State; Southeast Nigeria. Temperature variations in the different agroforestry ecosystems and control stations were collected using thermometers. Paired sample statistics were employed in comparing temperature variations between ecosystems using a statistical tool, GenStat version 7.22 DE. Temperature variations within and between the experimental sites indicated that the maximum and minimum temperature (^{0}C) from the control were higher than the agroforestry plantations within the year (2020/2021) under study with an annual mean temperature variation of 4.67^{0}C for maximum and 4.09^{0}C for minimum (2020); and 4.04^{0}C for maximum and 3.80^{0}C for minimum (2021) between the control and agroforestry plantation plots at FRIN Agroforestry site. Equally, the annual mean temperature variation of 4.06^{0}C for maximum and 4.67^{0}C for minimum (2020); and 4.00^{0}C for maximum and 4.22^{0}C for minimum (2021) temperatures between the control and agroforestry plantation plots at FCA, Ishiagu. These figures showed that agroforestry plantations ameliorated temperatures significantly within the range specified in the study. This finding highlighted the potentiality of agroforestry plantations to ameliorate the high atmospheric temperatures of the surrounding environment. From the findings of this study, the following are recommended: agroforestry plantation establishment be encouraged to ensure the modification of environmental temperature. Agroforestry plantation establishments will equally serve as a carbon sink, thus mitigating the effect of global warming and the attendant climate change.

Keywords: Agroforestry, Atmospheric Temperature, Microclimate, Plantations

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INTRODUCTION

It is widely recognised that trees can regulate local air temperatures through shading and evapo-transpiration (Jim and Chen, 2008; Yang, McBride, Zhou, and Sun, 2005). Shade from trees can decrease air temperature by reducing solar heating of dark surfaces below the canopy. Some of the solar energy absorbed by trees results in water loss through leaf pores and subsequent evaporation to the atmosphere. This evapo-transpiration also has a cooling effect, which occurs not only directly below the canopy but also in surrounding areas, as air movement rapidly disperses the cooled air (Nowak and

Dwyer, 2000). The temperature in urban areas is generally 2.5°C warmer than in nearby rural areas on a sunny afternoon, partly because there is less vegetation in cities (Akbari, Pomerantz, and Taha, 2001). The combined cooling effects of trees may be able to reduce air temperatures by as much as 5°C (Akbari, Davis, Huang, Dorsano, and Winnett,1992). Trees can also dramatically reduce wind speed, with larger areas of trees having a more widespread effect (Nowak and Dwyer, 2000). In cold climates, the shading effect of trees can substantially reduce building heating requirements. Equally, in warm climates, the impacts of windbreaks on cooling are fairly small compared with the benefits of shading (Akbari *et al*., 2001, Beckett, Freer-Smith, and Taylor, 1998).This study therefore seeks to determine the microclimate effect of agroforestry plantations on atmospheric temperature in Abia and Ebonyi States, Southeast Nigeria.

MATERIALS AND METHODS

Site Description

Two sites used in this study were: (i) Forestry Research Institute of Nigeria (FRIN) Sub-station Okwuta – Umuahia, Nigeria and (ii) Federal College of Agriculture (FCA), Ishiagu, Ebonyi State, Nigeria

Forestry Research Institute of Nigeria (FRIN) sub - station, Okwuta - Ibeku; Umuahia

The study was conducted at the agroforestry site of FRIN sub – station, Okwuta- Ibeku, Umuahia; Abia State in 2020 and 2021. The site is a mixed plantation of *Pinus caribaea* and *Gmelina arborea* and was established in 1979 (36 -year-old plantation) on 2.0 ha of land at an emplacement of 3.0 m x 3.0 m. The land was previously cultivated with mixed arable crops of yam, maize intercrop; and cassava as the sole crop. Several indigenous arable crops were consistently on rotation periodically. The mean height of the trees in the stand was 7.9 m; their mean stem diameter at breast height was 12.2 cm. It is situated 8.0 km Southeast of Umuahia. It is located between latitudes 5^0 29^1 and N and longitude $7^0 33^1$ and E; at an altitude of 122 m above the sea level. The mean annual rainfall of 2171 mm is distributed over eight months in a bimodal rainfall pattern. These are the early rain (March to July) and late rain (September to November), with three months (December to February) of dry season and a short dry spell in August. The dry season is characterized by a cool, dry Northeastern wind. The monthly minimum air temperature ranged from 20^0C to 24^0C while the monthly maximum air temperatures ranged from 28^0C to 35^0C. The average sunshine hours varied from 3 hours to 7 hours and appeared always lowest in the months of July, August, and September. Sunshine hours were always highest in May. The relative humidity varied from 51% to 87% (NRCRI, 1982).

Ishiagu Agroforestry Site

The study was carried out at the agroforestry site of the Federal College of Agriculture, Ishiagu; Ebonyi State, in 2020 and 2021. The site is a mixed plantation of *Gmelina arborea* and *Senna siamea* and was established in 1983 on 2 ha of land. The mean height of the trees in the stand was 6.9 m; their mean stem diameter at breast height was 10.2 cm.

Ishiagu is situated between latitude 05^0 56^1 and N and longitude 07 64^1 and E. The area lies within the tropical rainforest zone with annual average temperate of 29^0C and annual average rainfall of 1350 mm (FCA Meteorological Station, 2000). It had pre-cropped vegetation of *Sida acuta*, *Eluisine indica*, *Mimosa pudica*, *Panicum maximum*, C*hromoleana odorata,* and *Imperata cylindrica*. It has been previously planted with maize, okra, yam, and cassava at different times in rotation and was equally under fallow at several seasons in the past.

Map of Nigeria

Map of Ishiagu, Ebonyi state; Nigeria

Map of Okwuta- Ibeku, Umuahia, Abia State; Nigeria

Experimental Design

Reconnaissance surveys of each of the 2 ha sites were initially conducted at the start of the research in March 2020, using surveying equipment to demarcate the sites. In each of the two experimental sites (FRIN Agroforestry site, Okwuta - Ibeku, Umuahia (Abia State) and Ishiagu Agroforestry site (Ebonyi State), four plots measuring 25.0 m x 25.0 m were randomly laid. The meteorological stations at NRCRI, Umudike and FCA, Ishiagu were used as controls for the meteorological parameters under investigation. Thermometers measuring in degrees Celsius attached to sampled trees of *Pinus caribaea* and *Gmelina arboraea* in the agroforestry plantations were used for temperature measurement. In all, a total of eight (8) thermometers were used (that is, four (4) in each of the experimental locations).

Data Collection

Data from the study plots were collected using thermometer with the following parameters: Temperature variation in different agroforestry ecosystems and control stations.

Statistical Analysis

Paired sample statistics were employed in comparing temperature variations between ecosystems using a statistical tool, GenStat Release 7.22 DE.

RESULTS

Influence of Agroforestry Plantations on Atmospheric Temperature (T^0C) at Forestry

Research Institute of Nigeria (FRIN), Okwuta – Ibeku, 2020

Table 1a shows the variation in mean, maximum, and minimum atmospheric temperature measurements between the control (Met station) and sample plots in the agroforestry plantations. The control showed a higher maximum and minimum temperature measurement as compared to the temperature in agroforestry plantation plots. Cumulative mean temperature variation of 4.67^{0}C for maximum and 4.09^{0}C for minimum temperatures was observed between the control and agroforestry plantation plots for the season under study. This implied that the agroforestry plantations ameliorated the atmospheric temperature significantly.

Table 1a. Influence of Agroforestry Plantations on Atmospheric Temperature (T^0C) at Forestry Research Institute of Nigeria (FRIN), Okwuta - Ibeku Agroforestry site, 2020

T^0C	*CONTROL		Plot A		Plot B		Plot C		Plot Average		Temp Diff	
	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN
Jan	33	20	29	16	29	16	29	16	29.00	16.00	4.00	4.00
Feb	33.2	23.2	29	20	28	19	28	19	28.33	19.33	4.87	3.87
Mar	33.6	24	29	20	29	20	29	18	29.00	19.33	4.60	4.67
April	32.5	24	28	21	28	20	28	20	28.00	20.33	4.50	3.67
May	31.7	23.3	27	19	27	19	27	19	27.00	19.00	4.70	4.30
June	30.3	23.2	26	20	26	19	26	19	26.00	19.33	4.30	3.87
July	29.5	22	24	18	24	18	24	18	24.00	18.00	5.50	4.00
Aug	29.2	22	25	18	24	18	24	18	24.33	18.00	4.87	4.00
Sept	29.7	22	25	18	24	18	24	18	24.33	18.00	5.37	4.00
Oct	30.2	22	26	18	26	18	26	18	26.00	18.00	4.20	4.00
Nov	31.3	23	27	19	26	18	26	18	26.33	18.33	4.97	4.67
Dec	33.2	21	29	17	29	17	29	17	29.00	17.00	4.20	4.00
											4.67	**4.09**

**Control- NRCRI Meteorological station, Umudike, 2020*

Influence of Agroforestry Plantations on Atmospheric Temperature (T^0C) at Forestry Research Institute of Nigeria (FRIN), Okwuta – Ibeku in 2020

Table 1b shows the paired sample test for mean atmospheric temperature measurement in 2020 for Ishiagu agroforestry plantations. The results from the table indicated the following mean values: plot A maximum and control maximum, plot B maximum and control maximum, and plot C the maximum and control maximum were -4.45, -4.78 and – 4.78 with standard deviations of 0.399, 0.573 and 0.573, respectively. The result also showed t- calculated values of: -38.65, -28.90 and -28.90. All were statistically significant (as the 2-tailed P – value of 0.000 is less than 0.05). Equally, the mean values between plot A minimum and control minimum, plot B minimum and control minimum, and plot C minimum and control minimum were: -4.00, -4.33 and -4.50 with standard deviation of 0.604, 0.368 and 0.589 respectively. The t - calculated values of: -22.92, -40.83 and -26.45 were highly statistically significant at 5% level of probability (P value of 0.000 is less than 0.05). This implied that the atmospheric temperatures in the agroforestry plantations and control are different. Since the temperature of the control plot was higher than that of the agroforestry plantation, it implied that the agroforestry plantation significantly modified the atmospheric temperature.

Table 1b. Paired Sample Test for Influence of Agroforestry Plantations on Atmospheric Temperature (T^{0}C) at Forestry Research Institute of Nigeria (FRIN) Okwuta – Ibeku in 2020

		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	Df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	plotAmax2020-umucontmax2020	-4.45000	.39886	.11514	-4.70342	-4.19658	-38.648	11	.000
Pair 2	plotBmax2020 - umucontmax2020	-4.78333	.57340	.16553	-5.14765	-4.41901	-28.898	11	.000
Pair 3	plotCmax2020 - umucontmax2020	-4.78333	.57340	.16553	-5.14765	-4.41901	-28.898	11	.000
Pair 4	plotAmin2020 - umucontmin2020	-4.00000	.60453	.17451	-4.38410	-3.61590	-22.921	11	.000
Pair 5	plotBmin2020 - umucontmin2020	-4.33333	.36763	.10613	-4.56691	-4.09975	-40.832	11	.000
Pair 6	plotCmin2020 - umucontmin2020	-4.50000	.58930	.17012	-4.87442	-4.12558	-26.453	11	.000

Influence of Agroforestry Plantations on Atmospheric Temperature (T^{0}C) at Forestry Research Institute of Nigeria (FRIN), Okwuta – Ibeku, 2021

Table 2a. showed the variation in mean, maximum, and minimum atmospheric temperature measurements between the control (Met station) and sample plots in the agroforestry plantations in 2021. The control showed a higher mean, maximum, and minimum temperature measurement. Cumulative mean temperature variation of 4.04^{0}C for maximum and 3.80^{0}C for minimum temperatures was observed between the control and agroforestry plantation plots for the year under study. This implied that agroforestry plantations ameliorated the atmospheric temperature significantly.

Table 2a. Influence of Agroforestry Plantations on Atmospheric Temperature (T^{0}C) at Forestry Research Institute of Nigeria (FRIN), Okwuta – Ibeku, 2021

MONTHS	*Control		Plot A		Plot B		Plot C		Plot Average		Temp Diff	
T^{0}C	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Min	Max
JAN	33	21	29	18	29	17	29	17	29.00	17.33	3.67	4.00
FEB	33	24	29	21	29	20	29	20	29.00	20.33	3.67	4.00
MAR	34	25	31	22	30	21	30	21	30.33	21.33	3.67	3.67
APRIL	33	24	30	21	29	20	29	20	29.33	20.33	3.67	3.67
MAY	32.7	22.8	28	18	28	18	28	18	28.00	18.00	4.80	4.70
JUNE	30	23	26	20	26	19	26	19	26.00	19.33	3.67	4.00
JULY	29	22	25	18	25	18	25	18	25.00	18.00	4.00	4.00
AUG	29	23	25	19	25	19	25	19	25.00	19.00	4.00	4.00
SEPT	30	22	26	18	26	18	26	18	26.00	18.00	4.00	4.00
OCT	30	21	26	19	26	19	26	19	26.00	19.00	2.00	4.00
NOV	31.4	23.5	27	19	27	19	27	19	27.00	19.00	4.50	4.40
DEC	33	21	29	17	29	17	29	17	29.00	17.00	4.00	4.00
											3.80	**4.04**

**Control- NRCRI Meteorological station, Umudike, 2021*

Influence of Agroforestry plantation on Atmospheric Temperature (T^0C) at Forestry Research Institute of Nigeria (FRIN), Okwuta – Ibeku in 2021

Table 2b shows the paired sample test for the influence of Agroforestry plantation on atmospheric temperature at Forestry Research Institute of Nigeria (FRIN), Okwuta – Ibeku, 2021. The results from the table revealed the following mean values: plot A maximum and control maximum, plot B maximum and control maximum, and plot C maximum and control maximum were -3.93, -4.09 and – 4.09 with standard deviations of 0.485, 0.223 and 0.223 respectively. The result also showed t- calculated values of: -28.06, -63.44 and -63.44. Which were all statistically significant as the sig (2-tailed P – value of 0.000 is less than 0.05). Equally, the mean values between plot A minimum and control minimum, plot B minimum and control minimum, and plot C minimum and control minimum were: -3.53, -3.94and -3.94 with standard deviation of 0.808, 0.664 and 0.664 respectively. The t - calculated values of: -15.11, -20.57 and -20.57 were highly statistically significant at 5% level of probability (P value of 0.000 is less than 0.05). This implied that the temperatures in the agroforestry plantations and control are different. With the temperature of the control plot being higher than the agroforestry plantation. This implied that the agroforestry plantations significantly modified the atmospheric temperature.

Table 2b. Paired Sample Test for Influence of Agroforestry Plantations on Atmospheric Temperature (T^0C) at Forestry Research Institute of Nigeria (FRIN), Okwuta – Ibeku, 2021

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	plotAmax2021 - umucontmax2021	-3.92500	.48453	.13987	-4.23286	-3.61714	-28.061	11	.000
Pair 2	plotBmax2021 - umucontmax2021	-4.09167	.22344	.06450	-4.23363	-3.94970	-63.436	11	.000
Pair 3	plotCmax2021 - umucontmax2021	-4.09167	.22344	.06450	-4.23363	-3.94970	-63.436	11	.000
Pair 4	plotAmin2021 - umucontmin2021	-3.52500	.80806	.23327	-4.03841	-3.01159	-15.112	11	.000
Pair 5	plotBmin2021 - umucontmin2021	-3.94167	.66395	.19167	-4.36352	-3.51981	-20.565	11	.000
Pair 6	plotCmin2021 - umucontmin2021	-3.94167	.66395	.19167	-4.36352	-3.51981	-20.565	11	.000

Influence of Agroforestry Plantation on Atmospheric Temperature (T^0C) at Ishiagu, 2020

Table 3a showed the variation in mean, maximum, and minimum atmospheric temperature measurements between the control (Met. station) and locations in the agroforestry plantations. The control showed a higher maximum and minimum atmospheric temperature measurement. Annual mean atmospheric temperature variation of 4.06^0C for maximum and 4.67^0C for minimum temperatures was observed between the control and agroforestry plantation plots for the season under study. This implied that agroforestry plantations ameliorated the atmospheric temperature significantly as compared to the control.

Table 3a. Influence of Agroforestry Plantation on Atmospheric Temperature (T^0C) at Ishiagu, 2020

T^0C	*Control		Plot A		Plot B		Plot C		Plot Average		Temp Diff	
Months	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**
JAN	35	20	31	17	32	17	31	18	31.33	17.33	3.67	2.67
FEB	33	21	30	18	30	18	30	18	30.00	18.00	3.00	3.00
MAR	34	23	31	19	30	18	30	18	30.33	18.33	3.67	4.67
APRIL	34	25	30	21	29	20	29	20	29.33	20.33	4.67	4.67
MAY	33	26	29	22	28	21	28	21	28.33	21.33	4.67	4.67
JUNE	31	27	29	23	28	22	28	22	28.33	22.33	2.67	4.67
JULY	31	28	28	23	26	22	26	22	26.67	22.33	4.33	5.67
AUG	31	28	28	23	26	22	26	22	26.67	22.33	4.33	5.67
SEPT	31	27	28	22	27	21	27	22	27.33	20.37	3.67	5.33
OCT	31	25	28	21	27	20	27	20	27.33	20.33	3.67	4.67
NOV	33	25	28	21	27	20	27	20	27.33	20.33	5.67	4.67
DEC	34	22	30	17	29	16	29	16	29.33	16.33	4.67	5.67
											4.06	**4.67**

**Control- Ishiagu Meteorological station, 2020*

Influence of Agroforestry Plantation on Atmospheric Temperature (T^0C) at Ishiagu, 2020

Table 3b shows the paired sample test for mean atmospheric temperature measurement in 2020 for Ishiagu agroforestry Plantations. The results from the table revealed the following mean values: plot A maximum and control maximum, plot B maximum and control maximum, and plot C maximum and control maximum were -3.417, -4.333 and – 4.417 with standard deviations of 0.793, 0.9847 and 0.9003 respectively. The result also showed t- calculated values of: -14.926, -15.244 and -16.993. Which were all statistically significant as the sig (2-tailed P – value of 0.000 is less than 0.05). Equally, the mean values between plot A minimum and control minimum, plot B minimum and control minimum, and plot C minimum and control minimum were: -4.167, -5.000and -4.833 with standard deviation of 0.7177, 1.044 and 1.1934 respectively. The t - calculated values of: -20.11, -16.583 and -14.030 were highly statistically significant at 5% level of probability (P value of 0.000 is less than 0.05). This implied that the temperatures in the agroforestry plantation and control are different. With the temperature of the control plot being higher than the agroforestry plantation. This implied that the agroforestry plantations modified the temperature considerably.

Table 3b Paired Sample test for Influence of Agroforestry Plantation on Atmospheric Temperature (T^0C) at Ishiagu, 2020

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**				
					Lower	Upper			
Pair 1	plotAmax2020 - Ishcontmax2020	-3.41667	.79296	.22891	-3.92049	-2.91284	-14.926	11	.000
Pair 2	plotBmax2020 - Ishcontmax2020	-4.33333	.98473	.28427	-4.95900	-3.70766	-15.244	11	.000
Pair 3	plotCmax2020 - Ishcontmax2020	-4.41667	.90034	.25990	-4.98871	-3.84462	-16.993	11	.000
Pair 4	plotAmin2020 – Ishcontmin2020	-4.16667	.71774	.20719	-4.62270	-3.71064	-20.110	11	.000
Pair 5	plotBmin2020 – Ishcontmin2020	-5.00000	1.04447	.30151	-5.66362	-4.33638	-16.583	11	.000
Pair 6	plotCmin2020 – Ishcontmin2020	-4.83333	1.19342	.34451	-5.59159	-4.07507	-14.030	11	.000

Influence of Agroforestry Plantations on Atmospheric Temperature (T^0C) at Ishiagu, 2021

Table 4a showed the variation in mean, maximum, and minimum atmospheric temperature measurements between the control (Met. station) and locations in the agroforestry plantations. The control showed a higher maximum and minimum temperature measurement. Cumulative temperature variation of 4.00^0C for maximum and 4.22^0C for minimum temperatures was observed between the control and agroforestry plantation plots for the season under study. This implied that agroforestry plantations ameliorated the temperature significantly.

Table 4a. Influence of Agroforestry Plantations on Temperature (T^0C) at Ishiagu, 2021

T^0C	*Control		Plot A		Plot B		Plot C		Plot Average		Temp Diff	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
JAN	33	21	29	17	28	16	28	16	28.33	16.33	4.67	4.67
FEB	33	21	29	17	28	16	28	16	28.33	16.33	4.67	4.67
MAR	35	22	31	18	30	17	30	17	30.33	17.33	4.67	4.67
APRIL	33	24	29	20	29	19	29	19	29.00	19.33	4.00	4.67
MAY	31	27	29	23	28	22	28	22	28.33	22.33	2.67	4.67
JUNE	30	27	26	23	25	22	25	22	25.33	22.33	4.67	4.67
JULY	29	28	25	24	25	24	25	23	25.00	23.67	4.00	4.33
AUG	29	28	25	25	25	24	25	24	25.00	24.33	4.00	3.67
SEPT	29	27	25	24	25	24	25	23	25.00	23.67	4.00	3.33
OCT	31	26	29	22	29	22	29	22	29.00	22.00	2.00	4.00
NOV	32	23	28	20	28	19	28	19	28.00	19.33	4.00	3.67
DEC	33	23	29	20	28	19	28	19	28.33	19.33	4.67	3.67
											4.00	**4.22**

**Control- Ishiagu Meteorological station, 2021*

Paired Sample Test for Agroforestry Plantations on Atmospheric Temperature (^0C) at Ishiagu, 2021

Table 4b shows the paired sample test for mean atmospheric temperature measurement in 2021 for Ishiagu agroforestry Plantations. The results from the table revealed the following mean values: plot A maximum and control maximum, plot B maximum and control maximum, and plot C maximum and control maximum were -3.67, -4.17 and – 4.17 with standard deviations of 0.779, 0.937 and 0.937respectively. The result also showed t- calculated values of: -16.32, -15.40 and -15.40. Which were all statistically significant as the sig (2-tailed P – value of 0.000 is less than 0.05). Equally, the mean values between plot A minimum and control minimum, plot B minimum and control minimum, and plot C minimum and control minimum were: -3.67, -4.17and -4.58 with standard deviation of 0.492, 0.669 and 0.515 respectively. The t - calculated values of: -25.80, -22.89 and -30.83 were highly statistically significant at 5% level of probability (P value of 0.000 is less than 0.05). This implied that the temperatures in the agroforestry plantation and control are different. With the temperature of the control plot being higher than the agroforestry plantation. This implied that the agroforestry plantations modified the temperature markedly.

Table 4b paired sample test for Agroforestry Plantation with Atmospheric Temperature (^{0}C) at Ishiagu in 2021

		Paired Differences					t	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	plotAmax2021 - Ishcontmax2021	-3.66667	.77850	.22473	-4.16130	-3.17203	-16.316	11	.000
Pair 2	plotBmax2021 - Ishcontmax2021	-4.16667	.93744	.27061	-4.76229	-3.57105	-15.397	11	.000
Pair 3	plotCmax2021 - Ishcontmax2021	-4.16667	.93744	.27061	-4.76229	-3.57105	-15.397	11	.000
Pair 4	plotAmin2021 – Ishcontmin2021	-3.66667	.49237	.14213	-3.97950	-3.35383	-25.797	11	.000
Pair 5	plotBmin2021 – Ishcontmin2021	-4.41667	.66856	.19300	-4.84145	-3.99189	-22.885	11	.000
Pair 6	plotCmin2021 - Ishcontmin2021	-4.58333	.51493	.14865	-4.91050	-4.25616	-30.834	11	.000

DISCUSSION

Findings from tables 1a to 4b indicated that the mean, maximum, and minimum atmospheric temperature (^{0}C) from the control were higher than the agroforestry plantations within the year (2020/2021) under study with an annual mean temperature variation of 4.67^{0}C for maximum and 4.09^{0}C for minimum (2020) and 4.04^{0}C for maximum and 3.80^{0}C for minimum (2021) between the control and agroforestry plantation plots at FRIN Agroforestry site. Equally, the annual mean temperature variation of 4.06^{0}C for maximum and 4.67^{0}C for minimum (2020) and 4.00^{0}C for maximum and 4.22^{0}C for minimum (2021) temperatures between the control and agroforestry plantation plots at FCA, Ishiagu. This showed that agroforestry plantations ameliorated temperature significantly within the range specified above. The paired sample test from tables 4.2ai, 4.2bi,4.2ci, and 4.2di indicated a negative mean and *T- computed* values; which are statistically significant at 5% level of probability (P value of 0.000 is less than 0.05).

The findings indicated that the variation in atmospheric temperature between the control and agroforestry sites in Umuahia and Ishiagu confirms the fact that trees can regulate local air temperatures through shading and accompanying evapo-transpiration. These results are in line with the findings of: Jim and Chen, (2008); Yang *et al*., (2005); Akbari *et al*., (2001); Beckett *et al*., (2000) and Nowak and Dwyer, (2000). Nowak and Dwyer (2000) further affirmed that shade from trees can decrease air temperatures by reducing solar heating of dark surfaces below the canopy. Some of the solar energy absorbed by trees results in water loss through leaf pores and subsequent evaporation to the atmosphere. This evapotranspiration has a cooling effect, which occurs not only directly below the canopy but also in the surrounding areas, as air movement rapidly disperses the cooled air. Akbari *et al*., (2001) recorded the temperature in urban areas to be 2.5°C warmer than in nearby rural areas on a sunny afternoon, partly because there is less vegetation in the cities of US. In another finding, Akbari *et al*., (1992) noted that the combined cooling effects of trees may be able to reduce air temperatures by as much as 5°C. The results from this study attest to that of Akbari *et al*., (1992) with about average of 4^{0}C reduction in atmospheric temperature between the two (2) agroforestry plantations experimental sites (FRIN- Umuahia and Ishiagu) and the control (Meteorological Stations).

Microclimatic variables, particularly solar radiation, air temperature at the ground surface (also referred to as surface temperature), and soil temperature, are highly sensitive to changes in the overstory canopy and exhibit relatively high spatial and temporal variability within a forest (Reifsnyder, Furnival, and Horowitz, 1971). The degree of spatial variability in the microclimate also differs greatly among forest ecosystems (Reifsnyder *et al*., 1971). Old-growth Douglas-fir forests in southern Washington and mature mixed oak forests in the Ozarks of Southeastern Missouri (Xu, Chen, and Brookshire, 1997), also exhibited spatial variation in climatic variables, including air and soil temperatures, shortwave radiation, wind speed, and soil water content. The diurnal patterns in these variables differed as functions of daily local weather conditions (e.g., hot versus cool or wet versus dry days).

In another study (Breman and Kessler, 1995), it was reported that trees reduce the amount of sunlight reaching soils and crops through shading. The extent of reduction varies according to crown dimensions, phenology, and leaf density. Available evidence on the reduction of solar irradiance by tree canopy has reported that solar irradiance was by 45-65 percent under *Acacia tortillis* and *Adansonia digitata* (Belsky, Amundson, Duxbury, Riha, Ali, and Mwonga, 1989). Only about 20 percent of total radiation reached the understory of *A. tortillis* and *Balanites aegyptiaca* at midday in Sahelian Savanna (Akpo and Grouzis, 1996).

Several studies (Tiedemann and Klemmedson, 1977; Bemhard Reversat, 1982, Mclintyre, Flower, and Riha, 1993) in savanna ecosystems also suggested that tree shade increases understory herbaceous productivity because of the reduction of temperature and evapotranspiration. Temperature reduction has been held responsible for the enhanced yield under *Faidherbia* crowns. There are some evidence that extreme heat negatively affects crop establishment and subsequent growth (Ong and Monteith, 1985; Peacock, Miller, Kaoru, and Robinson, 1990; Mclintyre *et al*., 1993). Using vertical artificial screens, Van den Beldt and Williams (1992) at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) showed that the effect of shade on soil temperature contributed to better millet growth during seedling establishment. They argue that root damage due to high temperature rather than water deficits caused differences in millet performance and that crops would not be able to take advantage of the greater soil fertility around *F. albida* trees without the moderated temperature associated with them.

CONCLUSION

Ecological services of selected agroforestry plantations in microclimate amelioration in Okwuta, Umuahia, and Ishiagu sites in Abia and Ebonyi States; Southeast Nigeria were studied to determine the variation in temperature in the agroforestry plantations. The findings of the study highlighted the potentiality of agroforestry plantations to ameliorate the high atmospheric temperatures of the surrounding environment.

Recommendations

From the findings of this study, the following are recommended:

i. That agroforestry plantation establishment should be encouraged to ensure the modification of environmental temperature.
ii. Agroforestry plantation establishments will serve as a carbon sink, thus mitigating the effect of global warming and the attendant climate change.

REFERENCES

Akbari, H., Davis, S., Huang, J., Dorsano, S. and Winnett, S. (1992). Cooling our communities: a guidebook on tree planting and light-colored surfacing. Lawrence *Berkeley National Laboratory Report*, No. LBL-31587(Eds). U. S. Environmental Protection Agency, Office of Policy Analysis, Climate Change Division, Washington DC. 217.

Akbari, H., Pomerantz, M. and Taha, H. (2001). Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. *Solar Energy*,70: 295–310.

Akpo, E. and Grouzis, M. (1996). Interactions arbre/herbe en zones arides et semi-arides d’Afrique: ‘etat des connaissance. In E.G. bonkoungou, E.T. Ayuk & I. Issaka, eds. Les parcs agroforestiers des zones semi-arides d’Afrique de I’Quest, p. 59-73. Actes du seminaire International, ICRAF/IRBET/CILSS/LTC, Ouagadougon,Burkina-Faso, 25-27 Oct. 1993.

Beckett, K.P., Freer-Smith, P.H. and Taylor, G. (1998). Urban woodlands: their role in reducing the effects of particulate pollution. *Environmental Pollution,* 99: 347–360.

Belsky, A.J; Amundson, R.G; Duxbury, J.M; Riha, S.J; Ali, A.R and Mwonga, S.M. (1989). The effects of trees on their physical, chemical, and biological environments in a semi-arid Savanna in Kenya, *Journal of Applied Ecology*, 26: 1005-1024.

Bernhard-Reversat, F. (1982). Biogeochemical cycles of nitrogen in a semi-arid Savanna. *OIKOS*, 38: 321-332.

Breman, H. and Kessler, J. J. (1995). *Woody plants in agro-ecosystems of Semi-arid regions, with an emphasis on the Sahelian Countries*. Brelin Springer Verlag. 340pp.

Federal College of Agriculture Meteorological Station (2002). Location and Co-ordinate of Federal College of Agriculture (FCA), Ishiagu; Ebonyi State, Nigeria. 3.

Jim, C. Y. and Chen, W. Y. (2008). Assessing the ecosystem service of air pollutant removal by urban trees in Guangzhou (China). *Journal of Environmental Management*, 88: 665–676.

Mc lintyre, B. D; Flower, D. J. and Riha, S. J. (1993). Temperature and soil water status effects on radiation use and growth of Pearl millet in a semi-arid environment. *Agricultural and Forest Meteorology*, 66: 211-227.

Nowak, D. J. and Dwyer, J. F. (2000). Understanding the benefits and costs of urban forest ecosystems. Pp. 25–46.In Kuser, J.E. (Ed.): *Handbook of urban and community forestry in the northeast*. Springer, New York, USA.

National Root Crops Research Institute {NRCRI) (1982). *National Root Crops Research Institute (NRCRI), Umudike Geographic Information manual*.

Ong, D. J. and Monteith, J. L. (1985). Response of Pearl millet to light and temperature. *Field Crops Research*, 11: 141-160.

Orlandini, S., and Lamberti, A. (2000). "Effect of wind on precipitation intercepted by steep mountain slopes." *Journal of Hydrology Engineering*, 5(4), 346–354.

Peacock, J. M, Miller, W.B,Kaoru, M. and Robinson, D. L. (1990). Role of heat girdling in early seedling death of sorghum. *Crops Science*, 30: 138-143.

Reifsnyder, W.E. Furnival, G.M. and Horowitz, J.L (1971). Spatial and temporal distribution of solar radiation beneath forest canopies. *Agricultural Meteorology*, Volume 9, 1971–1972, Pages 21-37.

Xu, M., Chen, J. and Brookshire, B. L. (1997). Temperature and its variability in the oak forests of southeast Missouri's Ozarks. *Climate Research*, 8: 209 – 223.

Vandenbeldt, J. and Williams, J. H. (1992). The effect of soil surface temperature on the growth of millet in relation to the effect of *Faidherbia albida* trees. *Agricultural and Forest Meteorology***,** Volume 60, Issues 1–2, 15 August 1992, Pages 93-100.

Yang, J., McBride, J., Zhou, J. and Sun, Z. (2005). The urban forest in Beijing and its role in air pollution reduction. *Urban Forestry and Urban Greening*,3: 65–78.