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Full Length Research Paper

Climate variation based on temperature and solar radiation data over a 29 year period in Lilongwe City, Malawi

Chikumbusko Chiziwa Kaonga*, Ishmael Bobby Mphangwe Kosamu and Chifundo Tenthani

Physics and Biochemical Sciences Department, University of Malawi, The Polytechnic, P/Bag 303, Chichiri, Blantyre 3, Malawi.

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Economies that mainly depend on agriculture are to a large extent being negatively impacted by climate change. In this study, temperature and solar radiation data from Chitedze Weather Station, Lilongwe City, Malawi for a 29-year period (1985 to 2013) were assessed for the possibility of climate variation. In addition, the concentration of carbon dioxide over Malawi within the same period as temperature and solar radiation data was assessed for inferences. The highest mean minimum temperature (15.7°C) was recorded in 2010. The highest mean maximum temperature (27.9°C) and solar radiation (21.5 MJm^{-2}day^{-1}) were recorded in 2005. The mean minimum temperature showed an increasing pattern but both mean maximum temperature and solar radiation data showed a lot of variation. There were significant differences ($p < 0.05$) among mean minimum and maximum temperature and solar radiation. The carbon dioxide concentration over Malawi has been increasing over the years which is one of the contributors to rising mean minimum temperatures.

Key words: Climate variation, solar radiation, temperature, weather.

INTRODUCTION

The world's climate is changing and will continue to change into the coming century at rates projected to be unprecedented in recent human history (Adger et al., 2003). There is now ample evidence of the ecological impacts of recent climate change, from polar terrestrial to tropical marine environments (Walther et al., 2002). The impact of climate change on agriculture may add significantly to the development challenges of ensuring food security and reducing poverty (Jones and Thornton, 2003). Climate is generally one of the main determinants of agricultural production. Its shift alters the distribution of plant diseases and pests which may have adverse effects on agriculture (Wani et al., 2013). Additionally, temperature increases especially in spring leads to a decrease in net primary production of some native grass species making them more vulnerable to invasion by exotic species (Alward et al., 1999). Grain yields also decline by 10% for each 1°C increase in growing-season minimum temperature (Peng et al., 2004). In a study by Sorenson et al. (1998), it was found that increase in

*Corresponding author. E-mail: ckaonga07@gmail.com. Tel: +265 888855399.

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temperature leads to declining numbers in both wetlands and birds such as ducks due to drought. Climate change therefore impacts negatively on communities who depend on natural resources for their livelihood (Nuorteva et al., 2010). These mostly include those from developing countries who heavily depend on agriculture (Mendelsohn and Dinar, 1999) for their livelihood.

According to US-EPA (2014), the changing climate impacts society and ecosystems in a broad variety of ways. For example, climate change can increase or decrease rainfall, influence agricultural crop yields, affect human health, cause changes to forests and other ecosystems, or even impact energy supply. Climate change also creates new challenges for biodiversity conservation (Heller and Zavaleta, 2009). In the geologic past, natural climate changes have caused large-scale geographical shifts in species' ranges, changes in the species composition of biological communities, and species extinctions. It is predicted that the effects of anthropogenic climate change will be more severe because of the extremely rapid rate of the projected change (Peters, 1990). Third world countries particularly in Africa are threatened by the effects of these changes because of their economic dependence on climate for development whose backbone is agriculture (Ngaira, 2007). In Africa among several examples, over the 20th century, the areal extent of Kilimanjaro's ice fields has decreased by approximately 80%, and if current climatological conditions persist, the remaining ice fields are likely to disappear between 2015 and 2020 (Thompson et al., 2002). Also, the increased frequency and intensity of storms in Africa are related to climate change (Douglas et al., 2008).

One of the most important climate factors is temperature. The ambient temperature is of most interest to humanity (Hansen et al., 2013). Temperature is affected by the amount of solar radiation and concentration of greenhouse gases among several other factors. The earth`s surface behaves like a blackbody (an object that absorbs and emits radiation). According to Stefan-Boltzman law, the emitted radiation is proportional to the fourth power of the absolute temperature of an object. The earth's atmosphere is heated from below since the sun radiates shortwave radiation which is emitted back as long wave radiation (infrared radiation) by the earth (NASA, 2013). This means that if there is more radiation from the sun reaching the earth, then the earth will radiate more and hence high temperature of the earth's atmosphere. The increase in temperature of the earth's atmosphere is compounded by the presence of greenhouse gases. Greenhouse gases absorb infrared radiation causing warming of the atmosphere. Therefore, the amount of greenhouse gases in the atmosphere is directly related to the atmospheric temperature. Increased concentrations of greenhouse gases increase the temperature of the atmosphere leading to warming of the earth's surface (Takle and Hofstrand, 2013).

In this study, temperature and solar radiation data for Chitedze Weather Station in Lilongwe City, Malawi was analyzed for possibilities of climate variation. In addition, carbon dioxide data for Malawi was used to make further inferences. In Malawi, research linking climate change based on factors like temperature is very rare hence the need for this research. The research also adds further information to literature on climate variation for least industrialized countries.

METHODOLOGY

The ambient air temperature and solar radiation data was obtained from Malawi Department of Meteorological Services (MET). The data was from Chitedze Weather Station, Lilongwe, Malawi. Chitedze Weather Station is located at some 16 km west of Lilongwe City (Capital of Malawi) with 13° 59`S longitude and 33° 38`E latitude. The elevation is 1097 m above sea level (Luhanga, 1996). Figure 1 shows the position of Lilongwe in Malawi. Lilongwe has a population of about 700,000 people. It is an urban and industrial center in Malawi. Additional data used in this research was sourced from literature.

The data was analyzed using Microsoft Excel and Statistical Package for the Social Sciences (SPSS) version 18. Using Microsoft Excel, box plots and graphs were plotted and used in the comparisons of trends over the years. In SPSS, T-tests were used to check for significant differences while hierarchical cluster analysis (HCA) was used to further examine the distribution of the data sets and linkages as reported by Mapoma et al. (2014).

RESULTS AND DISCUSSION

Minimum and maximum temperatures and solar radiation variations

Figure 2 shows box plots of minimum and maximum temperature and solar radiation in Lilongwe City. The values showed a narrow range over the years. This is attributed to the fact that Malawi has a sub-tropical climate (MET, 2006) where temperatures are both seasonal and show a narrow range within a specific period of the year. Figure 3 shows trend in mean minimum and maximum temperatures and solar radiation. The highest mean minimum temperature (15.7°C) was recorded in 2010 while lowest (13.2°C) was in 1985. The highest mean maximum temperature (27.9°C) was recorded in 2005 while the lowest (26.2°C) was in 1986. The amount of solar radiation received is dependent on both the month and time of the year. The highest mean solar radiation (21.5 $MJm^{-2}day^{-1}$) was recorded in 2005 while the lowest (18.9 $MJm^{-2}day^{-1}$) in 1989. The trend of mean minimum temperature shows an increasing pattern. The trend in mean maximum temperature indicates a fluctuating pattern over the years. The mean maximum temperature pattern was related to solar radiation more than the minimum temperature. The increasing pattern in mean minimum temperatures in the study area indicates a possibility of sequential warming. A study in Malawi

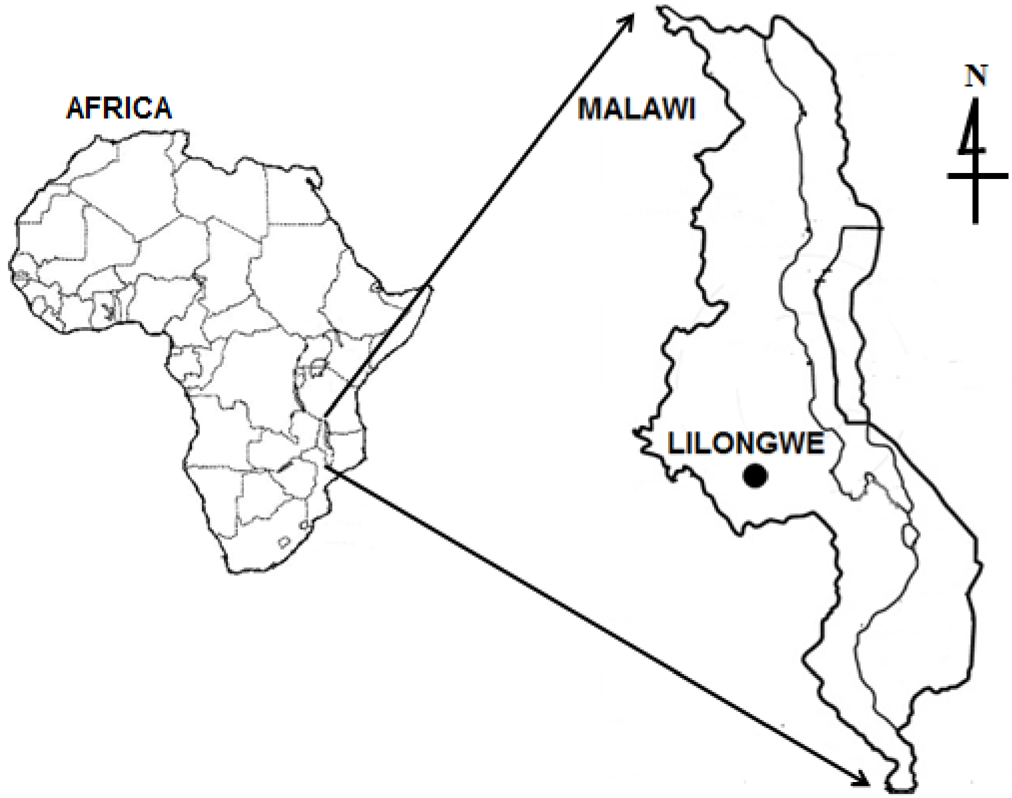


Figure 1. Map of Malawi showing the position of Lilongwe City.

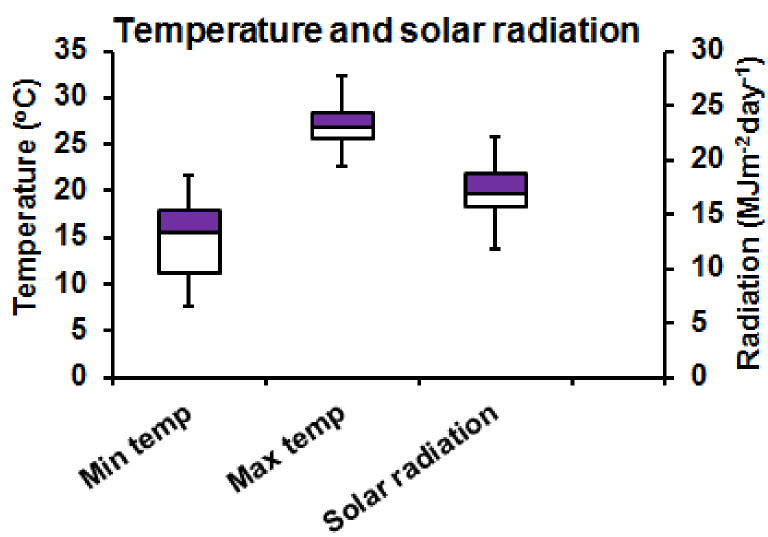
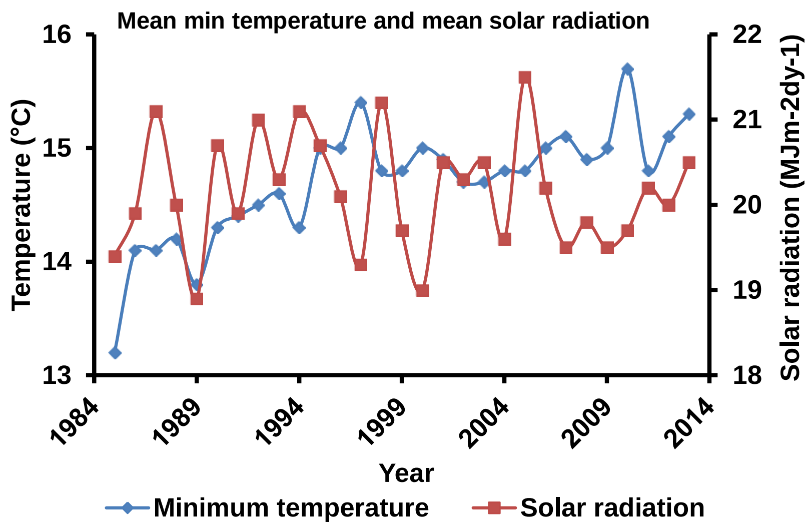


Figure 2. Box plots of minimum and maximum temperature and solar radiation in the study area (1985-2013).

over Chichiri weather station (A distance of about 365 km from the current study location) by Kaonga et al. (2012), also showed that in 2005, the temperature was higher than the preceeding years. The mean maximum and minimum temperatures recorded in that study were 26.8 and 15.8°C, respectively which are consistent with trends in the current study.

Figure 4 shows the observed and simulated net



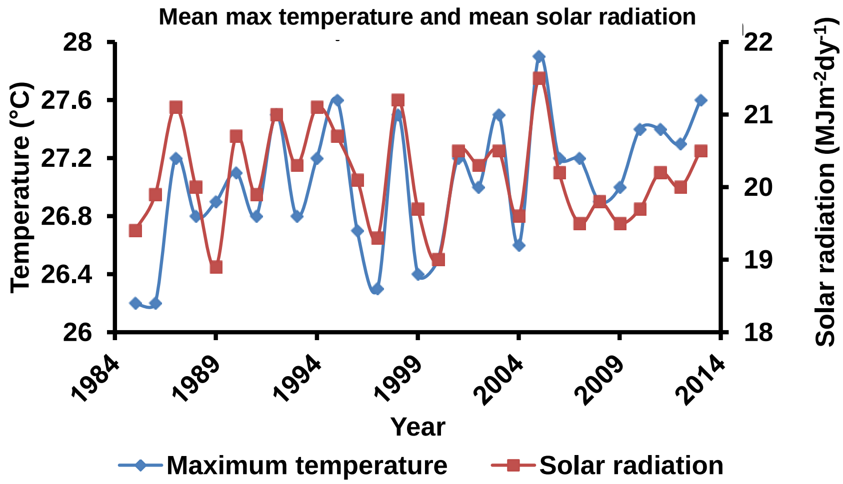


Figure 3. Trend in mean minimum and maximum temperature and solar radiation over Lilongwe city.

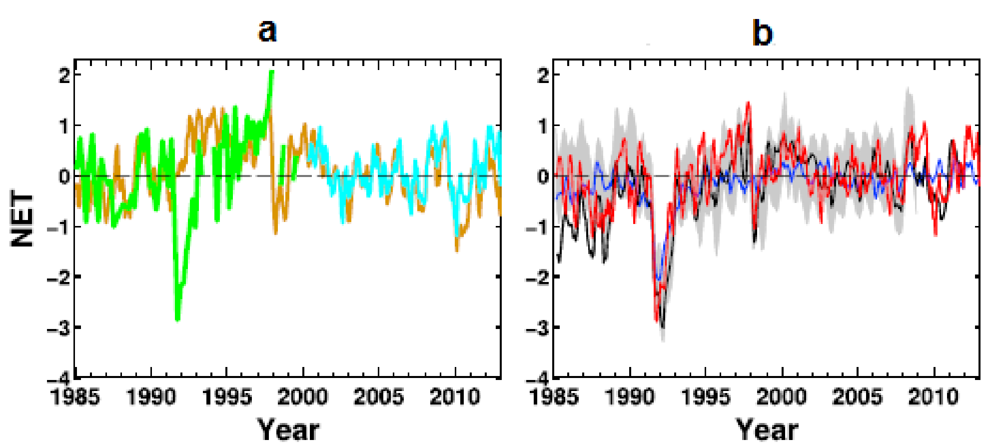


Figure 4. Changes in observed (a) and simulated (b) net downward radiation at the top of the earth's atmosphere (Adapted from Allan et al., 2014).

downward radiation at the top of the earth's atmosphere (Allan et al., 2014). The figure shows that there were no differences between the observed and simulated data. When these figures were compared with the current study, it was noted that the sudden drop and increase in temperature in 1992 and 1998 correlated with the mean maximum temperature trend. The mean minimum temperature agreed with the 1998 pattern only, that is, when there was a sudden increase in net solar radiation.

Relationship among minimum and maximum temperatures and solar radiation

Figure 5 shows that the correlations between mean minimum and maximum temperatures were weak. Statistical tests showed that there were significant differences ($p < 0.05$) between the mean minimum and maximum temperatures. This indicates that within the same year, the minimum temperature is independent of the maximum temperature. This is supported by the fact that the years when the minimum temperatures were highest, it was not the case with maximum temperature as indicated above. There were also significant differences ($p < 0.05$) between mean solar radiation as compared to both maximum and minimum temperatures. The correlations of solar radiation and both mean minimum and maximum temperatures were weak. This was further confirmed by cluster analysis. The frequencies (when the mean values were grouped into three clusters) were 7, 8 and 14 for clusters 1 to 3, respectively (comparison on mean maximum temperature and solar radiation using Ward method). Under the same conditions, the frequencies were 5, 16 and 8 when minimum temperature was compared with solar radiation. This means that the link among these factors was strong in the first cluster only with a bigger percentage of the values being dissimilar. This is an indication that other factors are responsible for warming in the studied area since temperature seem not to be dependent on the amount of solar radiation. According to Lashof and Ahuja (1990) and Paterson (2011), warming is largely caused by greenhouse gases, primarily carbon dioxide accruing in the atmosphere. In Malawi, carbon dioxide is an important greenhouse gas. This is mainly due to the fact that intensive use of firewood for energy purposes had reduced forest reserves to 28% by the year 2009 (UNEP, 2013). Forests are an important carbon dioxide sink since through photosynthesis, vegetation removes the gas from the atmosphere (FAO, 2013). In the absence of vegetation, most of the carbon dioxide remains in the atmosphere which causes warming. Figure 6 shows carbon dioxide emissions in Malawi from a number of sources. Mean solar radiation (as indicated in Figure 3) showed a lot of variation from 1985 to 2010 while during the same period, total carbon dioxide concentration showed an increasing pattern. The increase in total carbon dioxide emissions over the years could be contributed to warming as seen by the rise in mean minimum temperatures. This is a concern for both Malawi and global climate because increasing greenhouse gas concentrations are expected to have significant impacts not only locally but also to the world's climate on a timescale of decades to centuries (Hughes, 2000; Mendelsohn et al., 1994). The increase in total carbon dioxide was correlated to the increase in the same gas from liquids. These liquids include fuels like petrol and diesel. In Malawi, the number of vehicles (use petrol and diesel as fuels) has increased over the years. For example, from 1990 to 1999, the average registration of new vehicles was 5,282 per annum (GoM, 2002).

Already, the negative effects of climate change in Malawi are being felt especially in agriculture. According to Christian Aid (2015), in Malawi, farmers are no longer able to rely on the weather. The rains have become unpredictable since they can come too heavy and all at once. This is in addition to the fact that dry spells which have become common end up ruining crops or stunt the growth of young plants. This is further supported by Action Aid (2015) who postulates that Malawi is one of the most vulnerable countries to climate change and this has affected agriculture production which is the backbone of the country. The impacts in Malawi are being manifested in various ways such as intense rainfall, changing rainfall patterns, floods, droughts and prolonged dry spells.

Climate change is also having a negative impact on Malawi`s biodiversity and ecosystems. According to GoM (2012), it is on record that a high population of nyala antelopes died due to excessive heat and inadequate food. Also in 1995, one of the most important lakes (Lake Chilwa) in Malawi dried up with catastrophic consequences on fish species and fisheries. Therefore, the ecological problems that climate change is causing in Malawi cannot be underestimated.

Conclusion

This study assessed temperature and solar radiation data from Chitedze Research Station in Lilongwe, Malawi for the possibility of climate variation over a 29 year period. The results indicated that mean maximum temperatures have been fluctuating over the years. The mean minimum temperatures have been gradually increasing, indicating a possibility of warming. The mean maximum temperatures correlated with net solar radiation at the boundary of the earth's atmosphere. However, there were weak correlations among minimum and maximum temperatures with solar radiation from the study area an indication that other factors like carbon dioxide are responsible for warming. This is because the rise especially in minimum temperature was related to the increase in carbon dioxide concentration over the years.

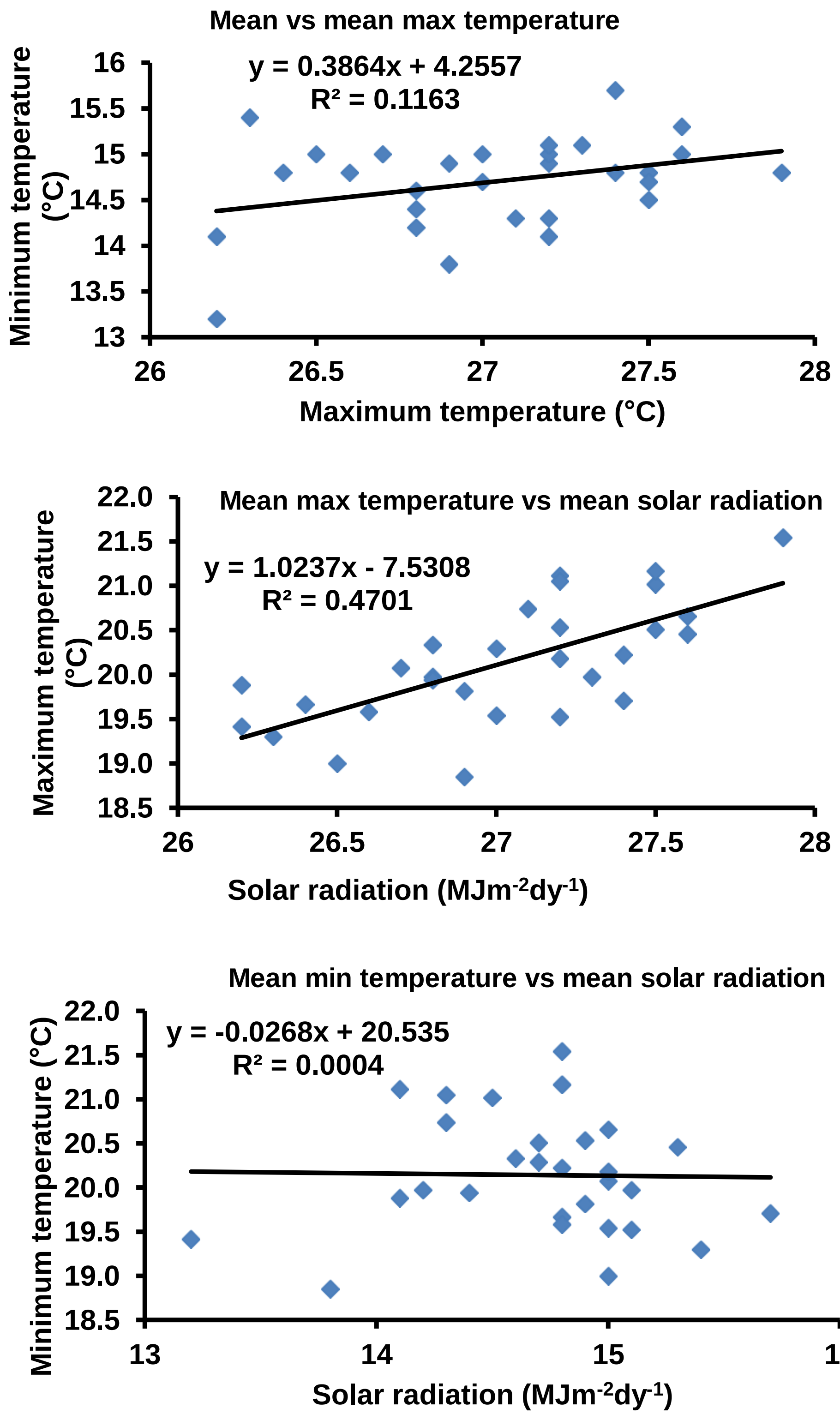


Figure 5. Correlation among minimum and maximum temperatures and solar radiation.

Conflict of interests

The authors did not declare any conflict of interest.

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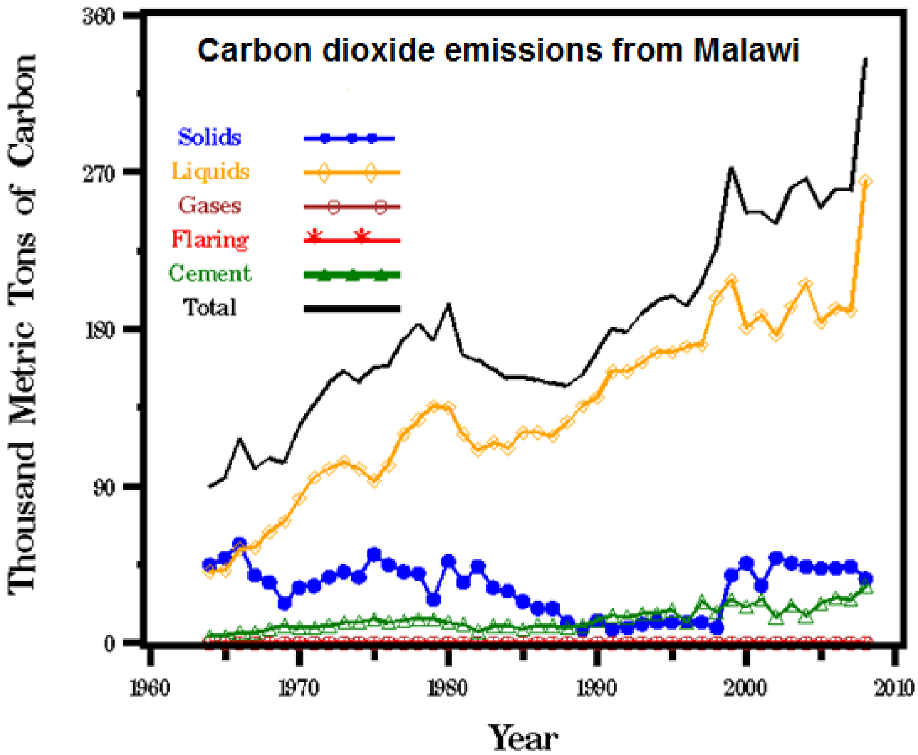

Figure 6. Carbon dioxide emissions for Malawi (Source; CDIAC, 2012).

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REFERENCES

Action Aid (2015). Climate change in Malawi. Accessed on 04/03/2015 from http://www.actionaid.org/malawi/stories/climate-change-malawi

Adger WN, Huq S, Brown K, Conway D, Hulme M (2003). Adaptation to climate change in the developing world. Prog. Dev. Stud. 3(3): 179-195. http://dx.doi.org/10.1191/1464993403ps060oa

Allan RP, Liu C, Loeb NG, Palmer MD, Roberts M, Smith D, Vidale PL (2014). Changes in global net radiative imbalance 1985-2012. Geophys. Res. Lett. 41: 5588–5597. http://dx.doi.org/10.1002/2014GL060962

Alward RD, Detling JK, Milchunas DG (1999).Grassland vegetation changes and nocturnal global warming. Science 283 (5399):229-231. http://dx.doi.org/10.1126/science.283.5399.229

CDIAC (Carbon dioxide information analysis center) (2014). CO2 emissions from Malawi. Accessed on 05/12/2014 from; http://cdiac.ornl.gov/trends/emis/mal.html

Christian Aid (2015). The impact of climate change in Malawi. Accessed on 04/03/2015 from http://www.christianaid.org.uk/whatwedo/partnerfocus/impact-of-climate-change-in-malawi.aspx

Douglas I, Alam K, Maghenda M, Mcdonnell Y, Mclean L, Campbell J (2008). Unjust waters: climate change, flooding and the urban poor in Africa. Environ. Urban 20(1):187-205. http://dx.doi.org/10.1177/0956247808089156

FAO (Food and Agricultural Organisation) (2013). Forest and climate change. Accessed on 10/03/2015 from ftp://ftp.fao.org/docrep/fao/011/ac836e/ac836e00.pdf

GoM (Government of Malawi) (2002). Initial national communication of Malawi. Ministry of Natural Resources and Environmental Affairs. Accessed on 01/12/2014 from http://unfccc.int/resource/docs/natc/mwinc1.pdf

GoM (Government of Malawi) (2012). National climate change response: Draft white paper. Accessed on 04/03/2015 from http://www.cepa.org.mw/documents/legislation/policies/Malawi%20National%20Climate%20Change%20White%20paper%20Dec%2014.pdf

Hansen J, Sato M, Russel G, Kharecha P (2013). Climate sensitivity, sea level and atmospheric carbon dioxide. Phil. Trans. R. Soc. A. 371:1-37. http://dx.doi.org/10.1098/rsta.2012.0294

Heller NE, Zavaleta EA (2009). Biodiversity management in the face of climate change: A review of 22 years of recommendations. Biol. Conserv. 142:14-32. http://dx.doi.org/10.1016/j.biocon.2008.10.006

Hughes L (2000). Biological consequences of global warming: Is the signal already apparent? Trends Ecol. Evol. 15(1): 56-61. http://dx.doi.org/10.1016/S0169-5347(99)01764-4

Jones PG, Thornton PK (2003). The potential impacts of climate change on maize production in Africa and Latin America in 2055. Glob. Environ. Chang. 13: 51-59. http://dx.doi.org/10.1016/S0959-3780(02)00090-0

Kaonga CC, Mapoma HWT, Kosamu IBM, Tenthani C (2012). Temperature as an indicator of climate variation at a local weather station. World Appl. Sci. J. 16(5):699-706.

Lashof DA, Ahuja DR (1990). Relative contributions of greenhouse gas emissions to global warming. Nature 344:529-531. http://dx.doi.org/10.1038/344529a0

Luhanga JH (1996). Chitedze Agricultural Research Station: Station guide. Accessed on 04/07/2014 from http://www.cabi.org/gara/FullTextPDF/2008/20083326878.pdf

Mapoma HWT, Tenthani C, Tsakama M, Kosamu IBM (2014). Air quality assessment of carbon monoxide, nitrogen dioxide and sulfur dioxide levels in Blantyre, Malawi: A statistical approach to a stationary environmental monitoring station. Afr. J. Evnviron. Sci Technol. 8(6): 330-343. http://dx.doi.org/10.5897/AJEST2014.1696

Mendelsohn R, Dinar A (1999). Climate change, agriculture, and

developing countries: Does adaptation matter? World Bank Res. Obs. 14(2):277-293. http://dx.doi.org/10.1093/wbro/14.2.277
Mendelsohn R, Nordhaus WD, Shaw D (1994). The impact of global warming on agriculture: A Ricardian analysis. Am. Econ. Rev. 84(4): 753-771.
MET (Malawi Meteological Services) (2006). Climate of Malawi. Accessed on 05/12/2014 from http://www.metmalawi.com/climate/climate.php
NASA (National Aeronautics and Space Administration) (2013). Climate science investigations. Energy: The driver of climate. Accessed on 04/03/2015 from http://www.ces.fau.edu/nasa/module-2/correlation-between-temperature-and-radiation.php
Ngaira JKW (2007). Impact of climate change on agriculture in Africa by 2030. Sci. Res. Essays 2(7):238-243.
Nuorteva P, Keskinen M, Varis O (2010). Water, livelihoods and climate change adaptation in the Tonle Sap Lake area, Cambodia: Learning from the past to understand the future. J. Water Clim. Change 1(1):87-101. http://dx.doi.org/10.2166/wcc.2010.010
Paterson NR (2011). Global warming: A critique of the anthropogenic model and its consequences. Geosci. Canada 38(1): 41-48.
Peng S, Huang J, Sheehy JE, Laza RC, Visperas RM, Zhong X, Centeno GS, Khush GS, Cassman KG(2004). Rice yields decline with higher night temperature from global warming. PNAS 101(27): 9971-9975. http://dx.doi.org/10.1073/pnas.0403720101
Peters RL (1990). Effects of global warming on forests. Forest Ecol. Manag. 35(1-2):13-33. http://dx.doi.org/10.1016/0378-1127(90)90229-5
Sorenson LG, Goldberg R, Root TL, Anderson MG (1998). Potential effects of global warming on waterfowl populations breeding in the Northern Great Plains. Clim. Change 40(2):343-369. http://dx.doi.org/10.1023/A:1005441608819
Takle E, Hofstrand D (2013). Global warming – Impact on greenhouse gases. Accessed on 03/04/2015 from http://www.extension.iastate.edu/agdm/articles/others/TakMar08.html
Thompson LG, Mosley-Thompson E, Davis ME, Henderson KA, Brecher HH, Zagorodnov VS, Mashiotta TA, Lin PN, Mikhalenko VN, Hardy DR, Beer J (2002). Kilimanjaro ice core records: Evidence of holocene climate change in tropical Africa. Science 298(5593): 589-593. http://dx.doi.org/10.1126/science.1073198
UNEP (United Nations Environmental Program, RISO) (2013). Emissions reduction profile Malawi. Supported by ACP-MEA and UNFCCC. Accessed on 10/03/2015 from http://www.unepdtu.org/PUBLICATIONS/Emissions-Reduction-Potential-Country-Profiles
US-EPA (United States Environmental Protection Agency) (2014). Climate change. Accessed on 11/11/2014 from http://www.epa.gov/climatechange/
Walther GR, Post E, Convey P, Menzel A, Parmesan C, Beebee TJC, Fromentin JM, Hoegh-Guldberg O, Bairlein F (2002). Ecological responses to recent climate change. Nature 416: 389-395. http://dx.doi.org/10.1038/416389a
Wani AS, Chand S, Najar GR, Teli MA (2013). Organic farming: As a climate change adaptation and mitigation strategy. SJAS 3(8):294-298. http://dx.doi.org/10.12944/CARJ.1.1.06