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The Impact of Climate Change on Agriculture and Health Sectors in Tanzania: A review

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Abstract— *The impact of climate change in Tanzania is dynamic and differs among regions as they are impacted in different ways. While other regions experience normal rainfall and temperature patterns, others have continued to experience temperature extremes, severe droughts, decline in crops production coupled with food insecurity, extreme weather episodes of heavy rainfall associated with floods, loss of lives and infectious disease outbreaks. Despite the effects of climate change being recognized in the country, awareness is limited among local people, in particular the vulnerable communities. Thus, this review aims to raise awareness by giving a broader picture of impacts of climate change on agriculture and health sector. It reveals that in many parts of Tanzania, agriculture and health sectors may continue to suffer from the effects of climate change aggregated with limited awareness among communities. It is expected, that outbreaks of infectious diseases including malaria and cholera may increase as they correlate positively with high temperatures and rainfall. As a result, health problems and deaths of people, and reduced crops production will continue. Therefore, it is recommended that, the best way to overcome climate change is to invest effectively on the irrigation agriculture; and the health sector's budget should be enough to improve health care services and prepare for outbreaks of climate change sensitive diseases. Most importantly, provision of climate change awareness to the vulnerable communities must be seriously considered. About 50 peer-reviewed articles, government and international reports published between 2000 and 2017 were reviewed.*

Keywords— Agriculture, Climate change, Food insecurity, Health, Poverty.

I. INTRODUCTION

Wu et al. (2016) defines climate change as the long-term changes in weather conditions and patterns of unusual extreme weather events. On the other hand, IPCC (2001) describes a climate change as a change of climate which is attributed either directly or indirectly to anthropogenic activities that alter the global atmosphere composition and which is in addition to observed natural climate variability over comparable time periods. It is a global problem that defies and threatens global sustainable development, economy, food security, biodiversity, agriculture, human health and water availability as shown in Brown and Crawford (2008), Enfors and Gordon (2007), IPCC (2001; 2007), Majule et al. (2013), Mwakisunga et al. (2012), Ojoyi, (2017), URT (2003), Van der Werf et al. (2009) and Wu et al. (2016). Both natural and anthropogenic factors are implicated as causes for climate change (IPCC, 2007). Natural factors include volcanic eruptions, variations in solar output, natural aerosol emissions, and variations in the earth's orbital characteristics, whereas, anthropogenic factors include burning of fossil fuels, industrial activities, cement production, land use changes, deforestation and agriculture (IPCC, 2001, 2007; Van der Werf *et al.*, 2009; Wu et al. 2016). All these activities produce high emission levels of greenhouse gases (GHGs) which include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (Brown et al. 2007; IPCC, 2007; Mwakisunga et al. 2012). Thus mounting of GHGs concentration in the atmosphere is the leading cause of climate change (Hemp, 2009; IPCC, 2007). Several studies including IPCC (2001, 2007), FAO (2013) and Shikuku et al. (2017) clearly show that the GHGs are positively correlated with the burning of fossil fuels, oils, forest destruction and agriculture. It has been indicated that, climate change takes place in the context of developmental stresses, poverty, food shortage, drought, outbreaks of infectious diseases, environmental change and land degradation (Brown and Crawford, 2008; Brown et al., 2007; Enfors and Gordon, 2007; FAO, 2013; IPCC, 2001). Because of these factors and stresses, maintaining sustainable agriculture and better health sector becomes a challenge in the global climate change (Levira, 2009; Majule et al. 2013; Wu et al. 2016). Brown and Crawford

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(2008), Boon and Ahenkan (2012), FAO (2013), IPCC (2001), URT (2005) claimed that, climate change is the foremost global challenge to human prosperity that will be faced and experienced for several years. In Africa particularly sub-Saharan Africa, other studies indicate that climate change continues to distress agriculture, biodiversity, livestock production, environment, and health sectors (Burke et al. 2009; IPCC, 2007; Orindi and Murray, 2005; Shikuku et al. 2017; URT, 2005). Evidence from the European Environment Agency (EEA, 2008) revealed that global average surface temperature is increasing. For example, in the 20th century it has increased by 0.74 °C, while, since 1991 increase in global sea level is 1.8 mm per year. Additionally, researchers report that, future climate change will continue to be a significant driver of ecosystem stress and significantly impact agriculture and health sectors (Brown and Crawford, 2008; Brown et al. 2007; FAO, 2013; IPCC, 2007; Rowhani et al. 2011). IPCC (2001) also reports that, climate change causes a direct effect on the environment, economy, water resources, health, weather events, sea level rise and desertification.

Moreover, the climate change in Tanzania threatens sustainable development and other socio-economic activities (Majule et al. 2013; Rowhani et al. 2011). Unusual extreme temperatures and rainfall alterations have shown strong impacts on agriculture, health and other sectors in the country (Enfors and Gordon, 2007; Hemp, 2009; Majule et al. 2013). Climate change related scenarios such as severe droughts, floods, livestock deaths, crop failures and outbreak of disease such as cholera, malaria episodes and deaths are regularly observed (Levira, 2009; URT, 2007). Its impact also accelerates food shortage, poverty, deforestation and forest degradation, poor livelihoods and occurrence of infectious diseases (Hatibu, 2003; NAPA, 2005; Wolbring, 2009; Wu et al. 2016). The poor and rural communities are particularly chiefly vulnerable owing to their complete dependence on subsistence agriculture and forests resources coupled with limited capacity to adapt to climate change (Brown *et al.*, 2009). Researches have shown that more than 80% of Tanzanian population directly rely on agriculture for their livelihoods; thus, 10% decrease in rainfall would make most of areas unsuitable for cultivation (Hemp, 2009; URT, 2003, 2007). Moreover, Craparo et al. (2015) reported that, a minimum temperature change in future will be severe in the interior regions of Tanzania and will considerably affect crops production and health sector. This review paper provides an overview of the impacts of climate change on agriculture and health sectors in Tanzania. Recommendations to overcome them have also been discussed.

II. MATERIALS AND METHODS

2.1. Methods

Shemsanga et al. (2010) asserted that the best way to explain the effect of climate change is to focus on the context of crops production and outbreaks of infectious diseases such as cholera and malaria. Crop yields have been used in many studies to justify the impact of climatic change (Burke et al. 2009; Hatibu et al. 2003; Shemsanga et al. 2010). This is because climate change influences crop yields by decreasing soil moisture content, increase drought and floods, and support diseases affecting crops. A broad literature search was conducted using Google Scholar (http://scholar.google.com), Open Doar-directory of pen access repository (http://www.opendoar.org), Agora (http://www.fao.org/agora/en/), Springer Online Journals (http://link.springer.com/), Doaj-directory of open access journals (https://doaj.org) and Elsevier ScienceDirect (http://www.sciencedirect.com/). The attention was given on the peer-reviewed articles and government reports between 2000 and 2017. Other reports from different websites were also reviewed, these include Tanzania Climate Change Information Repository (TaCCIRe) (http://www.taccire.suanet.ac.tz), Tanzania Metrological Agency (TMA) (http://www.meteo.go.tz/), United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP), World Health Organization (WHO), Group on Climate Change and Health (IWGCCH) and Intergovernmental Panel on Climate Change (IPCC).

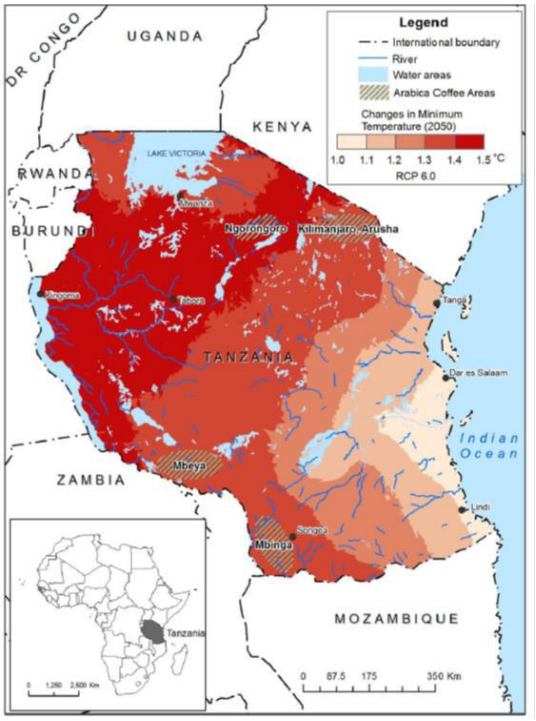

Fig.1: Map of Tanzania (Craparo et al. 2015)

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2.2. An overview of Tanzania

In the East Coast of Africa, Tanzania lies near to the equator between parallel 10S and 120S and meridians 300E and 400E (URT, 2007). It is the largest country in East Africa with a total area of 945,200 km2, of which 60,000 km^2 is inland water (URT, 2003). This area includes parts of Mafia, Zanzibar, and Pemba (Shemsanga et al. 2010). It borders Malawi and Zambia (South-West) Rwanda and Burundi (North-West), Kenya and Uganda in the North-East and North respectively, Mozambique (South) while the Indian Ocean in the East as shown in Fig 1.

III. DISCUSSION

3.1. **Impact of climate change on agriculture sector**

The agriculture sector in Tanzania is particularly vulnerable to climatic change because it is customarily dependent on rainfall (Ojoyi, 2017; URT, 2007; Yanda et al. 2008). This involves prolonged dry season, alteration in ecology of pests and diseases, unstable agro-ecological zones, poor or doubtful rainfall (URT, 2003), and uncertainty in cropping patterns (Shemsanga, 2010). Climate change catalyses competition between crops and weeds for light, moisture and nutrients (URT, 2007). Studies by Shemsanga et al. (2010) and Yanda et al. (2008) report that, increase or decrease in temperature and rainfall patterns in some cities accelerates shortage of food. This is because many crops die as a result of high temperature that increases evapotranspiration and moisture loss (Rowhani et al. 2011; URT, 2003, 2007). Furthermore, a decline in rainfall makes water inadequate for farming activities (Ojoyi, 2017), because many seasonal streams and rivers used for irrigation dry out (Craparo et al. 2015). For example, Rowhani et al. (2011) claim that, seasonal increase in temperature by 2^{o}C as projected by 2050 will reduce yields of rice, sorghum and maize by 7.6%, 8.8% and 13% respectively in Tanzania while a 20% increase in precipitation variability will decrease yields of rice, sorghum and maize by 7.6%, 7.2% and 4.2% respectively by 2050. In addition, increase in temperature between 2^{o}C and 4^{o}C will alter the ecosystem, causing ecosystem shifting (Rowhani et al. 2011). As a consequence, this will shift former areas suitable for cultivation of annual crops to perennial crops (Yanda et al. 2008). Severe droughts in Tanzania have been causing hunger as a result of dwindling in crops production. For instance, Shemsanga et al. (2010) reported that in Dodoma there was a decrease in harvest by 80% attributed to poor rainfall. In 2005, Kilimanjaro, Coastal and North-East regions experienced marginal rains, which led to food shortages and starvation. Besides, the food scarcity due to climate change, the phenomenon has also has resulted into an increase in malnutrition rate amongst children in the country (URT, 2005, 2007).

Furthermore, the rangelands which were suitable for use by pastoral communities for livestock keeping and settlements have declined because of climate change (Burke et al. 2009). Shortage of pastures and water due to shortage of rainfall and high temperature (DILAPS, 2007; URT, 2005) has caused considerable deaths of livestock which have been reported almost each year (Shemsanga et al. 2010; Yanda et al. 2008; URT, 2003). Escalation of tsetse flies has made the rangelands unsuitable for pastoralists and livestock settling (URT, 2007) and therefore decrease in their quality and size. As a result of this, pastoralists have been forced out of their former areas into farmers' areas to search for pastures and water for their livestock (URT, 2003). Subsequently, several conflicts between farmers and pastoralists that occur in the country have been reported in DILAPS (2007). These conflicts and associated deaths and injuries have been reported in Kilimanjaro district, Mara region, Morogoro region, Kilosa district, Mamba ward, and Arusha (DILAPS, 2007). Yet, livestock productivity, distribution and survival will continue to decline because of the present climate change variability, decrease in the quality of rangelands and prevalence of vector-born diseases.

3.2. **Impact of climate change on health sector**

It is not relatively simple to assess the effect of climate change on human health. This is because human health may be impacted due to extreme changes in cold and heat, droughts and floods. Other human health impacts may get up from ecological or social system alterations caused by climate change. The climate change affects the health sector in Tanzania by persistent burdens of diseases (Kibona, 2008; URT, 2007). This includes the basic elements of good health such as adequate food, clean air, safe water, adequate shelter, and health environment (Hulme et al. 2001). Climate change further impacts on health of people by multiplying the present health problems (Wu et al. 2016). Strong weather associated with heavy rainfall, landslides and floods destroy the infrastructures of health care services infrastructure and hence affect the health sector (URT, 2005; Yanda, 2005). In addition, it causes injuries and deaths, water supplies contamination, decrease in food production and disease outbreaks (Costello et al., 2009). The health sector is impacted in diverse ways, for example, the impact on food, system efficiency of local sewerage and the accessibility of fresh water supplies (Kibona, 2008). Furthermore, a decrease in food production also affects health of many people in form of malnutrition (FAO, 2013). A deficiency of water in most places of the country leads to consumption of unsafe water. This increases the chance of water borne disease outbreaks, a threat to

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health. There are many climatically sensitive illnesses in Tanzania; and they are very common during heavy rains, drought and flooding (Mboera et al. 2011; Shemsanga et al. 2010). Water related diseases linked to climate change are cholera, malaria, amoebiasis, cryptosporidiasis, giardiasis, leptospirosis, typhoid and schistosomiasis; and vector borne diseases such as dengue, encephalitis filariasis, leishmaniasis, Lyme disease, plague, rift valley fever, onchocerciasis, trypanosomiasis and yellow fever (Costello et al., 2009; Mboera et al. 2011; Paavola, 2003; Shemsanga et al. 2010; URT, 2007). Distribution of vectors causing water borne diseases can be limited by cold temperatures, however increasing global warming as a result of climate change accelerate the risk to human life (Mboera et al. 2011). This review focuses on two major climatic sensitive diseases (Cholera and malaria), however, other climatic infectious disease are also discussed in briefly.

3.2.1. Cholera

Cholera is a disease associated with climate change (Mboera et al. 2011; Trærup et al. 2011; Yanda, 2005). This means that climate change plays a positive role in spreading and escalating the disease (IPCC, 2001). It has been established in many parts of Tanzania that cholera outbreaks occur with increases in the amount of rainfall (URT, 2003; 2007; Yanda, 2005; Hulme et al. 2001). For example, Hulme et al. (2001) reported that cholera outbreaks in North East, South East, Lake Victoria basin and coastal areas of Tanzania were due to high rainfall. Trærup et al. (2011) also reported a significant relationship between cholera incidences and temperature in the country. He further showed that, initial risk of cholera increased by 15% to 19% for every 1^{o}C temperature increase. Additionally, he projected that in Tanzania by 2030, the total costs of cholera attributable to climate change variability will be in the range of 0.32% to 1.4% of national GDP. Similarly, Trærup et al. (2011) showed that the seasonal patterns that existed between June and October had the lower cholera cases which corresponded with lower minimum or maximum temperatures and total rainfall (Fig 2). Treatment and handling costs of people suffering from cholera as well as controlling the disease burden the country's economy. This is because more funds are injected in the health sector to combat it. In addition to the economic consequences, the disease also decrease labour force (URT, 2003; Yanda, 2005).

3.2.2. Malaria

Ahern et al. (2005) and Haines and Patz (2004) have shown that, incidences of malaria are highest during heavy rainfall and high temperature. The increase in precipitation and temperature is associated with global warming and therefore makes mosquitoes' habitats (such as ponds, pools, wells or bores, streams, rivers and canals) suitable breeding sites (Harrus and Baneth, 2005). Consequently, they grow and increase in population capable of spreading parasite causing malaria, *Plasmodium falciparum* (Lindsay et al. 2000; Kibona, 2008). Development rates of parasites and vectors are affected by temperature whilst mosquitoes' breeding sites are affected by the availability of rainfall (Craig et al., 2004; Zhou et al., 2004). Kibona (2008) in their study conducted in Lushoto district, Tanzania, reported that malaria cases were prominent during high rainfall seasons. For example, 249.1 mm of rainfall in April were associated with the increase of mean malaria cases in the same month (Fig 3). This is similar in other months in each rain season.

Kibona (2008) also reported an increase in malaria cases were linked with increased temperature (Fig 4). Largely, malaria cases tend to correspond with annual and monthly rainfall seasons and temperature (Lindsay et al. 2000). This correspondence is due to the temperature and rainfall patterns that favour the breeding and distributions of mosquitoes (Kibona, 2008; Ostfeld and Brunner, 2015; Reiter, 2001). This happens especially if the infrastructures such as pools, ponds, canals, streams and rivers are present to support their existence (Rodó et al., 2013). The burden of malaria on the health sector is very huge, it slows the health sector to provide better health care services. This is because the budget allocated in the sector is diverted to treatment and purchasing of malaria medicines every year. IPPC (2007) reported that a part from causing morbidity, malaria kills many children, elderly and pregnant women more than other diseases on the planet. Other studies indicated that the number of malaria cases are positively correlated with high extreme temperatures and rainfall (IPCC, 2001; Githeko and Ndegwa, 2001; Zhou et al. 2004). Moreover, Craig et al. (2004) reported that, incidences of malaria events are much more pronounced in rainy and warm days as a result of climate change.

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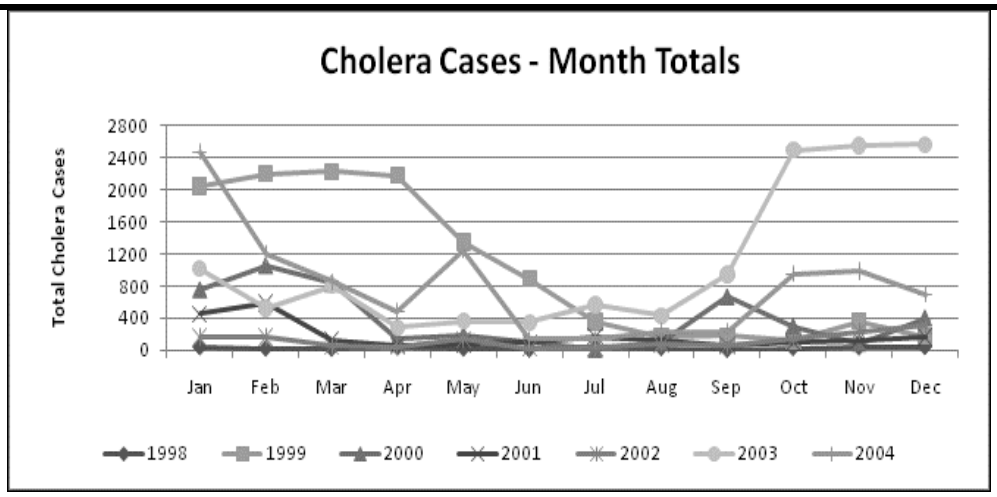
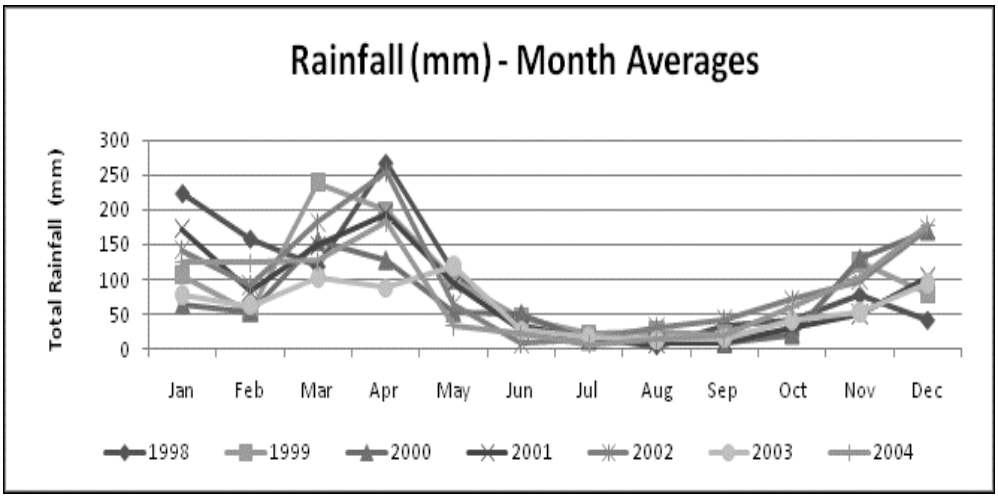


(a)



(b)

Fig.2: Seasonal distribution of cholera cases and rainfall in Tanzania (source: Trærup et al. 2011)

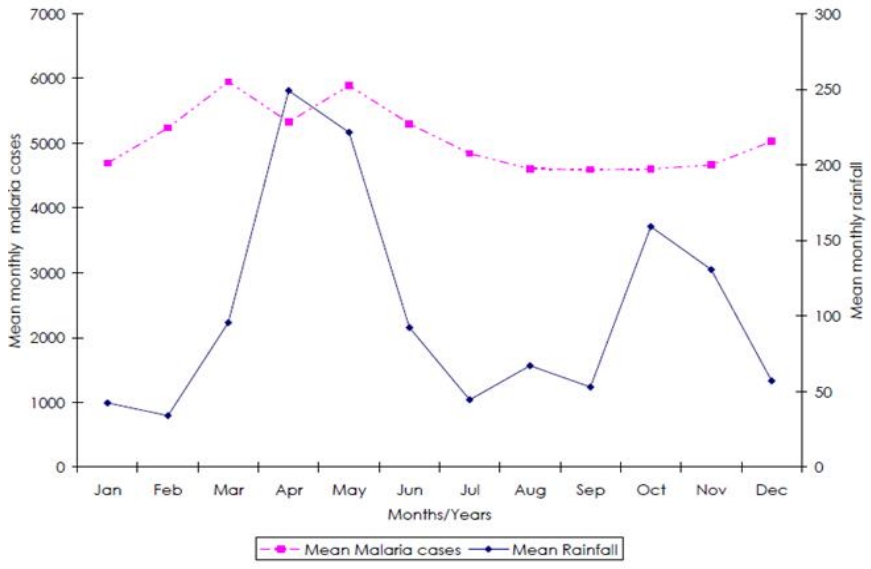


Fig.3: Mean monthly malaria cases and rainfall from Lushoto district, 1995-2004 (Source: Kibona, 2008)

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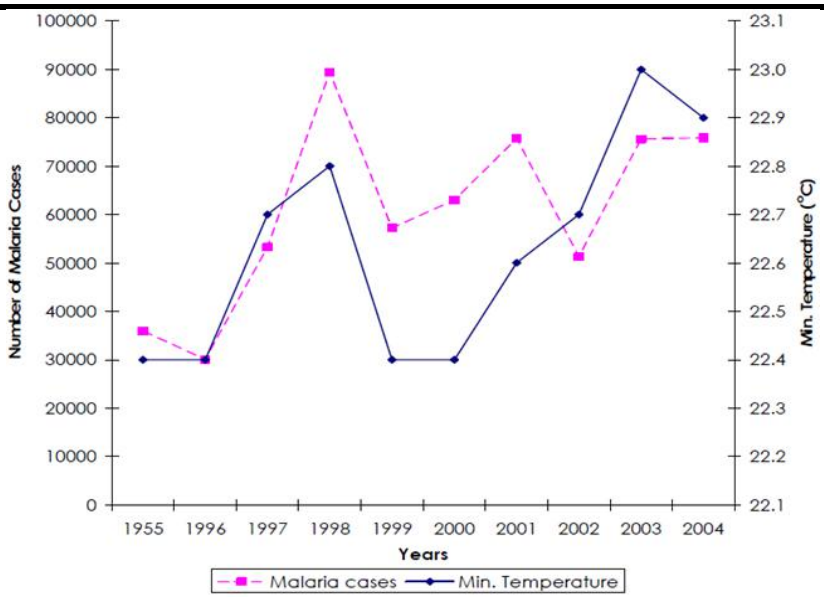

Fig. 4: Annual malaria cases and minimum annual temperature in Lushoto district, 1995-2004 (Source: Kibona, 2008)

3.3. Other climatic sensitive diseases which affect the health sector

There are other climatic associated diseases which have impact on health sector in Tanzania. These climatic diseases are summarised in Fig 5. Like cholera and malaria the rift valley fever is correlated to climate change variability (Mboera et al. 2011). It is documented that three quarters of the rift valley outbreaks occurred between 1950 and 1998 in East Africa during El Niño events (Patz et al., 2005). The outbreaks of the lift valley fever in Tanzania are usually correlated with high rainfall or El Niño and it is caused by Aedes and Culex mosquitoes (Zhou et al., 2004). Mboera et al. (2011) claims that, outbreak of rift valley fever was reported in January 2007 in Northern, Southwards and Westwards Tanzania districts while affecting about 511 people in 10 regions. On the other hand, African Trypanosomiasis caused by *Trypanosoma brucei rhodesiense* is transmitted by tsetse flies, a *Glosina* species (Moore et al. 2011). Its distribution is catalysed by climate change. When the ecosystem changes due to climate, vectors distribution also change. Factors such as high temperature and long term changes in rainfall affect the life cycle of tsetse flies and transmission of trypanosomiasis (Mboera et al. 2011). The tsetse flies distribution due to climate change and movement of people plus livestock accelerate the spread of sickness diseases caused by *Trypanosoma brucei* to different areas.

Dengue fever is caused by the arbovirus (Mboera et al. 2011; Mgonde et al. 2006). This disease is predominant in tropical and subtropical countries. Viruses causing dengue are transmitted to humans by mosquitoes, especially the two species, *Aedes aegypti* and *Aedes albopictus* (Mboera et al. 2011). Appropriate environment supported by warm conditions and rainfall is vital for these mosquitoes to breed and transmit dengue causing viruses. They breed in water contained in containers, flower pots, water tanks, tires filled with water, and in discarded cans and cups. Hence during rainfall, if these containers are filled with water they become suitable breeding sites for mosquitoes carrying dengue causing viruses. Urban communities with poor water and solid systems management are very vulnerable. Mboera et al. (2011) reports that, in Tanzania dengue occurred in February and May in 2010 in Dar es Salaam. In addition, Schistosomiasis disease is caused by *Schistosoma mansoni* and *Schistosoma haematobium.* The parasites are transmitted to humans via intermediate host, the snail (*Bulinus globosus*). Populations of the snails are dependent on water, temperature, water pH, water currents, and food availability. The density of the snails is influenced by rainfall patterns and therefore transmission of parasites. Human beings can have health problems if they use infected water or contaminated vegetable or fruits by *S. mansoni*.

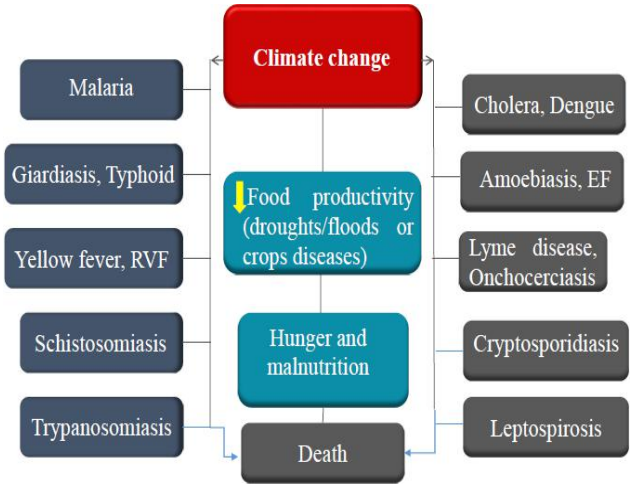

Fig.5: Impact of climate change on health sector and associated diseases (RVF and EF = Rift Valley Fever and Encephalitis Filariasis respectively). The yellow arrow pointing down mean a 'decrease'.

Another climate related disease is Leptospirosis. It is a zoonotic disease found mostly in tropical and subtropical countries favoured by extreme weather events (Biggs et al. 2011). It spreads via the urine of infected animals which gets into water or soil (Mboera et al. 2011). Areas experiencing repeated floods and typhoons particularly in urban slums and areas with poor sanitation are homes of leptospirosis infection. Biggs et al. (2011) reported cases of leptospirosis prevalence in two hospitals in Moshi region. This reveals that the disease affect health of people but also health sector in the country. Humans and animals are affected in a similar manner with this disease (Mgonde et al. 2006). They get infected through contact with contaminated soils or water, ingestion or inhalation of contaminated soils (Mgonde et al. 2006). Although the disease is climatic change related and affect people and animals, its epidemiological status to humans in the country is less considered probably due to its diagnostic complications and little awareness. Plague is also important climatic related disease caused by the bacteria known as *bacillus Yersinia pestis* (Stenseth et al. 2008). Distribution of the disease is regular with climate change (Drancourt et al. (2006; Stenseth et al. 2008; Nakazawa et al., 2008). For example, Pham et al. (2009) indicated that plague incidences usually tend to increase during hot and dry season and then followed by a period of seasonal rainfall. Drancourt et al. (2006) indicated that this bacteria lives in rodent hosts and transmitted to human and other animals through animal fleas. It can also be transmitted via predation, cannibalism or contaminated soils. In Tanzania, the disease is endemic in Lushoto district and causes human health problems, nevertheless, the plague cases are seasonal (Mboera et al. 2011).

IV. CONCLUSIONS

Human health is impacted by climate change directly or indirectly. Direct effects can cause mortality due to extreme heat and cold waves, flooding, droughts, and cyclones. Indirect effects are associated with increased health problems due to contaminated food and water, and malnutrition due to reduced food production. However, in Tanzania, mortality cases due to direct impacts are mainly caused by floods and droughts. In order to reduce the impacts of climate change on agriculture and health sectors, the government and other stakeholders should set up early warning system mechanisms and demonstrate optimal preparedness owing to the dynamic nature of climate change impacts. Preventive adaptation and mitigation measures against infectious diseases should be introduced, for example, good infrastructures for water and sanitation, and health service centres. These must be supplemented with Tanzania national goals of universal water and hygiene coverage. In agriculture sector, it is recommended that the best solution to overcome climate change is to effectively invest in the irrigated agriculture and also biotechnology whereby crops tolerant to various climate changes such as drought can be bred to ensure food security. It is also critical to provide education to farmers and livestock keepers about climate change adaptation and mitigation strategies. Most importantly, the government should massively sensitize and build the capacities of rural communities, who are also the chief victims of climate change, to practise sustainable and environmentally friendly agricultural technologies such as conservation agriculture, farrowing, agroforestry, afforestation, integrated plant nutrient management, integrated pest management etc. that have the capacity to increase resilience to, or mitigate effects of climate change. On a macro level, governments should consider investing in technologies with lower greenhouse gas emissions in key sectors of manufacturing, automobile, health and agriculture. Consequently, various global initiatives and agreements exist aimed at reducing climate change (effects), to which is Tanzania is a signatory, and must therefore remain committed to achieving such goals as Sustainable Development Goal(s) 13 (Climate Action). In accordance with this review, it is envisioned that the climate will continue to have impacts on both agriculture and health sectors. These impacts will extend to socio-economic aspects of rural communities which are most vulnerable to climate change. It must be noted that, climate change does not occur in void, as its effects and resulting environmental alterations interact with agriculture and health sectors.

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REFERENCES

[1] Ahern, M., Kovats, R.S., Wilkinson, P. et al. (2005) Global health impacts of floods: epidemiologic evidence. Epidemiol. Rev. 27: 36–46.
[2] Altizer, S., Ostfeld, R.S., Johnson, P.T.J. et al. (2013) Climate change and infectious diseases: from evidence to a predictive framework. Sci. 341, 514–519.
[3] Biggs, H.M., Bui, D.M., Galloway, R.L. et al. (2011) Leptospirosis among hospitalized febrile patients in

northern Tanzania. American J. Trop. Med. and Hyg. 88: 275-281.

[4] Boon, E., and Ahenkan, A. (2012) Assessing climate change impacts on ecosystem services and livelihoods in Ghana: Case Study of Communities around Sui Forest Reserve. J Ecosyst Ecogr. http://dx.doi.org/10.4172/2157-7625.S3-001.

[5] Brown, O. and Crawford, A. (2008) Climate change: A new threat to stability in West Africa? Evidence from Ghana and Burkina Faso. Afr. Security Rev. 17(3): 39-57.

[6] Brown, O. et al., (2007) Climate Change as the New Security Threat: Implications for Africa. Int. Affairs. 83(6): 1141–1154.

[7] Burke, M., Lobell, and Schlenker, D.W. (2009) Climate change impacts on African agriculture: uncertainties and implications for adaptation. Earth and Env. Sci. 6: 512006. doi:10.1088/1755-1307/6/1/512006.

[8] Costello, A., Abbas, M., Allen, A., Ball, S. et al. (2009). Managing the health effects of climate change. Lancet. 373: 1773–1964.

[9] Craig, M. H., Kleinschmidt, I., Nawn, J.B. et al. (2004). Exploring 30 years of malaria case data in KwaZulu-Natal, South Africa: part I. The impact of climatic factors. Trop. Med. and Int. Health. 9: 1247-1257.

[10] DILAPS (2007) Conflict-free land-use awareness workshop. Dar es Salaam, Tanzania. Nations Framework Convention on Climate Change, (UNFCCC). Vice-President's Office. (VPO). Government printers, Dar es Salaam.

[11] Drancourt, M., Houhamdi, L., and Raoult, D. (2006) Yersinia pestis as a telluric, human ectoparasite-borne organism. Lancet Infect. Diseases. 6: 234-241.

[12] Enfors, E. I. and Gordon, L.J. (2007) Analysing resilience in dry land agro-ecosystems: A case study of the Makanya catchment in Tanzania over the past 50 years. Land Degr. and Devel. 18: 680-696.

[13] Githeko, A.K., and Ndegwa, W. (2001). Predicting malaria epidemics in the Kenyan Highlands using climate data: a tool for decision-makers. Glob. Chan. and Hum. Health. 2: 54-63.

[14] Haines, A., and Patz, J.A. (2004). Health effects of climate change. J. Am. Med. Assoc. 291: 99–103.

[15] Hatibu, N., Young, M.D.B., Gowing, J.W. et al. (2003) Developing improved dry land cropping systems for maize in semi-arid Tanzania. Part I: Experimental Evidence for the Benefits of Rainwater Harvesting. J. of Exper. Agri. 39: 279-292.

[16] Hemp, A. (2009) Climate change and its impact on the forests of Kilimanjaro. Afr. J. Ecol. 47(1): 3–10.

[17] Hulme, M., Doherty, R., Ngara, New, T.M., Lister, D. (2001). African climate change: 1900-2100. Climate Res. 17: 145-168.

[18] IPCC. (2007) Issues Related to Mitigation in the Long Term Context, Contribution of Working Group III to the Fourth Assessment Report of the IPCC, Cambridge: Cambridge University Press.

[19] IPCC. (2001) Climate Change 2001: Synthesis Report. In: Watson, R.T., Team, C.W. (Eds.), A contribution of working groups I, II, and III to the third assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK, and New York, USA.

[20] Levira, P.W. (2009) Climate change impact in agriculture sector in Tanzania and its mitigation measure. Earth and Env. Sci. 6: 372049. doi:10.1088/1755-1307/6/7/372049.

[21] Lindsay, S.W., Bødker, R., Malima, R. et al. (2000) Effect of 1997–98 EI Niño on highland malaria in Tanzania. Lancet. 355: 989–990.

[22] Majule, A. E., Kauzeni, A. S and Mujwahuzi, M. (2013) Exploring opportunities for climate change adaptation in semi-arid areas of Tanzania: A case of Nzega District in Tabora region. Afr. J. of Env. Sci. and Tech. 7(8): 758-769. DOI: 10.5897/AJEST12.230.

[23] Mboera L.E.G., Mayala, B.K.., Kweka, E.J., and Mazigo, H.D. (2011) Impact of climate change on human health and health systems in Tanzania: A review. Tanzania J. of Health Res. 13:1. DOI: http://dx.doi.org/10.4314/thrb.v13i1.10.

[24] Mgode, G.F., Machang'u, R.S., Gorsi, M.G. et al. (2006) New Leptospira serovar Sokoine of serogroup Icterohaemorrhagiae from cattle in Tanzania. Int. J. of Syst. and Evol. Microb. 56: 593-597.

[25] Moore, S., Shresthna, S., Tomlinson, K.W., and Vuong, H. (2011) Predicting the effect of climate change on African Trypanosomiasis: integrating epidemiology with parasite and vector biology. J. of the R. Soc. Interf. doi: 10.1098/rsif.2011.0654.

[26] Mwakisunga, B. and Majule, A.E. (2012) The influence of altitude and management on carbon stock quantities in Rungwe forest, southern highland of Tanzania. Open J. of Ecol. 2: 214-221.

[27] Nakazawa, Y., Williams, R., Peterson, A.T. et al. (2007) Climate change effects on plague and tularemia in the United States. Vector Borne Zoo. Diseases. 7: 529-540.

[28] National Adaptation Programme of Action (NAPA) for Tanzania. (2005) Division of Environment, Vice President Office, Dar es Salaam, Tanzania.

[29] Ojoyi, M., Mutanga, O., Kahinda, J.M., Odindi, J. et al. (2017) Scenario-based approach in dealing with

climate change impacts in Central Tanzania. Fut. 85: 30–41.

[30] Orindi, V.A. and Murray, L.A. (2005), Adapting to climate change in East Africa: A Strategic Approach, Gatekeeper Series 117. Int. Inst. for Env. and Devel. Lond. UK.

[31] Ostfeld, R.S., and Brunner, J.L. (2015). Climate change and Ixodes tick-borne diseases of humans. Philos. Trans. R. Soc. Lond. Ser. B Biol. Sci. 370: (20) (140,051). DOI: 10.1098/rstb.2014.0051.

[32] Patz, J.A., Campbell-Lendrum, D., Holloway, T., and Foley J.A. (2005) Impact of regional climate change on human health. Nat. 438: 310-317.

[33] Pham, H.V., Dang, D.T., Tran Minh, N.N., Nguyen, N.D. and Nguyen, T.V. (2009) Correlates of environmental factors and human plague: an ecological study in Vietnam. Int. J. of Epid. 38: 1634-1641.

[34] Reiter, P. (2001). Climate change and mosquito-borne disease. Env. Health Perspect. 109: 141–161.

[35] Rodó, X., Pascual, M., Doblas-Reyes, F.J. et al. (2013). Climate change and infectious diseases: can we meet the needs for better prediction? Clim. Chang. 118: 625–640.

[36] Rowhani, P., Lobell, D.D., Linderman, M., and Ramankutty, N. (2011) Climate variability and crop production in Tanzania. Agri. and Forest Meteorolog. 151(4): 449–460. http://dx.doi.org/10.1016/j.agrformet.2010.12.002.

[37] Shemsanga, C., Omambia, A.N., and Gu, Y. (2010) The Cost of Climate Change in Tanzania: Impacts and Adaptations. J. of American Sci. 6(3):182-196.

[38] Shikuku, K.M., Valdivia, R.O., Paul, B.K. et al. (2017) Prioritizing climate-smart livestock technologies in rural Tanzania: A minimum data approach. Agri. Syst. 151:204–216.

[39] Stenseth, N.C., Atshabar, B.B., Begon, M., Belmain, S.R. et al. (2008) Plague: past, present, and future. PLoS Medicine, 5:e3.

[40] Trærup, S.L.M., Ortiz, R.A., and Markandya, A. (2011) The Costs of Climate Change: A Study of Cholera in Tanzania. Int. J. Env. Res. Public Health. 8: 4386-4405. doi:10.3390/ijerph8124386.

[41] United Republic of Tanzania (2007) National Adaptation Programme of Action (NAPA). Vice Presidents Office, Division of Environment, Dar es Salaam. Tanzania.

[42] United Republic of Tanzania, (2005) Tanzania Meteorological Agency (TMA) Annual Report. Government Printer, Dar es Salaam. Tanzania.

[43] United Republic of Tanzania (2003) Initial national communication under the United Nations framework convention on climate change (UNFCCC)

[44] United Nations Food and Agriculture Organization (FAO), 2013. Climate-smart agriculture Source book. FAO, Rome.

[45] Van der Werf, G.R., Morton, D.C., De Fries, R.S. et al. (2009) CO2 emissions from forest loss. Nat. Geoscience. 2:737–738.

[46] Wolbring, G. (2009) A Culture of Neglect: Climate discourse and disabled people. J. of Media and Cult. 12:4.

[47] Wu, X., Lub, Y., Zhou, S. et al. (2016) Impact of climate change on human infectious diseases: Empirical evidence and human adaptation. Env. Int. 86: 14–23.

[48] Yanda, P. Z., Kangalawe, R.Y.M. and Sigalla, R.J. (2005) Climatic and Socio-Economic Influences on Malaria and Cholera Risks in the Lake Victoria Region of Tanzania. AIACC Working Paper No. 12.

[49] Yanda, P.Z., Olson, J., and Moshy, P. (2008) Climate Change Vulnerability Impacts and Adaptation in Tanzania. CLIP Working Paper. Inst. of Res. Assessment, Univer. of Dares Salaam, Tanzania.

[50] Zhou, G., Minakawa, N., Githeko, A.K. et al. (2004) Association between climate variability and malaria epidemics in the East African highlands. Proceedings of the National Academy of Sci. of the U.S.A 101: 2375-2380. Eason, B. Noble,