Climate Risk Assessment and Management in Rwanda.

Ndayisenga Jean de Dieu

University of Rwanda, College of science and technology, School of Sciences, Kigali, Rwanda

Email address: ndajadhon@gmail.com

ABSTRACT

Motivated by the needs to predict the climate condition in Rwanda we use the national report for fundamental understanding the national mitigation and adaptation techniques for climate risk management and for management policy prediction. In this study the climate risk in Rwanda was identified and well mentioned, these risks have greater effect on population health and their economy. We also forecast for future using different models including MAGICC for greenhouse gases prediction and SCENGEN for temperature, precipitation and pressure in their variability, and a range of other statistics and also we use HYSPLIT Model for transboundary sources of air pollution in dry season using GDAS meteorological data for backward air pollution sources in Rwanda and forecasting the future sources, which will be very helpful in developing new mitigation and adaptation project for climate resilience, during August the air pollutants comes very far some from Asia mainly in Syria, Indian Ocean other from North Africa mainly in Libya, while the forward does not go beyond DRC. During this study we was realize that the seasonal shift in Rwanda threaten population planed activities and cause disasters and reduce yield production, the greenhouse gases emission in Rwanda will be reduced in 2050 compared to the baseline situation and the global annual temperature change will be 1.58 degree celicius and 24.8% in Rwanda while the annual pressure is 9.5% and annual precipitation is -13.3% in 2050.

Keywords: Climate change, MAGICC, SCENGEN, HYSPLIT, Climate risk assessment, Climate risk management, mitigation, adaptation, GHGs, Rwanda.

1. Introduction

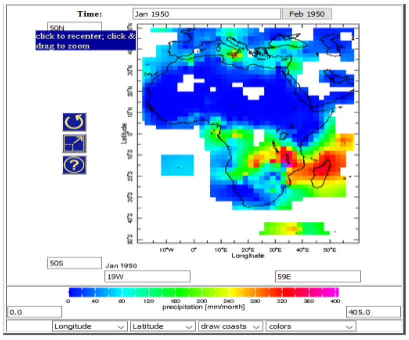
Climate change is among the global health problems in 21st century including animals' health, human health and ecosystem health. Rwanda was affected by these issues of climate changing in many ways such as floods, droughts, landslides, windstorms and rainstorms which affect populations' health in many ways like food security, water sanitation and urbanization. (Mubaya and Mafongoya, 2017)a. Other climatic variables includes rising of temperature, variance in rainfall (Tripathi and Mishra, 2017). This is due to the extreme climate and weather events together with vulnerability and exposure by population and generally by nature (IPCC, 2012). This is common to the east Africa country where there is a frequently increases of drought (Lyon and Vigaud, 2017). This issues of climate change is mainly caused by increases of green house gases emission comes at big amount from anthropogenic activities (Rojas-Downing *et al.*, 2017). This changing of climate is directly proportional to the decreases in crops production caused by soil degradation and animals production (Joosten and Grey, 2017).

2. Climate change and water sanitation

The big impact of climate change facing the developing countries more than developed countries (Rizvi *et al*., 2015). There is some studies shows that climate changes affect drinking water quality and its availability to the populations due to the droughts, higher rainfall, increased temperature all of this affect water distribution, its treatment and sometimes can cause contamination with toxic chemicals, nutrients, algae, and bacteria (Boholm and Prutzer, 2017). Also the climate changes cause an increased waterlogging, which likely drive pits, tanks and sewers to be inundated with groundwater, and affect the processes of treatment. By putting together the result of all of these factors will cause an increase in the outbreak of waterborne diseases (Washington, 2016).

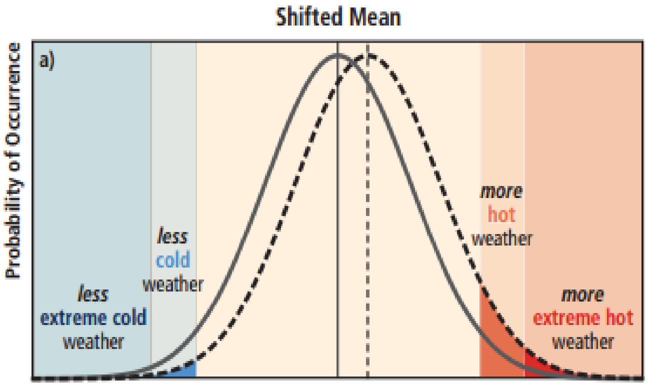
3. Climate change and agriculture

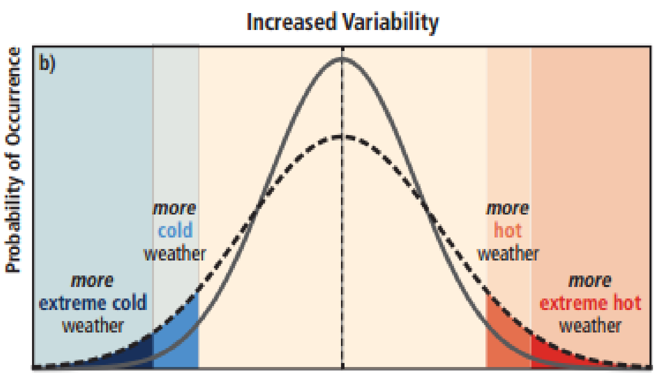
The Rwanda ministry of foreigner affairs (2018) shows that the most common activities in Rwanda is agriculture, in case of intense rain or drought becomes a key drivers of food security. Farmers becomes vulnerable to the risks in agriculture sector (Mubaya and Mafongoya, 2017)b. The smallholder farmers possess in many country small land and weak habitants and due to disaster they looses their basic needs and cause to miss investment leads to reducing agricultural yields production which affect welfare of their families (Boholm and Prutzer, 2017).



Map 1: The 20-year running average precipitation for Africa.

The research conducted in East Africa on the sites of Nyando, Kenya; Hoima, Uganda; Lushoto, Tanzania; and Borana, Ethiopia; shows that farmers' attitudes across the sites tended to favor managing of crop including the ideas of introducing the new crops, varieties change, and also changes in crops planting times, soil management and water management for irrigation (Shikuku *et al.*, 2017). Climate change was influenced by mainly anthropogenic activities and also there is different shift caused by these changes including shift in mean, in variance, and both in mean and variance (IPCC, 2012).





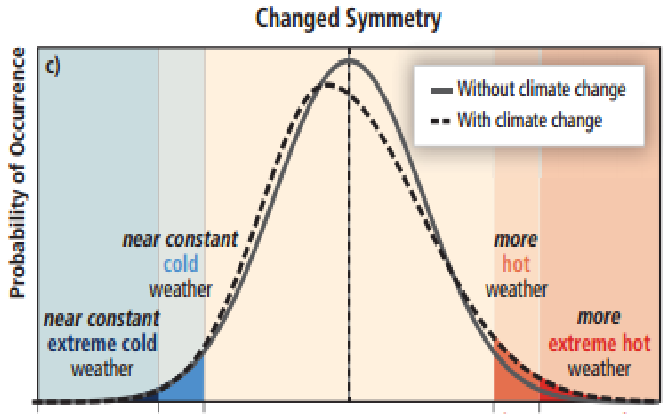
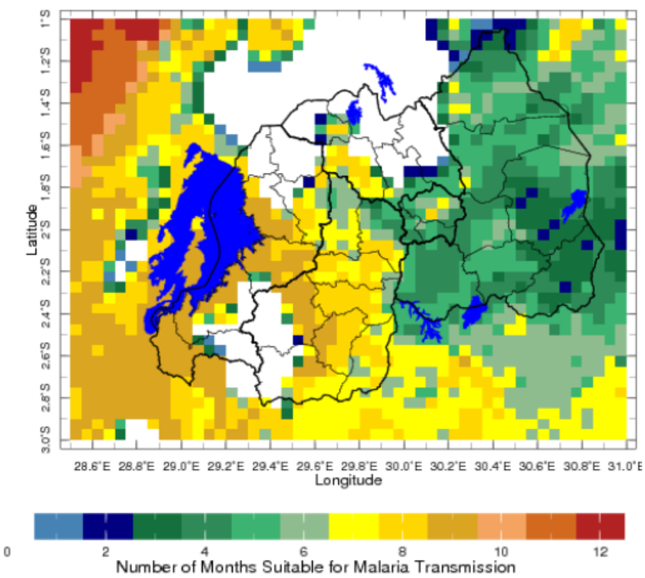


Figure 1: climate shift (IPCC Report, 2012).

4. Climate change and diseases

Climate change is also a driver of diseases due to long exposures to the polluted air may cause respiratory diseases (WHO, 2014). It is not easy to quantify the respiratory diseases related immediately to the climate changes, and other diseases like malaria which is more intense in equatorial zone (Boholm and Prutzer, 2017). Diarrheal disease and undernutrition diseases (WHO, 2014).



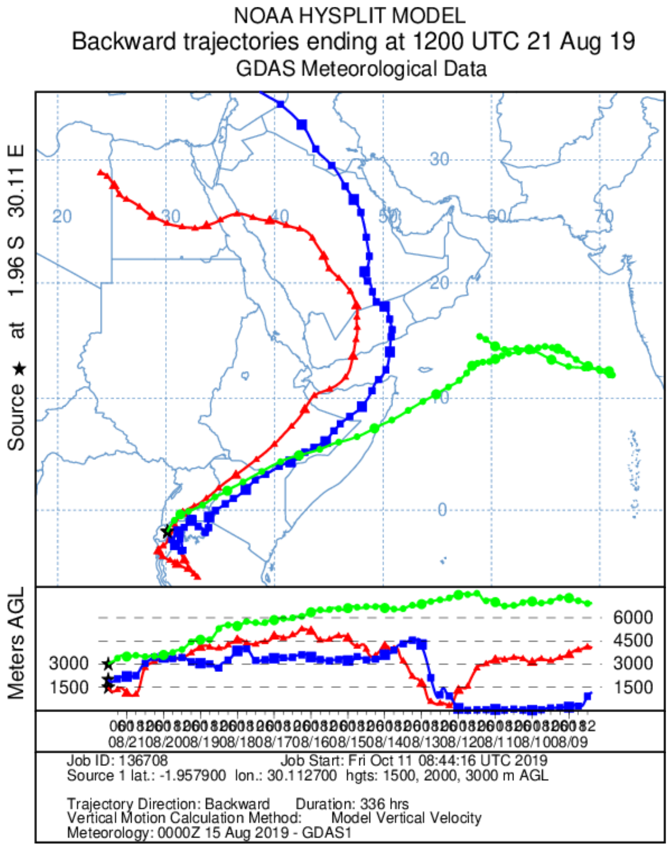
Map 2: Number of months suitable for malaria transmission (Meteo Rwanda)

This map shows malaria transmission based on climatologically averages as mentioned on meteo Rwanda the favorite for mosquito to develop easily refer to the condition of temperature between 18ºC to 32ºC, precipitation above 80mm and relative humidity greater than 60%.

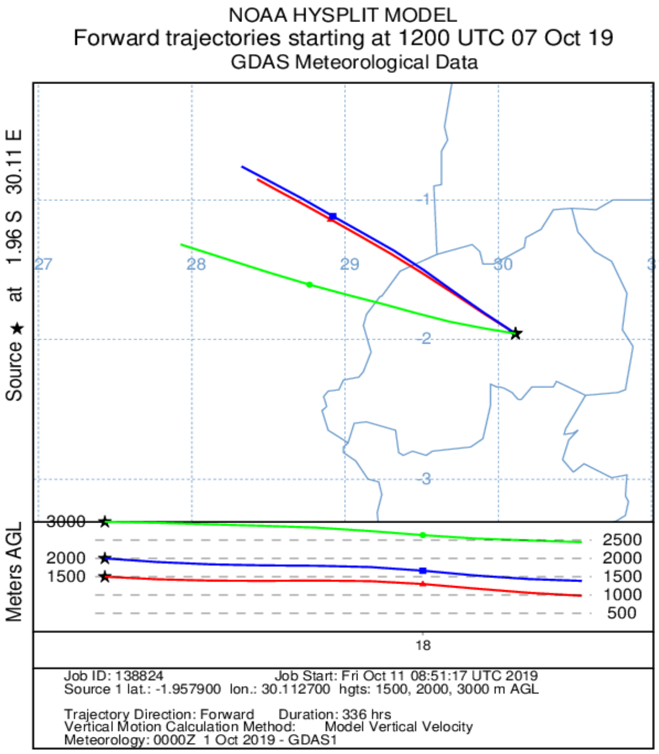
5. Key cause of climate changes in Rwanda

Climate change is a global problem as we share the same atmosphere, insolation radiation, and also the connection of the factors of climate systems, whenever pollution comes from it affect global health. Taking an example of emission of long lived toxic compound it can cause impact all over the globe as it is transmitted due to worker circulation, ocean current and other global phenomenon. Rwanda National Environment and Climate Change Policy, (2019) said that urbanization is among the cause of climate change in Rwanda. Rwanda is among the highest population densities in Africa where the population density is 456 inhabitants per square kilometer and becomes doubled when projected in 2050 where 70% of population will be in urban area and this will be another climate change driver in Rwanda.

The transboundary pollution also play a big role in Rwanda climate, as the following map (map 3a) shows the transboundary air pollution between 7 to 21 August 2019 comes from Libya, Syria, Indian Ocean at 1500 mACL, 2000 mACL, 3000 mACL respectively as shown while the forward pollution from Rwanda from 7 to 21 October does not reach the far away it end in DRC (map 3b), this is due to the biomas burning impact as it is in dry season.



Map3a: Backward and forward pollution



Map3b: Backward and forward pollution

6. Factors determining climate changes

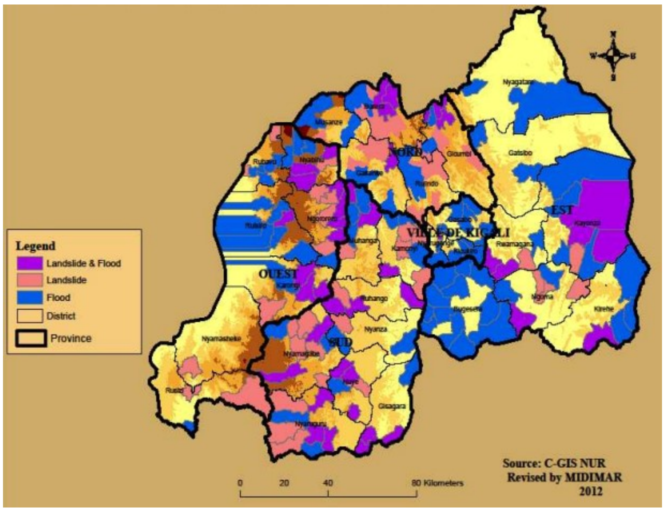
There are many factors determining global climate change which are natural and anthropogenic activities. Most of human activities are discussed above, now let look on natural activities; the major driving factor is energy from the sun. The electromagnetic radiation from the sun propagate up the earth's surface most of incident short waves are absorbed in atmosphere due to its wavelength belong to the absorption wavelength band and the others short waves reach the ground then absorbed and re-emitted back in atmosphere in form of long waves invisible infrared energy and its magnitude is determined by the temperature of the earth atmospheric system. The change in incoming short waves from the sun and emitted long waves from the earth's surface causes radiative forcing on climate. Another factor is the greenhouse effect, this effect is due to the long waves emitted from the earth's surface absorbed by trace gases known as greenhouse gases and re-emitted back to the earth's surface and this process cause global warming. The green house gases include carbon dioxide (CO_2), water vapor (H_2O), tropospheric ozone (O_3), methane gas (CH_4), SF_6 and HFCS.

7. Risk of climate change management

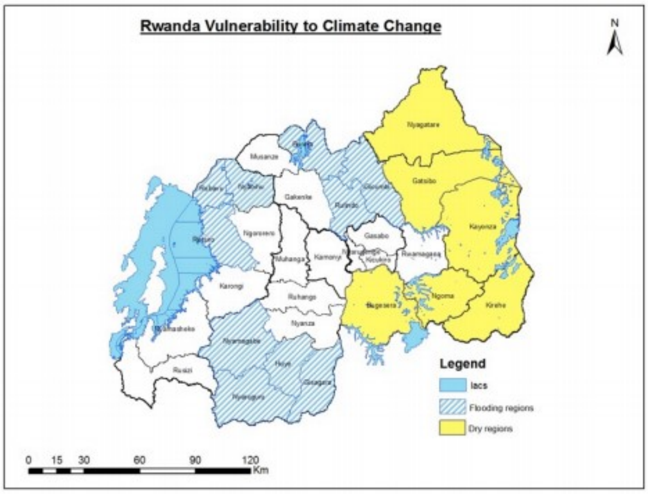
Climate risk rising and it has a big implication on country's economy as world bank mentioned this affect the implementation of projects which help in country's development (World Bank, 2006). Thus it is very necessary to consider climate impact during project implementation design. We do not neglect the way for which climate change may cause conflict, taking a simple example on declining water resources and diminishing arable land due to climate change are already intensifying competition populations or those moving in search of improved livelihoods this is what happen to the population of Darfur, the Sahel, DRC and northern Kenya, for those resources, and creating tensions for displaced (Besada & Sewankambo, 2009).

The major factors affecting the climates in East Africa where Rwanda is located include altitude, the proximity of the warm Indian Ocean, the migration of the Inter-Tropical Convergence Zone (ITCZ) and the place of high and low atmospheric pressure systems (Daron, 2014). The most major disaster in Rwanda is floods and landslide which have a bid impact on population economy, properties, infrastructures and Rwandan environment. Based on the baseline information on climate change it is easy to specify the high risk zone for hazardous event to the community and then develop policy or invest in mitigation and adaptation project to save the community (MIDIMAR, 2012).

Climate-related risks are now evolving over time due to both climate change and development and this require the decision maker to introduce the ways of adaptation and mitigation for reducing the climate change impact (IPCC, 2014).



Map 4a: Landslide and Flood risk location (MIDIMAR, 2012).



Map 4b: Rwanda vulnerability (Munyazikwiye, 2014).

Since 2011 at least 10 peoples was killed by flooding and hundreds displaced, 349 houses was destroyed and 3,000 hectares of farmer's land was damaged and 14 peoples was killed also by landslide in Gikoro cell in Nyabihu district in Western province. This comes following 43 peoples lost their lives 73 peoples injured and 1854 houses and 100 classroom destroyed and 2,989.2 hectares of crops damaged in 2010 (MIDMAR,2012). MINEMA disaster annual report from 2016 to 2019 shows that since 2016, 183 deaths was occurred 172 injured and 2 people missed 75 houses destroyed, 5821 houses and 82 classroom damaged and 40 bridges, 7449 crops hectares damaged. In 2017, there was 82 deaths 151 injured 5802 houses, 203 classroom, 13 roads, 37 churches, 49 bridges, 5277.1 crop hectares was damaged. In 2018 there was 254 deaths, 346 injured, and 15910 houses, 73 classrooms, 32 roads, 27 churches, 64 bridges damaged. In 2019 there was 80 deaths, 212 injured, and 4796 houses, 8424.9 crops hectares, 169 classrooms, 7 roads, 59 churches, 22 bridges damaged.

Map 5: Flood at Gakenke

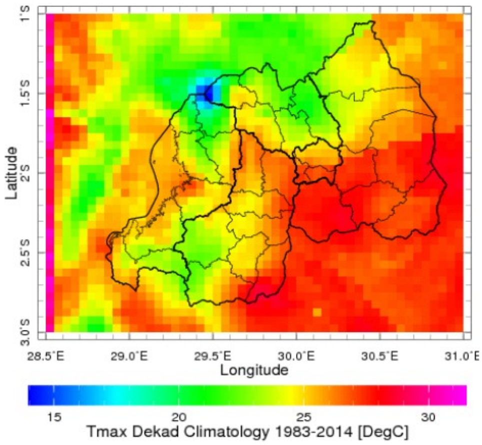
Map 6: Flooded area in Nyabihu 2011 (MIDIMAR, 2012).

Maps 7: Catastrophic deseaster

8. Vulnerability assessment

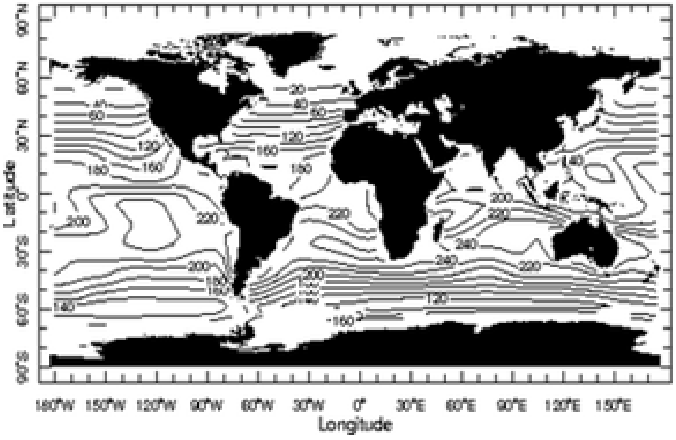
8.1. Temperature

Rwanda is among developing country for which the development is more affected by climate change, the increase in temperature varies between 1.4ºC to 2.56ºC over south west and east region of Rwanda from 1971 to 2016, where in the northern region the increase in temperature was 0.1 ºC to 1.7 ºC *(U. N. F. C. C., 2018).*



Map 8: Mean temperature in Rwanda

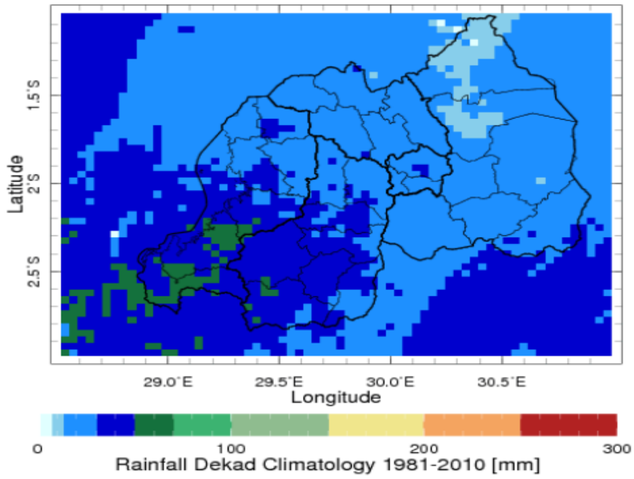
As more incoming radiation reach the ground surface the higher sea surface temperature and even temperature on ground increases here the greenhouse gases play a big role.



Map 9: Averages of monthly solar radiation (IRI Columbia modal Sept. 2019)

8.2. Precipitation

Nowdays the seasonal variation in Rwanda is among the factors showing the climate change, the rain variability in Rwanda was occurring in mean, in variance and both in mean and variance.



Map 10: Total mean rainfall 01 september 1981 to 31 december 2016 (Meteo Rwanda)

9. Greenhouse gases

This is the gases that absorbs long waves radiations and emits radiant energy within the thermal infrared range. The most abundant greenhouse gases in Earth's atmosphere include; Water vapor (H_2O) ,Carbon dioxide (CO_2), Methane gas (CH4), Nitrous oxide (N_2O), Ozone (O_3), Chlorofluorocarbons (CFCs) and Hydrofluorocarbons (includes HCFCs and HFCs).

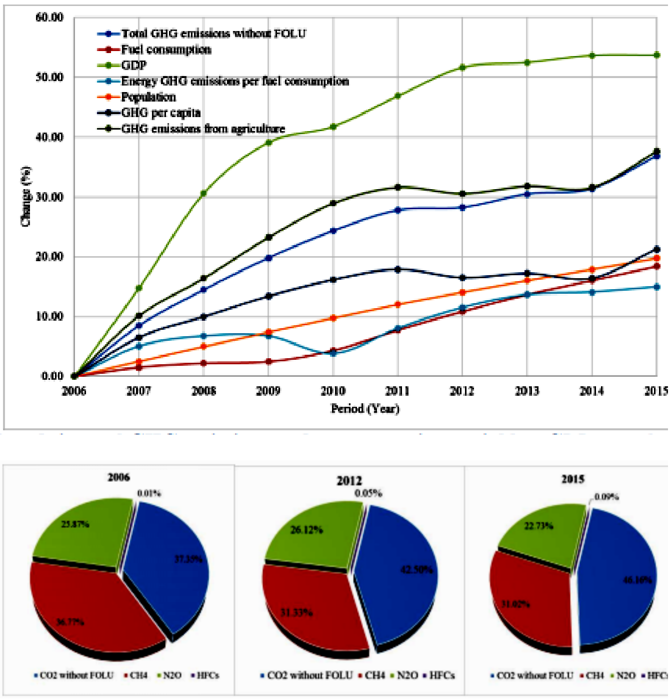


Figure 2: GHG emissions in Rwanda (U. N. F. C. C., 2018).

9.1. Global mean changes based on GHGs emissions (1990-2100)

In assessing the emission, the concentration and the radiative forcing of global greenhouse gases we are going to use MAGICC and SCENGEN. The MAGICC and SCENGEN couple, are user-friendly interactive software suites that allow users to investigate future climate change and its uncertainties at both the global-mean and regional levels. MAGICC carries through calculations at the global-mean level using the same upwelling-diffusion, energy-balance climate model that has been and is employed by IPCC. SCENGEN uses these results, together with spatially detailed results from the CMIP3/AR4 archive of AOGCMs, to produce spatially detailed information on future changes in temperature, precipitation in their variability, and a range of other statistics.

MAGICC is a coupled gas-cycle/climate model. It has been used in all IPCC reports to produce projections of future global-mean temperature and sea level change, and their produced results was used in the IPCC Reports. MAGICC can be used to extend results given in the IPCC latest report to other emissions scenarios.

9.1.1. Carbon dioxide emissions

The main anthropogenic sources of carbon dioxides are the use of fossil fuel even if you do not neglect other sources such as land use and industrial processes. The natural sources of carbon dioxide include ocean-atmosphere exchanges, plants and animals respiration, soil respiration and decomposition and volcanic eruption.

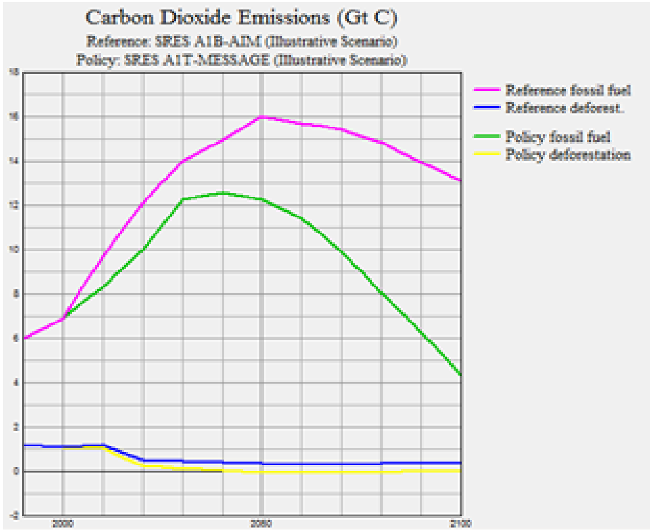


Figure 3: Global Carbon dioxide emissions

This map shows the global amount of carbon dioxide emitted in gigatone of carbon from 1990 up to 2100 along with two different scenarios A1B-AIM and A1T-MES. Also it show the information of what happen in case of deforestation. From 1990 up to 2000 both scenarios shows that CO_2 emissions increases from 6Gt C to 7 Gt C. For A1B-AIM scenario CO_2 emission increases more than that of A1T-MES up to now. CO_2 emission for A1B-AIM scenario will continue to increase up to its maximum emission of 16Gt C up to 2050 where it start to decrease up to 13 Gt C in 2100. For A1T-MES scenario CO_2 emission will increases also up to its maximum of around 12.5 Gt C in 2040 and start to decrease up to 4.5 Gt C in 2100.

In case of deforestation both scenarios has around 1.2 Gt C initially since 1990 and decreased up to 1Gt C in 2000. For both scenarios CO_2 emission decreases up to 2100 where for A1T-MES scenario it decrease slightly more than A1B-AIM.

9.1.2. Methane emissions

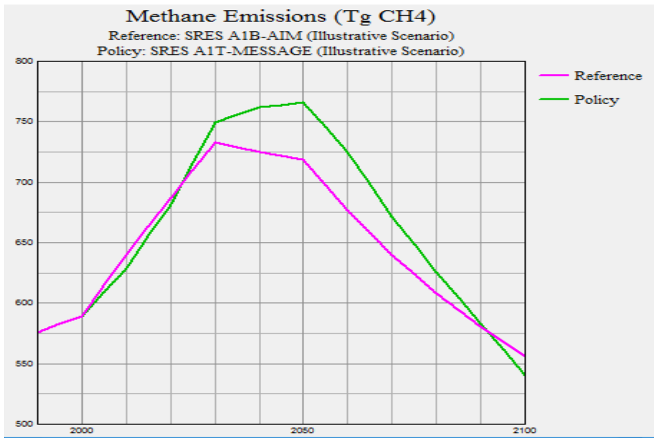


Figure 4: Global methane emission

As mentioned above on carbon dioxide emission for A1B-AIM and A1T-MES scenarios from 1990 to 2000 emission of methane increases equally from 575 Tg up to 587.5 Tg. And up to now the emission was continue to increase even A1B-AIM scenario shows high emission than that shown by scenario A1T-MES. For both scenarios the emission will continue to increase but before reaching their maximum emissions, around 2032 both scenarios shows that they will be the same emissions of 700Tg. And also in 2091 the emission will be 575Tg for both scenarios. The maximum emissions for A1B-AIM scenario is around 730 Tg in 2030 where in 2100 their predicted emission will be around 560 Tg. For A1T-MES the maximum emissions will be around 762.5Tg in 2050 and the emissions in 2100 will be around 539Tg. Simply A1B-AIM scenario emission of methane is low compared to that of A1T-MES scenario.

9.1.3. Nitrous oxide emissions

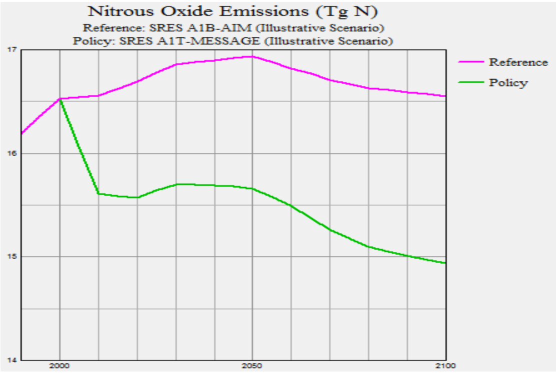


Figure 5: global Nitrous oxide emissions

Since 1990 up to 2000 both A1B-AIM and A1T-MES scenarios shows that the nitrous oxide emission increases at the same rate from around 16.2Tg N up to 16.5Tg N. For A1T-MES the emission decreases faster up to 2010 from its maximum of 16.2Tg N to 15.6Tg N. The emission will continue to decreases not dramatic up to 2020 and increase up to2030 followed by decrease until 2100 with around 14.9Tg N of emissions. But for A1B-AIM scenario the emission will continue to increase from 2000 up to its maximum in 2050 with 16.9Tg N of emission where it start to decreases up to 2100 with 16.6Tg N of emission.

Therefore A1T-MES scenario shows lower nitrous oxide emission compared to that of A1B-AIM scenario.

9.1.4. Sulphur dioxide emissions

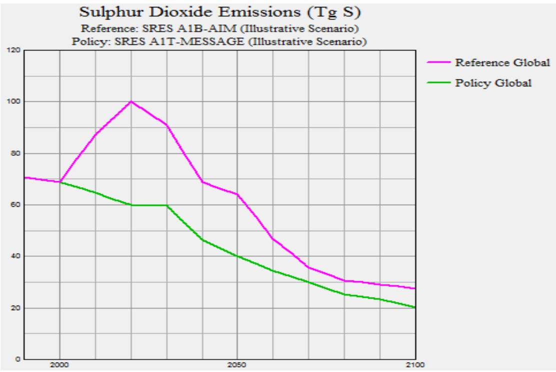


Figure 6: Global Sulphur dioxide emissions

Similar to the above discussed emissions, both A1B-AIM and A1T-MES scenarios their sulphur dioxide emissions was equals and decreases from 70Tg S in 1990 to 69Tg S in 2000. For A1T-MES scenario the emission continue to decreases up to 60Tg S in 2020 where it remain constant up to 2030, and continue to decrease up to 2100 with 20Tg S of emissions. But for A1B-AIM scenario their emission start to increase from 69Tg S in 2000 up to its maximum of 100Tg S in 2020 where it start to decrease up to around 19Tg S in 2100.

Thus A1T-MES scenario shows the lower emissions of sulphur dioxide compared to that shown by A1B-AIM scenario.

9.2. Global mean changes based on concentrations (1990-2100)

9.2.1 Carbon dioxide concentrations

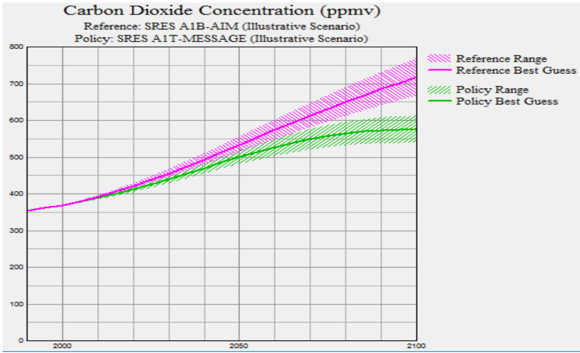


Figure 7: Global Carbon dioxide concentrations

Both A1B-AIM and A1T-MES scenarios has the same carbon dioxide concentration since 1990 up to 2010. For A1B-AIM the concentration continue to increase more than that shown on A1T-MES scenario. In 2100 the carbon dioxide concentration will be around 720 ppmv for A1B-AIM scenario and around 575 ppmv for A1T-MES scenario. This graph shows that carbon dioxide concentration will be low for A1T-MES scenario.

Thus, based on emission and concentration graph for both A1B-AIM and A1T-MES scenarios, we conclude that concentration and emissions of carbon dioxide are proportional.

9.2.2. Methane concentrations

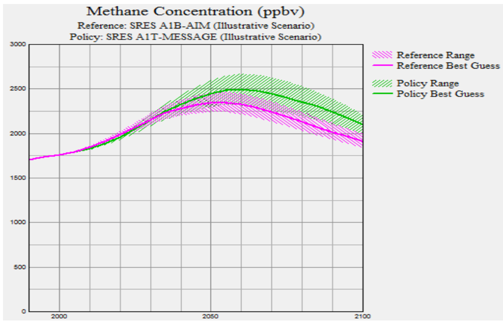


Figure 8: Global Methane concentrations

Both A1B-AIM and A1T-MES scenarios have the same methane concentration since 1990 up to 2035 which are around 1740 ppbv to 2250ppbv respectively. For A1T-MES the concentration continue to increase more than that shown on A1B-AIM scenario until it reaches its maximum concentration of 2500 ppbv in 2060, and start to decrease up to around 2240 ppbv in 2100. For A1B-AIM scenario the concentration increases also up to its maximum concentration of around 2350ppbv in 2051, where it start to decrease up to around 1900 ppbv in 2100.

Therefore the lower concentration of methane are obtained by A1B-AIM scenario.

9.2.3 Nitrous oxide concentrations

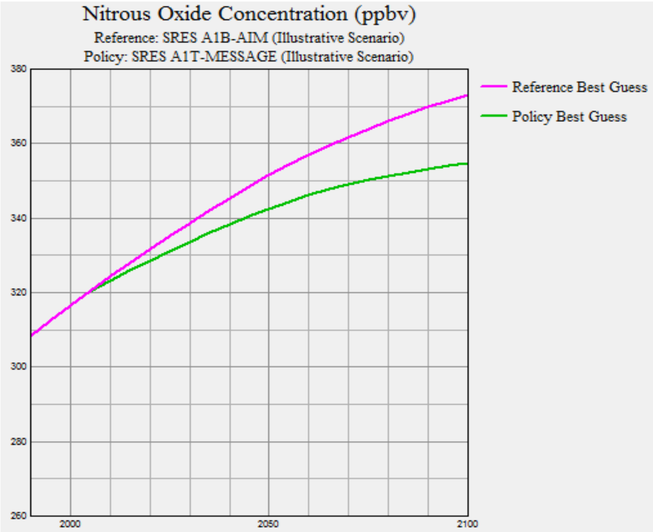


Figure 9: Global Nitrous oxide concentrations

As the above graph shows, both A1B-AIM and A1T-MES scenarios have the same Nitrous oxide concentration since 1990 up to 2005 which are around 309 ppbv to 320 ppbv respectively. For A1B-AIM scenario the concentration continue to increase more than that shown on A1T-MES scenario until it reaches around 372 ppbv in 2100. For A1B-AIM scenario the concentration continues also to increase less than that shown on A1T-MES scenario until it reaches around 354 ppbv in 2100. Thus A1T-MES scenario show the lower nitrous oxide concentration compared to that shown by A1B-AIM scenario.

9.3. Radiative forcing

Radiative forcing is the balance of radiation change between incoming radiation into the atmosphere and radiation going out. This is caused by different factors such as changes in insolation, changes in albedo, ozone, the concentrations of greenhouse gases present in atmosphere and aerosols content. There are two types of radiative forcing which are Positive forcing (incoming energy exceeding outgoing energy) known as warming and negative forcing (outgoing energy exceeding incoming energy) known as cooling.

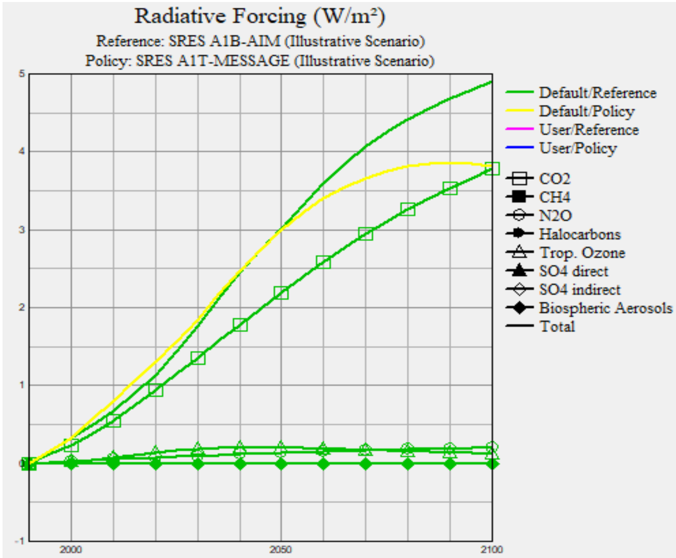


Figure 10: Global radiative forcing

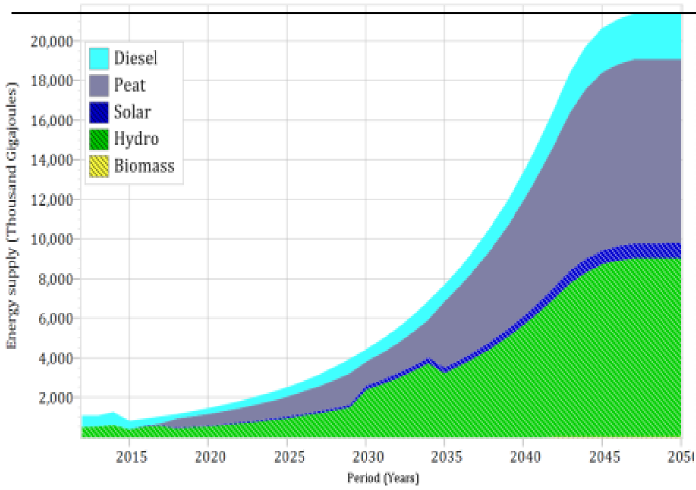
Changes in variability (annual pressure, annual mean temperature and annual precipitation) based on the scenario A1B-AIM, at this step we use SCENGEN by default.

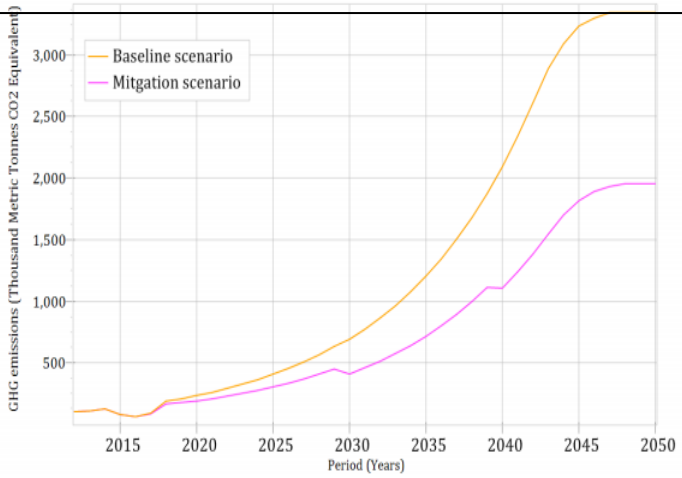
By using geographic coordinate of 2.5°s-0° and 27.5°E-30.0°E including a part of Rwanda , we obtain that the annual precipitation is -13.3%, the annual pressure is 9.5% and the annual mean temperature is 24.8% in 2050 this implies that there is a variability of annual precipitation, pressure and mean temperature in that region. We can link this information to the seasons we have here in Rwanda.

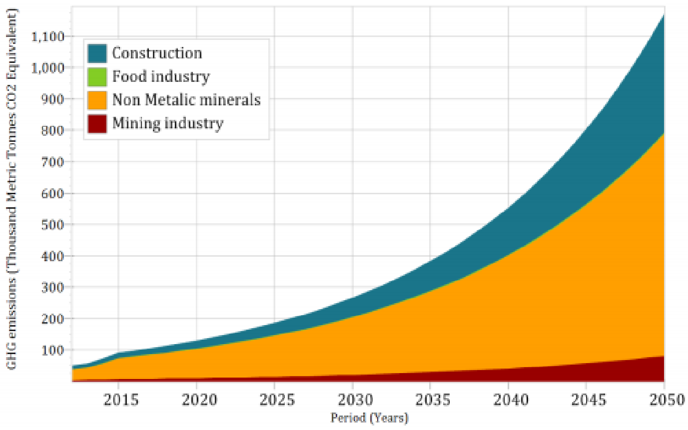
Rwanda's long rainy season lasts from about March to May, when the rain is heavy and persistent. Then from June to mid-September is the long dry season. October to November is a shorter rainy season and it's followed by a short dry season from December to February and based on the information obtained on the map the season will be dramatically changed in 2050. During both of Rwanda's dry seasons, there is often light cloud cover. This helps to moderate the temperatures, but also occasionally brings light rain showers.

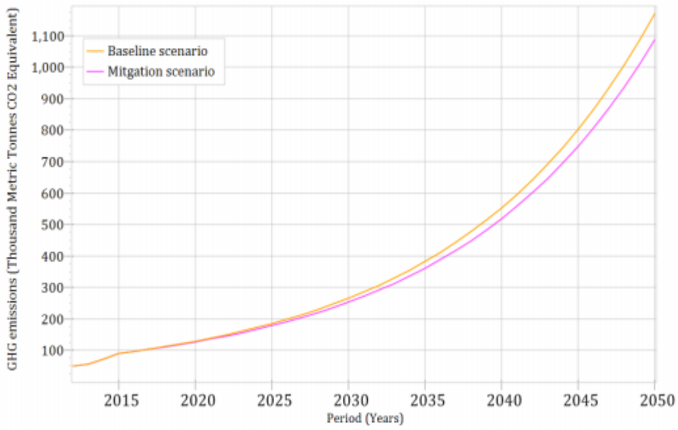
10. Climate change management in Rwanda

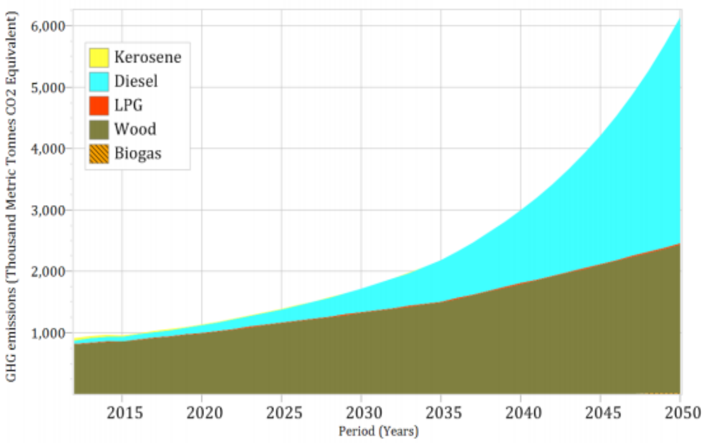
As mentioned in different national institution report, Rwanda has many climate change management strategy. The following figure shows the mitigation policy projection result in reducing greenhouse gases.


Diesel
Peat
Solar
Hydro
Biomass
Energy supply (Thousand Gigajoules)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
2015
2020
2025
2030
2035
2040
2045
Period (Years)


Baseline scenario
Mitgation scenario
GHG emissions (Thousand Metric Tonnes CO2 Equivalent)
3,000
2,500
2,000
1,500
1,000
500
2015
2020
2025
2030
2035
2040
2045
2050
Period (Years)


Construction
Food industry
Non Metalic minerals
Mining industry
GHG emissions (Thousand Metric Tonnes CO2 Equivalent)
1,100
1,000
900
800
700
600
500
400
300
200
100
2015
2020
2025
2030
2035
2040
2045
2050
Period (Years)


Baseline scenario
Mitgation scenario
GHG emissions (Thousand Metric Tonnes CO2 Equivalent)
1,100
1,000
900
800
700
600
500
400
300
200
100
2015
2020
2025
2030
2035
2040
2045
2050
Period (Years)


Kerosene
Diesel
LPG
Wood
Biogas
GHG emissions (Thousand Metric Tonnes CO2 Equivalent)
6,000
5,000
4,000
3,000
2,000
1,000
2015
2020
2025
2030
2035
2040
2045
2050
Period (Years)

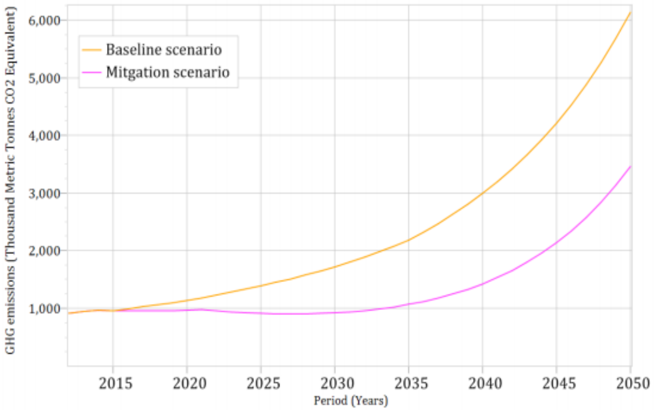


Figure 12: mitigation scenario of solid waste management (U. N. F. C. C., 2018).

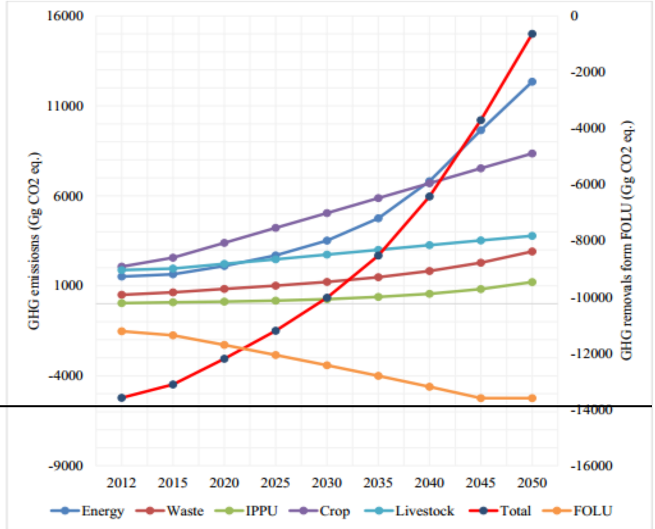
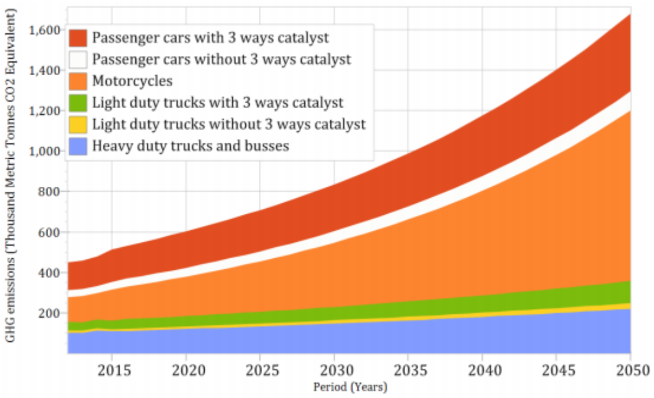
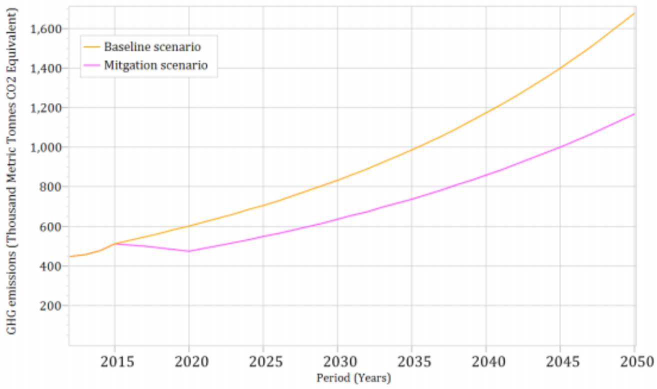


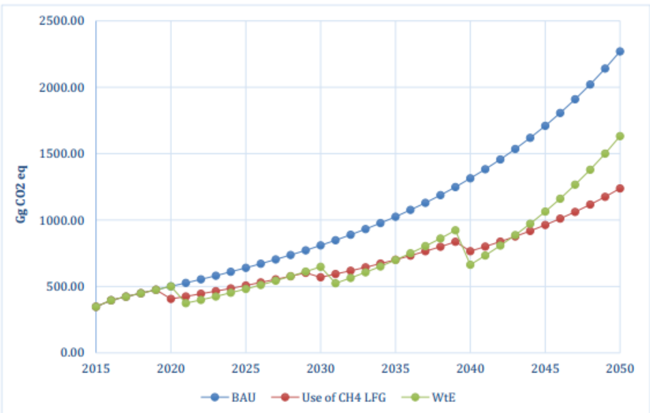
Figure 13 a: Emission simulation trends baseline and its mitigation respectively (U. N. F. C. C., 2018).





Figures 11: GHG emission sources and its corresponding mitigation and baseline scenario in Rwanda 2012-2050 (U. N. F. C. C., 2018).

Managing the greenhouse gases emission from solid waste is also summarize on the following figure as its baseline emission and its mitigation scenario projection from 2015S to 2050.



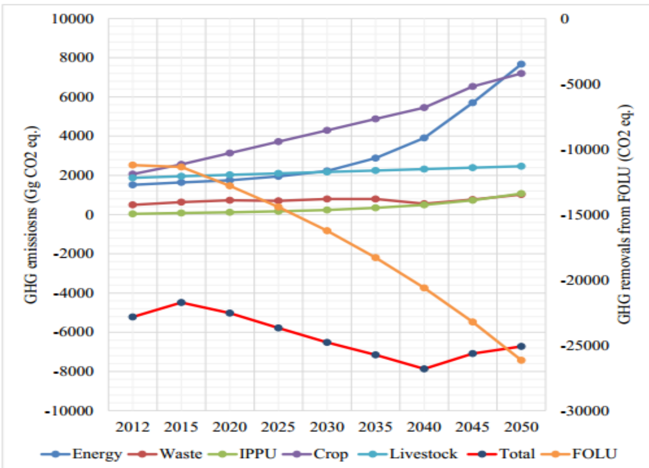


Figure 13 b: Emission simulation trends baseline and its mitigation respectively (U. N. F. C. C., 2018).

Conclusion

The Rwanda varied agriculture and livestock production systems that are at risk from climate change in distinct ways. Weather-related crop and livestock losses are affecting economic losses leading to the food security in the different region as mentioned on map 4. The heavy rainfall events in different region raise the risk of storm and flood damage to agricultural production. The increase in temperature which is proportional to the evaporation rates is likely to increase water stress, especially in dry season (USAID, 2018). Climate risks to agriculture combined with rapid population growth may threaten the food security and economies of the countries (IFPRI, 2013). The global projections for greenhouse gases concentration will be increased up to 2100 while most of greenhouse emission will increases up to 2050 and start to reduce; this difference in emission and concentration is due to the long lived of some greenhouse gases.

From temperature projections for IPCC Fifth Assessment Report (Riahi et al 2011) and Policy Reference including implementation of the proposed mitigation (Rogelj et al. 2010), all the two was close or exceed by a substantial margin, 1.5°C warming (UNEP, 2012). From the modol used we have seen that the warming will be 1.58°C in 2100. The Rwanda will need to continue investing in climate change adaptation and mitigation project in order to improve population economy and generally country' economy.

Acknowledgements

It is more acknowledged to use the following data set and model for getting the information covered in this research. We are using meteo Rwanda data set for the information contained on maps regarding rainfall, malaria transmission, and temperature in Rwanda. We also use IRI Columbia data set using www.IRI data library to retrieve the global information and forecasting up to 2050 based on change in model standard deviation for annual mean temperature, annual pressure, annual precipitation and we use The MAGICC model and SCENGEN which are software used to investigate future climate change and its uncertainties at both the global-mean and regional levels.

References

Mubaya, C. P., & Mafongoya, P. (2017). The role of institutions in managing local level climate change adaptation in semi-arid Zimbabwe. *Climate Risk Management*, *16*, 93–105. https://doi.org/10.1016/j.crm.2017.03.003

Tripathi, A., & Mishra, A. K. (2017). Knowledge and passive adaptation to climate change: An example from Indian farmers. *Climate Risk Management*, *16*(2017), 195–207. https://doi.org/10.1016/j.crm.2016.11.002

Report, S., The, O. F., Panel, I., & Change, O. N. C. (2012). Climate Change, Disaster Risk, and the Urban Poor. In *Climate Change, Disaster Risk, and the Urban Poor*. https://doi.org/10.1596/978-0-8213-8845-7

Rwanda National Environment and Climate Change Policy. (2019). (June), 1–59.

Bank, W., & Operations, G. (2006). *Managing Climate Risk World Bank Group Global Environment Facility Program*. Retrieved from http://siteresources.worldbank.org/GLOBALENVIRONMENTFACILITYGEFOPERATIONS/Resources/Publications-Presentations/GEFAdaptationAug06.pdf

Daron D., (2014). *Regional Climate Messages for East Africa*. 1–29.

Shikuku, K. M., Winowiecki, L., Twyman, J., Eitzinger, A., Perez, J. G., Mwongera, C., & Läderach, P. (2017). Smallholder farmers' attitudes and determinants of adaptation to climate risks in East Africa. *Climate Risk Management*, *16*, 234–245. https://doi.org/10.1016/j.crm.2017.03.001

Mubaya, C. P., & Mafongoya, P. (2017)b. The role of institutions in managing local level climate change adaptation in semi-arid Zimbabwe. *Climate Risk Management*, *16*, 93–105. https://doi.org/10.1016/j.crm.2017.03.003

Rojas-Downing, M. M., Nejadhashemi, A. P., Harrigan, T., & Woznicki, S. A. (2017). Climate change and livestock: Impacts, adaptation, and mitigation. *Climate Risk Management*, *16*, 145–163. https://doi.org/10.1016/j.crm.2017.02.001

Boholm, Å., & Prutzer, M. (2017). Experts' understandings of drinking water risk management in a climate change scenario. *Climate Risk Management*, *16*, 133–144. https://doi.org/10.1016/j.crm.2017.01.003

MIDIMAR. (2012). *Identification of Disaster Higher Risk Zones on Floods and Landslides in Rwanda Republic of Rwanda Ministry of Disaster Management and Refugee Affairs Unit of Research and Public Awareness Disaster High Risk Zones on*. (March), 1–33.

Rizvi, A. R., Baig, S., Barrow, E., & Kumar, C. (2015). *Synergies between Climate Mitigation and Adaptation in Forest Landscape Restoration*. 75.

U. N. F. C. C. (2018). *REPUBLIC OF RWANDA Rwanda Environment Management Authority THIRD NATIONAL COMMUNICATION UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON Third National Communication Report to the*

United Nations Framework Convention on Climate Change. (September).

WHO. (2014). *Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s*. Retrieved from http://www.who.int/globalchange/publications/quantitative-risk-assessment/en/

Washington, R., Todd, M., Reason, C., Pokam, W., Hart, N., Blamey, R., Kolusu, S., Desbiolles F.& James R., (2016). *Africa's Climate*. (November), 112.

Joosten, K., & Grey, S. (2017). *Integrating climate change adaptation and mitigation into the watershed management approach in Eastern Africa; Discussion paper and good practices*.

IPCC. (2014). Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. *Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of TheII Ntergovernmental Panel on Climate Change.*, (1–32).

Lyon, B., & Vigaud, N. (2017). *Unraveling East Africa's Climate Paradox*. (June), 265–281. https://doi.org/10.1002/9781119068020.ch16

Munyazikwiye, F., (2014). Climate Change and International Obligations Dpt /REMA. *Climate Change impact, risks, mitigation and adaptation Strategies in* Rwanda. (May).

Besada, H. & Sewankambo, N. (2009). *CIGI Special Report Climate Change in Africa: Adaptation, Mitigation and Governance Challenges*. Retrieved from ww.creativecommons.

Rwanda ministry of foreigner affairs, (2018). *Climate Change Profile Rwanda*.

USAID. (2018). *Climate Risk Profile West Africa*. (December). Retrieved from https://www.climatelinks.org/sites/default/files/asset/document/West_Africa_CRP_Final.pdf

IFPRI. (2013). West African agriculture and climate change.

UNEP. (2012). *Climate-change impacts, adaptation challenges and costs for Africa*

Riahi, K., S. Rao, V. Krey, C. Cho, V. Chirkov, G. Fischer, G. Kindermann, N. Nakicenovic and P. Rafaj (2011). *"RCP 8.5—A scenario of comparatively high greenhouse gas emissions."* Climatic Change 109(1): 33-57.

Rogelj, J., C. Chen, J. Nabel, K. Macey, W. Hare, M. Schaeffer, K. Markmann, N. Höhne, K. Krogh Anderson and M.

Meinshausen (2010). "*Analysis of the Copenhagen Accord pledges and its global climatic impacts, a snapshot of dissonant ambitions."* Environmental Research Letters 5(3): 034013.