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Full Length Review Article

CLIMATE ANALYSIS FOR GREENHOUSE DEVELOPMENT IN IBADAN, NIGERIA

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ABSTRACT

The impact of climate change on global agricultural production requires no emphasis. Nigeria, in recent times have had her own share of climate change impacts of which her agricultural sector is majorly affected. The location of the country along low-lying coastal lines makes it vulnerable to climate change. This is further worsening her state food insecurity. In lieu of this, greenhouse farming was contemplated among other possible alternatives to farming in a changing climate. However, construction materials that will generate the desired greenhouse conditions at minimum cost is of great importance. In order to efficiently maximize the use of greenhouses, this study was conducted to analyse climatic factors influencing greenhouses in Ibadan, Nigeria and to recommend suitable glazing materials. Data on climatic parameters were obtained from three relevant sources (International Institute of Tropical Agriculture, Ibadan; Nigeria Meteorological Agency, Ibadan and Department of Geography, University of Ibadan, Nigeria). The data covered a span of 32 years. These data were subjected to inferential statistical techniques to ascertain the level of deviation that has taken place. A model greenhouse was used in the study. The highest value of temperature and solar radiation recorded in the 32 year period was also used in the thermal equations. The results showed that temperature has been consistent in Ibadan and the most suitable glazing material for Ibadan is high-density corrugated polyethylene.

KEY WORDS: Climate analysis, Greenhouse, Temperature, Humidity, Glazing materials.

INTRODUCTION

Climate Change and Its Impact

The earth's climate is changing with increasing frequency. This is attributable directly or indirectly to human activities that alter the atmospheric composition of the earth leading to global warming. Global warming has the potential of affecting human development and survival, socially, politically, and economically. Climate change is one of the most critical challenges ever to face humanity. It determines the health of global resources and can cause the worst of economic problems (Kuta, 2011). It is projected that crop yield in Africa may fall by 10 to 20 per cent by 2050 or even up to 50 per cent due to climate change (Jones and Thornton, 2002). The negative impact of climate change in Nigeria's agricultural sector requires no emphasis as the yield from agricultural land has dwindled. For the past one century, Nigeria has been experiencing persistent increase in temperature and it will be most affected by the negative impacts of climate change because of its low-lying coastal lines (Bello *et al.*, 2011). The Nigeria Meteorological Agency (NIMET, 2010) stated that Nigeria's weather is gradually changing for the worst due to climate change caused by greenhouse gases. Nigerian agriculture is being impacted by climate change. NBS (2007), reported that this is a serious development since this sector contributes up to 41.73 per cent of the countries Gross Domestic Product (GDP), employing about 70 per cent of the country's total labour force and the main source of food and raw material for individuals and industries and also another means of earning foreign exchange (Kuta, 2011).

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Mitigating Climate Change

There are several means of combating the threat of climate change in the agricultural sector especially on crop propagation. Some of them includes planting of resistant varieties, controlled environment agriculture (greenhouses), mixed cropping, organic farming, zero tillage, drainage, irrigation and a combination of many of these practices. The most efficient means however, is greenhouse production which provides a microclimate for optimum crop productivity.

MATERIALS AND METHODS

Study Area

Ibadan (coordinates: 7°23′47″N 3°55′0″E) is the capital city of Oyo State. It is located on seven hills with an average elevation of 200m and 160km from the Atlantic coast (Wikipedia, 2012). It is the third largest metropolitan area in Nigeria, after Lagos and Kano, with a population of 1,338,659 according to the 2006 census. At Nigeria's independence, Ibadan was the largest and most populous city in the country and the third in Africa after Cairo and Johannesburg.

Data Collection

Data on climatic parameters influencing greenhouse development and operation were collected for a period of thirty-two years (1980-2011) from three different reliable sources. These included the International Institute of Tropical Agriculture (IITA), Ibadan campus, Geography Department, University of Ibadan and NIMET, Ibadan.

Thermal Balance

The greenhouse inside temperature was taken to be 28°C. The highest permissible temperature for the selected crops shown on Table 3. The highest daily value of temperature, and solar radiation experienced during the period (40°C, and 31.7MJ/m^2/day respectively) were used in the computations. A standard single standing gable roofed greenhouse model which is 9m wide, 40m long, with 2m side wall height and roof slope of 26° adopted by Jones (2001) and Kendirli *et al*. (2007) was also being used.

Table 1. U-values and Transmittance of Greenhouse Glazing Materials

Material	U (W/m^2°C)	Transmittance (%)
Glass		
Single layer	6.26	85-90
Double layer	3.42-2.85	70-75
Acrylic		
Double layer	2.85	87
Polycarbonate		
Double layer	2.85	83
Fibreglass	6.83	80-90
Polyethylene film		
Single layer	6.55	80-90
Double layer	3.42	60-85
Plastic film		
Single layer	6.83	65-80
Double layer	3.98	
Double layer over glass	2.85	
High-density corrugated		
Polyethylene	1.88-2.28	70-75

Source: Ryan, 2011.

Table 2. Air Exchange for Some Glazing Materials

Construction system	Air exchange per hour
New glass or fibre glass	0.75-1.50
New double layer polyethylene film	0.5-1.0

Source: Jones, 2008.

Table 3. Common Vegetables and Their Environmental Requirements

Vegetables	Optimum Mean Monthly Temp.(°C)	Minimum Mean Monthly Temp.(°C)	Maximum Mean Monthly Temp.(°C)	Relative Humidity (%)
Garlic, Onion	12-24	7	29	60-70
Cabbage	15-18	5	24	85-95
Carrot, Lettuce, Potato	15-28	7	24	60-80
Cucumber	18-24	15	32	60-75
Tomato	21-24	18	27	60-80
Green bean	21-29	18	32	60-80

Source: www.kzndae.gov.za, 2012.

The intermediate values of the glazing material properties that is, their transmittance, overall heat transfer coefficients, and rate of air exchanges were used in the equations. This was because these properties vary significantly within the same material and between authors. Also, transmittance among other parameters vary significantly with the angle of incidence of solar radiation. Heat exchange between the greenhouse interior and exterior is the sum of heat available from all sources and the rate of heat loss from the greenhouse:

$h_s = TI_S A_f$ (Aldrich and Bartok, 1994) --- (1)

Where

$h_s =$ solar gain, W
$T =$ transmittance of greenhouse glazings to solar radiation
$I_S =$ intensity of solar radiation on a horizontal surface outside, W/m^2
$A_f =$ area of greenhouse floor, m^2

The greenhouse glazing is the medium through which heat is lost by conduction. Heat loss due to air exchange is lost through the greenhouse openings.

$h_c = AU(t_i - t_o)$ (Aldrich and Bartok, 1994) ---------- (2)

where

$h_c =$ conduction heat, W
$A =$ area of greenhouse, m^2
$U =$ overall heat transmission coefficient, W/m^2-K
$t_i =$ inside temperature, °C
$t_o =$ outside temperature, °C

U-value (or U-factor) is a measure of the rate of heat loss or gain through a construction material. Table 1 shows U-values for some glazing material. The lower the U-factor, the greater the material's resistance to heat flow and the better the insulating value.

During air exchange, heat is transferred in both sensible and latent forms. The sensible heat is transferred by increasing the temperature of the incoming air. The latent heat is removed as water vapour through evapotranspiration. Table 2 shows air exchange rate for some glazing materials.

$h_{sa} = 0.3V_g C(t_i - t_o)$ (Jones, 2001) ---- (3)

Where

$h_{sa} =$ air exchange heat, W
$C =$ number of air exchange, /hr
$V_g =$ volume of the greenhouse, m^3

For the purpose of energy estimation, some selected crops with overlapping environmental requirements were selected. These crops shown on Table 3 were also selected based on their similar cultivation requirements, biological companionship, quick maturation, and high marketability.

RESULTS AND DISCUSSION

Analysis of Climatic Parameters

The climatic parameters were subjected to the inferential statistical techniques. It was quite apparent that the discrepancies between the sources are negligible especially when the maximum temperatures were compared. From Table 4, the minimum and maximum values of each parameters are independent of each other. Temperature showed minimal deviation from the mean value. This means that Ibadan's temperature has been somewhat consistent for the past three decades (1980-2011). The highest temperature (40°C) was recorded on February 23, 2005.

Table 4. Mean Deviation of Climatic parameters

Year	Wind speed (km)	Solar radiation ($MJ/m^2/day$)	Min. temperature (°C)	Max. Temperature (°C)	Min. Relative humidity (%)	Max. Relative humidity (%)	Sunshine(hr)
1980	0.8	2.0	0.7	0.9	3	1.4	0.3
1981	0.5	2.1	0.6	0.4	0.7	0.5	0.1
1982	0.2	2.1	0.2	0.4	1.2	1.7	0.4
1983	1.1	1.8	0.3	0.0	1.8	1.3	0.2
1984	0.6	2.4	0.0	0.2	0.3	1.1	0.2
1985	0.5	1.3	0.1	0.6	1.4	0.5	0.0
1986	0.6	1.4	0.0	1.0	1.7	1.4	0.1
1987	0.4	2.0	0.9	0.4	1.4	0.5	0.3
1988	0.2	0.1	0.5	0.8	3.1	0.0	0.2
1989	0.4	2.9	0.2	0.5	3.0	0.5	0.0
1990	0.3	2.0	0.2	0.2	1.6	1.4	0.1
1991	0.6	0.8	0.2	0.0	2.2	1.0	0.6
1992	0.5	0.8	0.7	0.3	1.8	1.7	0.0
1993	0.0	1.3	0.6	0.2	3.1	1.9	0.2
1994	0.1	0.1	0.9	0.2	0.5	5.1	0.1
1995	0.1	0.2	0.8	0.4	3.6	0.2	0.3
1996	0.9	0.6	0.4	0.2	1.0	2.5	0.1
1997	0.5	0.9	0.0	0.1	1.6	2.4	0.4
1998	0.1	0.3	1.1	0.9	0.0	2.2	0.4
1999	0.5	0.7	0.4	0.2	4.0	3.7	0.1
2000	0.6	0.6	0.2	0.5	1.6	2.9	0.4
2001	1.8	0.8	0.1	0.5	2.6	3.5	0.2
2002	2.1	1.0	0.4	0.1	1.7	1.4	0.3
2003	2.0	1.0	0.1	0.0	5.2	1.2	0.6
2004	1.6	0.9	0.1	0.3	5.1	1.9	0.0
2005	0.9	1.0	0.0	0.3	1.0	0.9	0.4
2006	0.1	1.9	1.1	0.2	2.5	2.1	1.5
2007	0.3	1.0	0.4	0.2	0.9	4.0	0.3
2008	0.2	0.5	0.5	0.1	0.9	4.0	0.3
2009	0.2	0.7	0.0	0.4	2.8	4.9	0.1
2010	0.1	3.1	0.5	0.5	3.5	3.1	0.3
2011	0.1	1.4	0.1	0.1	3.4	0.0	0.2

Table 5. Thermal Load For Different Glazing Materials

Glazing Material Type	Conduction Load (W)	Infiltration Load (W)	Solar Gain (W)	Total (W)	Rank
High-density corrugated polyethylene	13879	2338	92454	108675	1
Double layer polyethylene film	25235	1949	85854	113038	2
Double layer plastic film	29441	3897	85854	119192	3
Double layer glass	25235	2923	92458	120616	4
Double layer polycarbonate	21029	2338	109629	132996	5
Double layer acrylic	2029	2338	114912	138279	6
Single layer polyethylene film	48366	2338	105667	156371	7
Single layer glass	46263	2923	112271	161457	8
Single layer plastic film	50469	3897	112270	166636	9
Single layer fibreglass	50469	2923	116233	169625	10

Wind speed has been consistent except for the records between 2001 and 2005 which showed a high degree of deviation from the mean value. These years showed a reduction in wind speed followed by seemingly consistent years (2006-2011) of wind speed. The highest recorded wind speed within the last three decades was 11.9km/hr on January 4, 2002 when the north trade wind was prominent. Solar radiation showed a high degree of deviation, second only to relative humidity. The trend was such that for the past three decades, solar radiation is on the decrease. Decreasing gradually until a high average value in 1989 to the lowest value in 2010. These two years show a sharp deviation from the mean value of the three decades interval. Sunlight hours showed little or no significant deviation from the mean value. It has been relatively consistent for the past three decades. This might need substantiation if crops are to have ample day length in greenhouses. The highest value of 11.8 hours was recorded on October 8, 1999. Relative humidity showed the highest level of inconsistency as most of the yearly averages deviate substantially from the mean value. Rarely is a single year the same with another. With respect to the data obtained, relative humidity showed the greatest indices of climate change in Ibadan and a determinant factor in open field agriculture. The highest value of 98% was recorded on June 11, 2005. The order of deviation was relative humidity, solar radiation, temperature, wind speed, and sunshine hours the least deviated.

Thermal Balance Generated By Glazing Materials

Table 5 was generated using equations 1-3. It shows the thermal balances obtainable from the glazing materials in Ibadan. This table shows the opposite of what is obtainable in temperate regions where greenhouses are often used. Heat is being conducted into the greenhouse via the glazing materials. This is due to the fact that the greenhouse has to be maintained at a lower temperature relative to the outside and since equilibrium has to be achieved, heat will be conducted into the greenhouse. The conducted heat is further increased by solar gain (heat generated within the greenhouse by virtue of the solar radiation entering the greenhouse). Solar gain which is usually unavoidable is used in temperate region to furnish the greenhouse with heat or substantiate furnace heat, but in Ibadan, both the conduction heat and solar gain must be removed to maintain the greenhouse at the permissible temperature for the crops under propagation. Table 5 further showed that of the three heat sources, the greatest heat source is solar gain followed by conduction heat and infiltration heat being the least.

Also, the heat load within the greenhouse is dependent on the properties (especially U-values) of individual materials making up the greenhouse. No single glazing material attained the lowest or highest value in the respective heat load sources. High-density corrugated polyethylene showed the least conduction heat (13879W) while single layer plastic film and single layer fibreglass are on per (50469W) as the highest value of conduction heat. On the other hand, double layer polyethylene film showed the least infiltration load (1949W) while single and double layer plastic film showed the highest infiltration load of 3897W. Single layer fibreglass showed the highest value (116233W) for solar gain followed by double layer acrylic (114912W) while double layer polyethylene film and double layer plastic film are on per (85854W) as the least on solar gain.

Furthermore, layering of glazing materials reduces conductance of heat but transmittance is reduced thereby reducing the solar gain. This implies that the PAR needed for the plant metabolic activities will also be reduced and has to be substantiated. Finally, since heat removal in greenhouses could be quite costly, Table 5 showed that the best glazing material for greenhouses in Ibadan region is high-density corrugated polyethylene film as it generated the least heat load needed to be removed and therefore ranks number one followed by double layer polyethylene film. The least desirable glazing material for greenhouses in Ibadan is fibreglass as it generated the greatest quantity of heat load requiring removal.

Conclusions

Relative humidity and solar radiation comparatively showed significant deviation from mean values. Temperature and sunshine hours remain relatively consistent over the three decades. There will be little or no heating requirements or internal blankets for greenhouses in Ibadan, but lighting will be required to extend day length. The most suitable glazing material for greenhouses in Ibadan is high-density corrugated polyethylene followed by double layer polyethylene film.

REFERENCES

Aldrich, R. A. and Bartok J. W. 1994. Greenhouse Engineering, Third edition. Northeastern Regional Agricultural Engineering Service, Ithaca, NY

Bello, O. B.; Ganiyu, O. T.; Wahab, M. K.; Afolabi, M.S.; Oluleye, F.; Ig, S. A.; Mahmud, J.; Azeez, M. A.; and Abdulmaliq, S. Y. 2012. Evidence of Climate Change Impacts on Agriculture and Food Security in Nigeria. International Journal of Agriculture and Forestry. Vol. 2. Pgs 49-55. Vol. 87. Pgs 39-49.

Greenhouse Vegetables. Accessed on September 2, 2012 through www.kzndae.gov.za/.

Ibadan. Accessed on September 2, 2012 from http://en.wikipedia.org/wiki/ibadan

Jones, P. G. and Thornton, P. K. 2002. Croppers To Livestock Keepers: Livelihood Transition To 2010 in Africa Due To Climate Change. World Health Organisation, Geneva, Switzerland, pp 489-493.

Jones, P. H. 2001. Greenhouse Environmental Design Consideration-Florida Greenhouse Vegetable Production Handbook. North Florida research and Educational Centre-Suwannee Valley, Vol.2 pp 1-4.

Kendirli, B; Cakmak, B; and Gokalp, Z. 2007. Analysis of Climatic Factors for The Development of Greenhouses in Eastern Blacksea Region. Building and Environment. Vol.42, pp4072-4078.

Kuta, D. A. 2011. Nigeria: Climate Change and Agriculture in The Country. Accessed through www.allafrica.com.

National Bureau of Statistics, 2007

Nigeria Meteorological Agency, 2010.

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