RELATION BETWEEN GLOBAL RADIATION AND FOOD PRODUCTION IN A HUMID TROPICAL CLIMATE OF WEST AFRICA

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ABSTRACT

Obvious is the fact that globally the climate is changing. Solar energy and water availability are the key factors affecting agricultural productivity in Subtropical Africa. In this paper is presented the global radiation for Owerri, Nigeria (latitude 5.48^{o}N, longitude 7.03^{o}E) between 1985-1997 which has a mean annual value of 76.17 W/m^2 per day. With appropriate crop specie selection and management, food production, including poultry output can be boosted in this high solar radiation area. The introduction of solar egg incubator, solar manure dryer and brooder has been strongly advocated.

KEY WORDS: global radiation, food production, crops, West Africa

INTRODUCTION

The production of crops depends primarily on the proper balance of light, water, carbon dioxide and minerals, which through the photosynthetic process, results in the production of plant dry matter and oxygen. In Nigeria that is well endowed with solar energy throughout the year, the main limiting factors affecting crop production are water and minerals. If the supply of water and minerals is near optimum, then the efficiency of conversion of the sun's electromagnetic energy into chemical energy of plant dry matter will depend mainly on the effective interception of light by the crop among other factors [4]. Climate variability and change, drought and other climate-related natural disasters can have a direct, often adverse, influence on the quantity and quality of agricultural production, especially in developing countries.

The implication is that the basic requirements needed for efficient development of natural resources (solar radiation, water and soil) in West Africa, with the viewpoint of raising agricultural production will lie in the exploitation and efficient utilization of the following:

a) utilization of available water through a rational approach like matching water requirements to crop water supply,

b) exploitation of the high radiation input by introducing crops or agronomic practices designed to promote high efficiency of energy conversion,

c) matching nutrient supply of crops to high level of sustained production.

If water and plant nutrients are adequate and not a limiting factor in food production, then the key issue will be selection of crop varieties that are responsive and efficient in utilizing the abundant solar radiation. Another factor that may be of interest is the rate of light interception and carbon dioxide assimilation by the crop surface.

In poultry production, farmers conventionally employ the use of electric and kerosene powered systems. The inherent problems associated with these are many. For example, electricity is not available in most parts of sub Saharan Africa, especially the rural areas, where the farms are located, discouraging the establishment of medium to large-scale poultry production systems [7]. With frequent power outages, the production system becomes inactive, unproductive and non-sustainable. The kerosene systems are known to be associated with environmental pollution and fire outbreaks in the farms. In addition, they contribute to accelerate the global climate change with the attendant negative consequences on sustainable food production. This paper describes the global radiation for Owerri (latitude 5.48°N, longitude 7.03°E) in a humid climatic zone of West Africa. The application of this in poultry production has been highlighted.

SOLAR RADIATION AND SUNSHINE DURATION

The effect of cloud cover on microclimate and on the rate and efficiency of radiation assimilation is pronounced. Secondly, clouds, affecting the rate and efficiency of photosynthesis [4] also alter the intensity of radiation. On the other hand, diffuse radiation from clouds or an overcast sky, characterized by a low radiation intensity flux, results in low rates of photosynthesis and high efficiency of assimilation. Under these conditions, extinction of light in a dense canopy, designed for optimum interception of high light intensities, might be excessive, resulting in low yields. Conversely, direct radiation and radiation reflected from clouds is characterized by a high intensity flux, resulting in high rates of photosynthesis. When this obtains, the assimilation under these conditions depends on the efficient interception of light by the crop canopy.

Again, the energy exchange balance is influenced by the degree of cloud, affecting the rates of evaporation and variation in day and night temperatures [4]. The rate of photosynthesis is closely related to the intensity of radiation, therefore, one of the basic requirements for assessing potential photosynthesis is knowledge of the distribution and duration of light intensity especially during the growing season [5]. The growing season in the humid tropical climate of West Africa is between April – October. During the dry season period of October to March, the knowledge of the intensity and duration of the solar radiation and sunshine is important in planning the design of solar energy technology like those for poultry production and crop drying. On clear days and on completely overcast days, the intensity of solar radiation is sinusoidally distributed between sunrise and sunset [5].

GLOBAL RADIATION AT OWERRI

The results of the solar radiation regime in Owerri obtained by analyzing the data collected for 1987-1997 in this humid tropical climate of West Africa is presented in this section. As the solar radiation passes through the atmosphere, reflection, scattering and absorption lose some amount. The agents are clouds, aerosols and dust. The actual amount that finally reaches the earth at vegetation height (global radiation, Rg) will depend on the degree of cloud cover and altitude. Its magnitude, duration and intensity largely determine the potential productivity of crops. Based on data collected from the Department of Meteorological Services Owerri between 1987-1997, the mean annual value for the global radiation in Owerri is 76.17 W/m^2 per day, which is impressive, both for crop and poultry production. The full results of the global radiation for Owerri are listed in [2].

In Table 1 is shown the monthly mean global radiation levels at Owerri showing in KW m^{-2} (unit used for convenience) between 1985-1997. In 1985, the maximum value of 327.8 KWm^{-2} was recorded in February while the minimum value of 236 KWm^{-2} was recorded at the peak of the wet season month of July (Table 1). A maximum value of 308.5 KWm^{-2} was recorded in the month of April in 1986 with the month of July again recording the least amount of global radiation at this site. The results in Table 1 underscores the fact that in majority of the years used for the study (1985-1997), the global radiation was least in the month of July, except for the year 1997. In this case, the month of August had a global radiation of 240.7 KWm^{-2} which was higher than the July amount that was 247.3 KWm^{-2}. The peak amount of global radiation is recorded during the dry season months of November to March. One point that must be emphasised is the fact that there is minimal variation in the global radiation during the year in comparison to other factors that affect food production like water availability and nutrients. In food and poultry production for example, farmers need to come to terms with the fact that solar energy is abundant, environmentally-friendly, free and can be properly harnessed to boost production in a sustainable manner.

At the study site, the number of observations was 156 (13 years x 12 months). The global radiation for Owerri between 1985 - 1997 was achieved by plotting global radiation (W m^{-2}) against the months of the year. From Fig. 1, the mean solar power for the whole period (1985-1997) was observed to fluctuate with maximum and minimum in February and July respectively. The implication is that maximum output from solar energy devices for poultry production in Owerri should be in February. Efforts at storing enough energy during the trough months of July need to be considered in developing appropriate technology. The mean sunshine hour (1985-1997) also fluctuates with its maximum observed value in November and minimum in August. This implies that solar energy harnessing devices stationed at Owerri will perform maximally during the months of December to February and minimally during the months of April – September that coincides with the wet season. We have listed in Figure 2, the patterns of monthly mean Global radiation (Rg), Sunshine hours and Evaporation (mm) for 1985-1997 at Owerri, Nigeria have been presented. The evaporation amount has a similarity of the signatures of sunshine hours (Fig. 2). One high point of this is that poultry farmers need to be informed about the expected patterns of the sunshine duration and evaporation while planning for their brooder houses or while planning on

Table 1: Long-Term Global Solar Radiation (KW/m^2) at Owerri computed from Temperature

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1985	270.9	327.8	320.6	295.2	288.2	268.2	236.0	265.5	270.2	276.4	262.3	293.1	281.2
1986	282.8	304.6	307.9	308.5	278.2	261.4	232.1	252.5	266.6	266.1	267.0	298.5	277.2
1987	307.9	307.6	309.5	306.9	294.7	266.5	256.4	265.5	275.7	260.8	274.8	294.5	285.1
1988	284.3	303.1	287.8	303.6	278.2	261.4	245.5	250.5	257.1	264.4	274.8	266.4	273.1
1989	342.2	338.9	323.7	301.9	274.8	261.4	234.0	242.7	262.8	273.0	270.2	283.6	284.1
1990	264.7	315.0	335.8	306.9	274.8	252.7	220.0	232.5	268.4	271.3	255.8	252.7	270.9
1991	291.4	297.0	303.0	298.6	269.6	256.2	239.8	252.5	257.1	262.6	259.1	285.0	272.6
1992	310.6	332.0	304.6	288.4	279.9	247.3	237.9	242.7	270.2	267.9	282.3	293.1	279.7
1993	303.9	322.2	314.3	303.6	284.9	257.9	241.7	244.7	266.6	286.4	267.0	286.3	281.6
1994	294.2	320.8	323.7	318.1	299.5	269.9	234.0	267.3	259.1	279.8	283.8	340.4	290.9
1995	334.9	340.2	323.7	313.3	297.9	273.2	224.1	258.1	275.7	278.1	295.4	285.0	291.6
1996	288.6	300.0	299.7	300.3	291.5	249.1	289.8	203.8	191.1	197.8	187.7	168.5	247.3
1997	292.8	352.1	319.0	295.2	288.2	254.4	247.3	240.7	272.1	283.1	274.8	275.1	282.9
MEAN	297.6	320.1	313.3	303.1	284.7	260.0	241.4	247.6	261.0	266.7	265.8	278.6	278.3

how to use solar energy.

SOLAR ENERGY APPLICATION IN POULTRY PRODUCTION

Research results over the years at the National Centre for Energy Research and Development (NCERD), University of Nigeria Nsukka, have shown that solar energy appears the most attractive option in poultry production applications in Nigeria today. Such projects as solar egg incubator, solar energy brooder and solar manure dryer could form an integrated poultry production system, depending solely on the abundant energy from the sun that is freely available in our environment [7]. This will help in sustainable poultry production, especially in the face of rising production costs arising from increased tariffs on energy.

As an example, the Imo State University farm can cut down production costs by relying on solar energy for poultry production. Other areas where the abundant solar energy that is available in Owerri will find viable and sustainable applications will be in crop drying, water heating and cooking of food in the farms. This will help to protect the environment, save our forests, poverty alleviation while generating employment. [7] reported that chicks brooded at NCERD using solar energy were discovered to have better body weight and weight gain than those brooded using electric and kerosene systems. In addition, while solar-brooded systems recorded average mortality rate of 3%, kerosene system had average mortality rate of 7% while those brooded using electricity systems gave 10% mortality. The obvious advantage of using solar energy in raising poultry production is very obvious in this case.

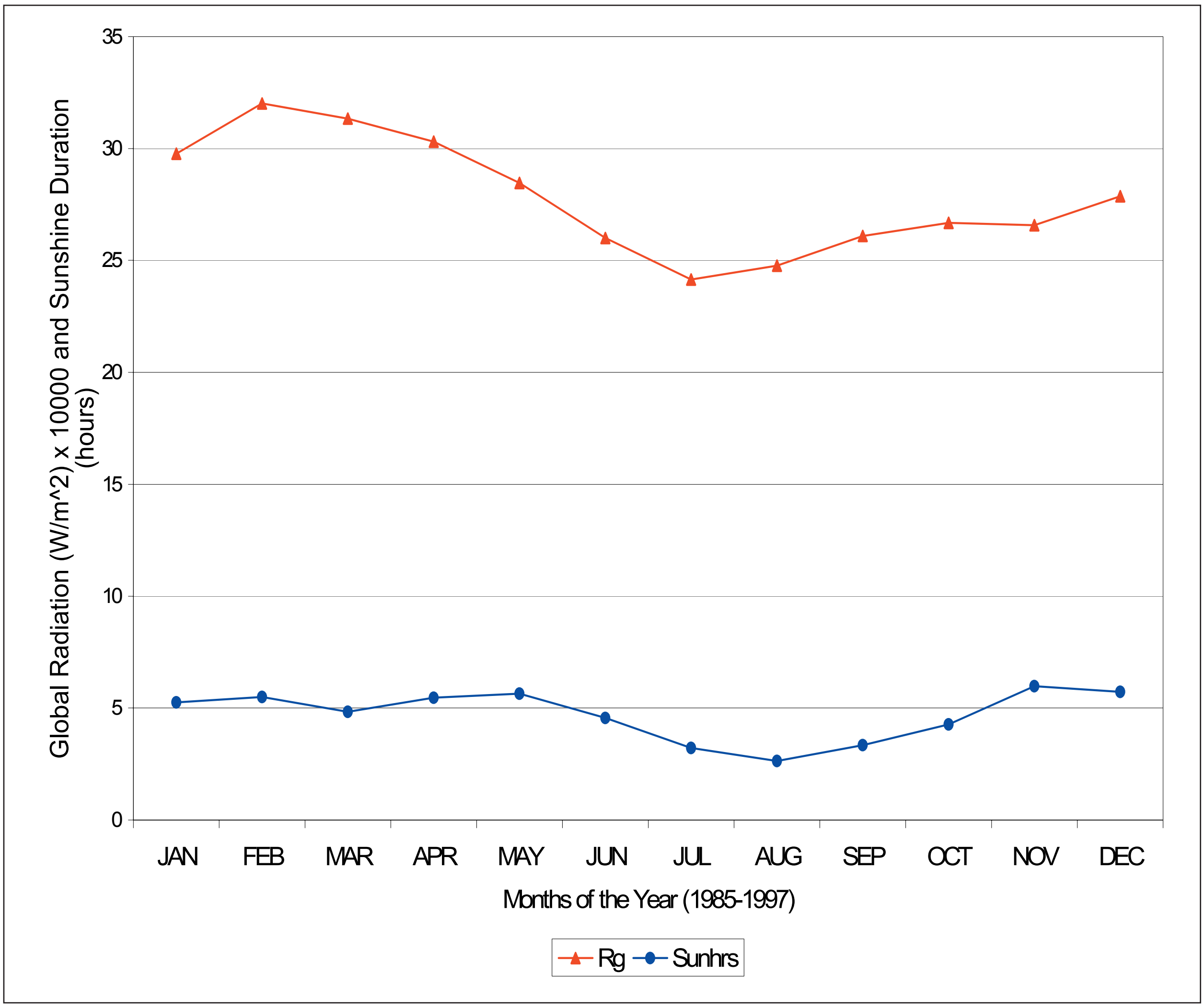

Fig 1: Long-term mean Global radiation (Rg) and Sunshine hours for 1985-1997 at the Study site

COST IMPLICATIONS OF USING SOLAR ENERGY IN POULTRY PRODUCTION

Table 2 gives a cost implication of brooding with kerosene, electricity and solar energy [7]. The Table shows a cost advantage of about 100% in realizable meat by using solar brooding over the conventional systems of kerosene and electricity, used by poultry farmers in most parts of the humid tropical climate of West Africa. It is important to note that the weight gain using solar brooding does not translate to more feed consumption as less feed is consumed by solar brooded birds than in the conventional brooding systems. As a result, there is some significant monetary saving associated with feed conservation while using solar brooders compared to the other two brooding systems, although very small on the short run. Finally, energy saving beyond 10 orders of magnitudes is accomplished with solar-based brooding systems.

CONCLUSIONS

This study and related ones, which seek to highlight the important links between solar radiation and food production, are particularly useful for predicting possible food production trends under various climate change scenarios. This is because such scenarios include significantly changes in available solar radiation such as from changing aerosol loading or solar activity [8]. On the basis of this study therefore, scenarios that favor increased solar radiation available directly to crops in the tropics and indirectly utilized by solar based brooding and agricultural processing systems obviously improves food production in the tropics. This may however affect local temperature variability, precipitation, sea level

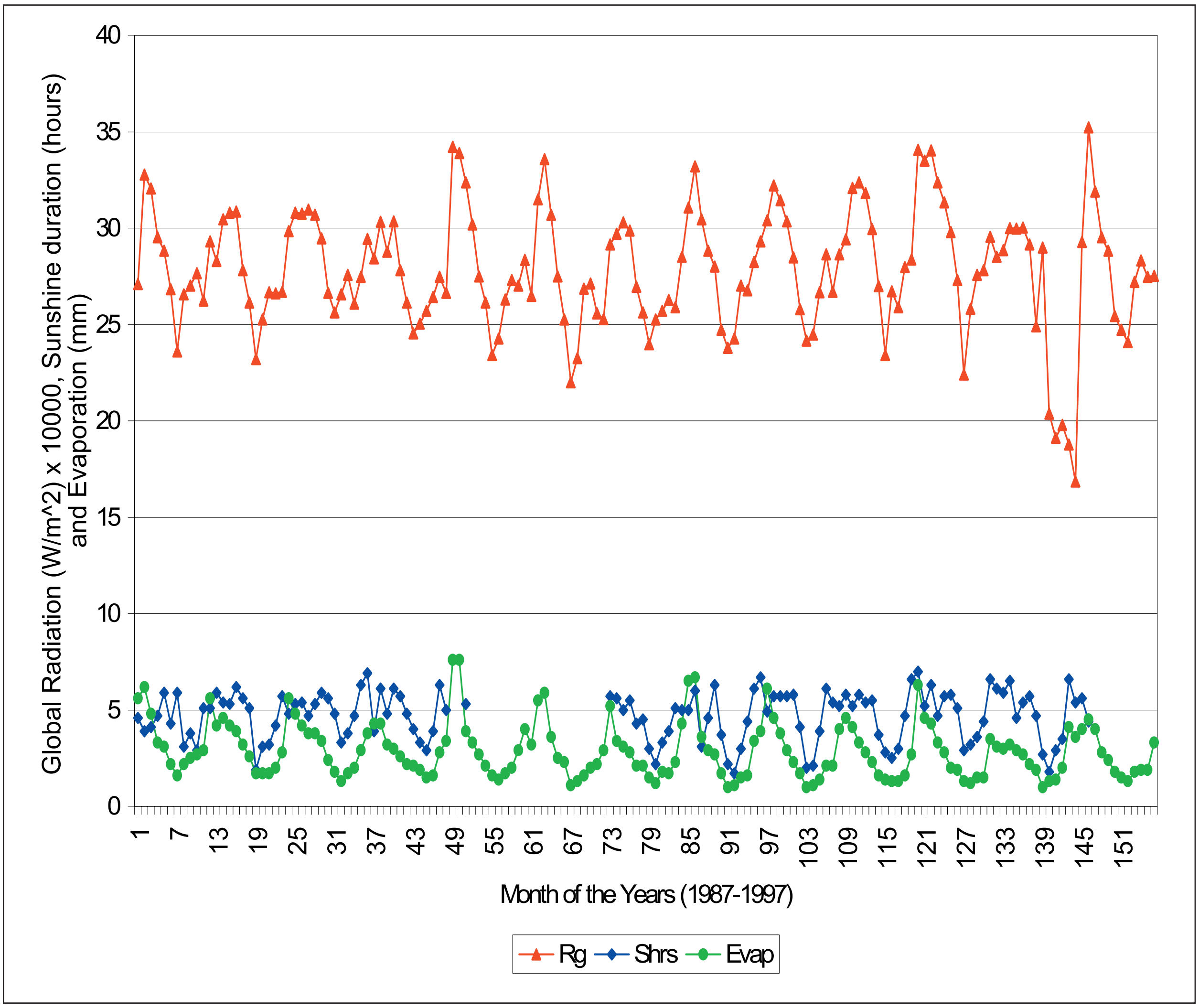

Fig 2: Patterns of monthly mean Global radiation (Rg), Sunshine hours and Evaporation (mm) for 1985-1997 97 at Owerri, Nigeria

Table 2: Cost implication of chicken brooding by kerosene, electricity and solar energy (adapted from Okonkwo, 2001) –figures represent average values

	Brooding System		
	Kerosene	electricity	solar
Weight gain of chicken over a 28day period (kg)	0.402	0.350	0.513
Weight gain of chicken per day (kg/day)	0.014	0.0125	0.018
Monetary equivalent ($USD/day) at 1kg =$10	0.14	0.125	0.18
Feed conversion to body weight by chicken (kg/day)	0.00273	0.00298	00212
Monetary equivalent($USDday) at 1bag (50kg=$10)	0.000546	0.000596	0.000424
Mean energy consumption(MJ/bird)	-	7.138	2.840
Monetary equivalent($USD/bird) at 10^3 MJ =$1.48*	-	0.0105	0.0042

*We have used the cost equivalent of 1 litter of petrol~370MJ

change and inception and evolution of extreme events like hurricanes, drought, flooding that have grave consequences in agriculture.

There are several results of practical importance to be derived from this study. First, environmental differences during various stages of crop growth can be identified as limiting crop production. This may suggest improvements either by changes in crop husbandry or by selection of crop varieties that will more efficiently intercept the abundant solar radiation. Secondly, the assessment of potential crop production for various periods of the year will provide a measure on which to justify introducing irrigation.

In addition, changes in the annual pattern of solar radiation, although small, are equal in importance with rainfall as an environmental parameter determining the potential productivity of crops. Another factor to be considered is introduction of crops and crop management practices that will take into account, the "quasi-static" growing season in the humid tropical climate of West Africa, which can be attributed to climate change. It has also been argued that production costs can be lowered, and output increased, by relying on solar energy for crop drying, manure drying and in poultry production systems. The success case at the National Centre for Energy Research and Development (NCERD) of the University of Nigeria, Nsukka has been trumpeted. The viewpoint is to encourage farmers in Owerri to not only understand the local patterns of global radiation, but also to show them that solar energy can be used to improve food production in a sustainable and cheaper manner.

During the past two or three decades, natural disasters have resulted in increasingly serious economic and agricultural loss. Examples of such disasters include severe drought in sub-Saharan Africa, flooding in Sudan and Bangladesh, locust infestations in Africa and the Middle East, the recent TSUNAMI disaster in Bangladesh, India, the Philippines, Madagascar, and tropical cyclones in the Caribbean and the United States of America. In many cases, these have led to unprecedented famine and mass migration. Extreme variations in rainfall and temperature-frosts, cold spells, heat waves affect crop production. Droughts, floods, and tropical storms create food security problems and mass movement and migration of people. Forecasts and warnings of such severe weather events help governments to take preventive measures, where feasible, to reduce loss of human life and crops, the occurrence of famine and human suffering.

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