CLICC Country Level Impacts of Climate Change

# CLICC Phase 2 Pilots – Malawi

DRAFT outputs for cross-pilot QA

09/06/2019

This document presents **observed** and **projected** climate impacts in Malawi using the Country Level Impact of Climate Change (CLICC) templates. The templates have been specifically designed primarily for countries to collate and present a synthesis of **existing** information. While the presentation of the impacts for all the five sectors, comprising Agriculture, Energy, Water, Built Infrastructure and Ecosystems, is based on a synthesis of available literature, it is also supported by expert judgement.

**Table 1: Observed climate impacts**

| Sector | Observed climate impacts | Global impact rating | National impact rating | Confidence rating | Data quality rating | Time period | Metadata identifier(s) |
|---|---|---|---|---|---|---|---|
| **AGRICULTURE** | | **Low-High** | **Low- High** | **High** | **Low** | **1992-2017** | **1** |
| **Crops** | | Medium-High | Medium-High | Medium- High | Low | 1992-2017 | 1.1 |
| | Reduced crop yield associated with heat and drought stress. | | | | | | 1.1 |
| | Changes in crop suitability due to shifts in agroecological zones. | | | **Low** Expert opinion only | | | 1.2 |
| | Economic losses due to severe reductions in crop yields caused by frequent floods and droughts. | | | | | | 1.1 |
| **Livestock** | Increased animal mortality associated with intense heat, frequent droughts and floods. | Low- Medium | Low-Medium | Low | Low | 1992-2017 | 1.3 |
| **ENERGY** | Reduction in hydropower generation through changes in the mean annual streamflow and shifts of seasonal flows. | **High** | **High** | **High** | **Low** | **1992-2017** | **2** |
| **WATER** | | **Medium-High** | **Medium-High** | **Medium-High** | **Low** | **1992-2018** | **3** |

| Sector | Observed climate impacts | Global impact rating | National impact rating | Confidence rating | Data quality rating | Time period | Metadata identifier(s) |
|---|---|---|---|---|---|---|---|
| **Water supply** | Water quantity and quality disrupted by increasing frequency of droughts and floods. | Medium-High | Medium-High | Medium-High | Low | 1992-2018 | 3 |
| **Water treatment** | Increased sediment, nutrient, and pollutant loadings from heavy rainfall and floods and droughts. | Medium-High | Medium-High | Medium-High | Low | 1992-2018 | **3** |
| **Water collection** | Damage to water infrastructure and contaminated ground and surface water sources | Medium-High | Medium-High | Medium-High | Low | 1992-2018 | 3 |
| **Surface water management** | Increased frequency and magnitude of floods associated with torrential rains. | Medium-High | Medium-High | Medium-High | Low | 1992-2018 | 3 |
| | Reduction in waterflow in major rivers of the country due to reduction in rainfall | | | | | | 3 |
| **BUILT INFRASTRUCTURE** | | **Medium-High** | **Medium-High** | **High** | **Low** | **1992-2018** | **4** |
| **Buildings** | Damage to infrastructure and settlements caused by increased frequency and intensity of floods. | High | High | High | Low | 2006 -2016 | 4 |
| | Destruction of buildings caused by intense floods. | | | | | 2006 -2016 | 4 |

| Sector | Observed climate impacts | Global impact rating | National impact rating | Confidence rating | Data quality rating | Time period | Metadata identifier(s) |
|---|---|---|---|---|---|---|---|
| **Roads** | Loss of 3,530 km of paved and unpaved roads to floods. | | | | | 2006 -2016 | 4 |
| **Pipelines** | Water pipelines exposed and broken by floods | | | | | 2006 -2016 | 4 |
| **Waterways** | Flooding and siltation of waterways. | | | | | 2006 -2016 | 4 |
| **ECOSYSTEMS** | | **Low-Medium** | **Low-Medium** | **Low** | Low | **1984-2006** | **5** |
| **Terrestrial Ecosystems** | | Low-Medium | Low-Medium | Low | Low | | 5 |
| | Loss of essential ecosystem functions due to increased frequency/intensity of wildfires resulting from increased drought and temperatures. | | | | | | 5 |
| | High animal mortality due to declining wildlife forage quality and quantity, and water shortage resulting from excessive heat and droughts. | | | | | | 5 |
| **Freshwater ecosystems** | | Low-Medium | Low-Medium | Low | Low | | 5 |

| Sector | Observed climate impacts | Global impact rating | National impact rating | Confidence rating | Data quality rating | Time period | Metadata identifier(s) |
|---|---|---|---|---|---|---|---|
| | Surges in algae growth, causing sudden fish kills in rivers and lakes, linked to high temperatures. | | | | | | 5 |
| | Fish breeding and development affected by heavy siltation due to intense rainfall and high rates of runoff. | | | | | | 5 |

**Table 2: Projected climate impacts**

| Sector | Projected climate impacts | Impact rating | Confidence rating | Data quality rating | Time period | Metadata identifier(s) |
|---|---|---|---|---|---|---|
| **AGRICULTURE** | Declining yield among all types of crops in all parts of the country except in the northern region. | Medium | Low-Medium | Low | 2007-250 | 6 |
| **ENERGY** | Hydropower production negatively affected by high rainfall variability. | Medium | Medium | Low | 2007-2050 | 7 |
| **WATER** | Reduced water quality and water supply due to frequent flooding | Medium | Low | Low | 1950-2050 | 8 |
| **BUILT INFRASTRUCTURE** | Increased damage to infrastructure and human settlement due to intense flooding | High | High | Low | 1992-2050 | 9 |
| **ECOSYSTEMS** | Loss of habitat quality and quantity due to frequent droughts. | Medium | Low | Low | 1992-2030 | 10 |

**Table 3: Definitions of national ratings of observed impacts (which for Malawi are the same as the definitions of global rating)**

| Observed impacts | Economic | Social | Environmental |
|---|---|---|---|
| High | **Major damage and disruption** (~£100 million) | **Potential for many fatalities or serious harm or major disruption** (~ millions affected, thousands harmed, hundreds of fatalities) | **Major or widespread loss or decline in long-term quality of valued habitats** (~5,000 hectares lost/gained, ~10,000km river water quality affected) |
| Medium | **Moderate damage and disruption** (~£10 million) | **Significant numbers affected** (~hundreds of thousands affected, hundreds harmed, tens of fatalities) | **Medium term or moderate loss** (~500 hectares lost/gained, ~1,000km river water quality affected) |
| Low | **Minor damage and disruption** (~£1 million) | **Small numbers affected/within coping range** (tens of thousands affected etc.) | **Short-term / reversible / local effects** (~50 hectares lost/gained, ~100km river water quality affected) |

**Table 4.1: Agriculture sector data quality scoring and rating**

| Data quality | | |
|---|---|---|
| **Dataset** | | |
| **Data quality criteria** | **Levels** | **Score** |
| **1. Transparency and auditability** | 1. Data unavailable to public | |
| | **2. Limited summary data available** | **2** |
| | 3. Full raw/primary data set and metadata available | |
| **2. Verification** | **1. Unverified data** | **1** |
| | 2. Limited verification checks in place | |
| | 3. Detailed verification in place and documented | |
| **3. Frequency of updates** | **1. Sporadic** | **1** |
| | 2. Every 3-5 years | |
| | 3. Annual or biennial | |
| **4. Security** | 1. Future data collection discontinued | |
| | **2. Future data collection uncertain** | **2** |
| | 3. Future data collection secure | |
| **5. Spatial coverage** | **1. Partial national coverage** | **1** |
| | 2. National coverage, some bias | |
| | 3. Full national coverage, including adjacent marine areas, if and where appropriate | |
| **TOTAL SCORE** | | **7** |
| **RATING** | | **Low** |

**Table 4.2: Energy sector data quality scoring and rating**

| Data quality | | |
|---|---|---|
| **Data quality** | | |
| **Dataset** | | |
| **Data quality criteria** | **Levels** | **Score** |
| **1. Transparency and auditability** | 1. Data unavailable to public | |
| | **2. Limited summary data available** | **2** |
| | 3. Full raw/primary data set and metadata available | |
| **2. Verification** | **1. Unverified data** | **1** |
| | 2. Limited verification checks in place | |
| | 3. Detailed verification in place and documented | |

| Data quality | | |
|---|---|---|
| **3. Frequency of updates** | **1. Sporadic** | **1** |
| | 2. Every 3-5 years | |
| | 3. Annual or biennial | |
| **4. Security** | 1. Future data collection discontinued | |
| | **2. Future data collection uncertain** | **2** |
| | 3. Future data collection secure | |
| **5. Spatial coverage** | **1.** Partial national coverage | |
| | 2**. National coverage, some bias** | 2 |
| | 3. Full national coverage, including adjacent marine areas, if and where appropriate | |
| **TOTAL SCORE** | | **8** |
| **RATING** | | **Low** |

**Table 4.3: Built Infrastructure sector data quality scoring and rating**

| Data quality | | |
|---|---|---|
| **Dataset** | | |
| **Data quality criteria** | **Levels** | **Score** |
| **1. Transparency and auditability** | 1. Data unavailable to public | |
| | **2. Limited summary data available** | **2** |
| | 3. Full raw/primary data set and metadata available | |
| **2. Verification** | **1. Unverified data** | **1** |
| | 2. Limited verification checks in place | |
| | 3. Detailed verification in place and documented | |
| **3. Frequency of updates** | **1. Sporadic** | **1** |
| | 2. Every 3-5 years | |
| | 3. Annual or biennial | |
| **4. Security** | 1. Future data collection discontinued | |
| | **2. Future data collection uncertain** | **2** |
| | 3. Future data collection secure | |
| **5. Spatial coverage** | 1. Partial national coverage | |
| | **2. National coverage, some bias** | 2 |
| | 3. Full national coverage, including adjacent marine areas, if and where appropriate | |
| **TOTAL SCORE** | | **8** |

| Data quality | |
|---|---|
| **RATING** | **Low** |

**Table 4.4: Water sector data quality scoring and rating**

| Data quality | | |
|---|---|---|
| **Dataset** | | |
| **Data quality criteria** | **Levels** | **Score** |
| **1. Transparency and auditability** | **1. Data unavailable to public** | 1 |
| | 2. Limited summary data available | |
| | 3. Full raw/primary data set and metadata available | |
| **2. Verification** | **1. Unverified data** | **1** |
| | 2. Limited verification checks in place | |
| | 3. Detailed verification in place and documented | |
| **3. Frequency of updates** | **1. Sporadic** | **1** |
| | 2. Every 3-5 years | |
| | 3. Annual or biennial | |
| **4. Security** | 1. Future data collection discontinued | |
| | **2. Future data collection uncertain** | **2** |
| | 3. Future data collection secure | |
| **5. Spatial coverage** | 1. Partial national coverage | |
| | **2. National coverage, some bias** | 2 |
| | 3. Full national coverage, including adjacent marine areas, if and where appropriate | |
| **TOTAL SCORE** | | **8** |
| **RATING** | | **Low** |

**Table 4.5: Ecosystems sector data quality scoring and rating**

| Data quality | | |
|---|---|---|
| **Dataset** | | |
| **Data quality criteria** | **Levels** | **Score** |
| **1. Transparency and auditability** | 1. Data unavailable to public | |
| | **2. Limited summary data available** | **2** |
| | 3. Full raw/primary data set and metadata available | |
| **2. Verification** | **1. Unverified data** | **1** |

| Data quality | | |
|---|---|---|
| | 2. Limited verification checks in place | |
| | 3. Detailed verification in place and documented | |
| **3. Frequency of updates** | **1. Sporadic** | **1** |
| | 2. Every 3-5 years | |
| | 3. Annual or biennial | |
| **4. Security** | 1. Future data collection discontinued | |
| | **2. Future data collection uncertain** | **2** |
| | 3. Future data collection secure | |
| **5. Spatial coverage** | 1. Partial national coverage | |
| | **2. National coverage, some bias** | 2 |
| | 3. Full national coverage, including adjacent marine areas, if and where appropriate | |
| **TOTAL SCORE** | | **8** |
| **RATING** | | **Low** |

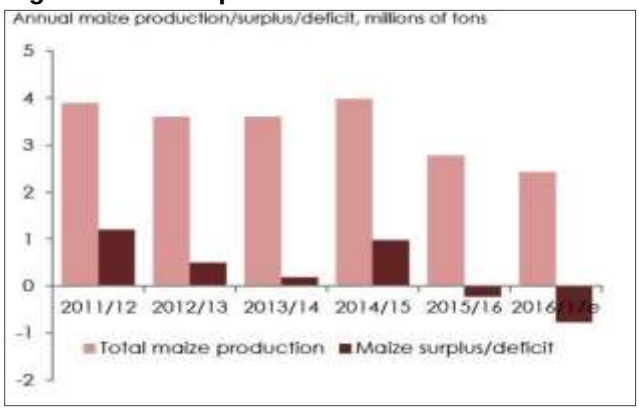
**Table 5: Definitions of national ratings of projected impacts (which for Malawi are the same as the definitions of global rating)**

| Observed impacts | Economic | Social | Environmental |
|---|---|---|---|
| High | **Major damage and disruption** (~£100 million) | **Potential for many fatalities or serious harm or major disruption** (~ millions affected, thousands harmed, hundreds of fatalities) | **Major or widespread loss or decline in long-term quality of valued habitats** (~5,000 hectares lost/gained, ~10,000km river water quality affected) |
| Medium | **Moderate damage and disruption** (~£10 million) | **Significant numbers affected** (~hundreds of thousands affected, hundreds harmed, tens of fatalities) | **Medium term or moderate loss** (~500 hectares lost/gained, ~1,000km river water quality affected) |
| Low | **Minor damage and disruption** (~£1 million) | **Small numbers affected/within coping range** (tens of thousands affected etc.) | **Short-term / reversible / local effects** (~50 hectares lost/gained, ~100km river water quality affected) |

**Table 6: Metadata tables**

| Metadata identifier | 1 |
|---|---|
| **Source(s)** | **Primary source:**<br>○ Government of Malawi (2017). Strategic Program for Climate Resilience: Malawi Pilot Program on Climate Resilience (PPCR). Lilongwe.<br>○ Government of Malawi (2017). Strategic Program for Climate Resilience: Malawi Pilot Program on Climate Resilience (PPCR). Lilongwe.<br>○ Pauw, K., J. Thurlow, M. Bachu and D. E. Van Seventer, 2011, 'The Economic Costs of Extreme Weather Events: A Hydro-Meteorological CGE Analysis for Malawi', Environment and Development Economics, 16: pp. 177–98.<br>○ MoFEPD, 2011, Economic Valuation of Sustainable Natural Resource Use in Malawi. Poverty and Environment Initiative. UNDP/UNEP, Ministry of Finance and Development Planning, Lilongwe.<br>**Other sources:**<br>○ Zulu, Leo. 2017. Existing Research and Knowledge on Impacts of Climate Variability and Change on Agriculture and Communities in Malawi. Malawi Report No. 9. East Lansing, Michigan: Global Center for Food Systems Innovation, Michigan State University, January.<br>○ Irish Aid, 2018. Malawi Country Climate Risk Assessment Report. Irish Aid, Resilience and Economic Inclusion Team, Policy Unit. https://www.climatelearningplatform.org. |
| **Explanation for impact rating** | **Low-High:** Available literature agrees on the devastating impacts of frequent and severe floods and droughts on the<br>agriculture sector in Malawi. The sector suffers the greatest losses, effecting declines in GDP ranging from 1.1 to 21.5% during Return Period of 5 years (RP5) and Return period of 25 years (RP25) for droughts, respectively. Furthermore, the literature and experts agree that low agriculture productivity resulting from climate change result in food shortages, cause domestic grain prices to rise while grain imports increase rapidly to cover the shortfall. Maize imports, for example, increase by between 6 and 256% during RP5 and RP25 droughts, respectively. The possibility for high rating of the impacts implies that spatial coverage is at times wide, and frequency of the impact increases to high. For example, maize is by far the dominant crop produced in Malawi, occupying more than 70 per cent of available agricultural land and is critically important to livelihoods. The average land holding size per household for smallholders in Malawi in the period under consideration was 1.2 hectares. Over 90% of the total agricultural value-added came from about 1.8 million smallholders who on average owned only 1 hectare of land. Flooding in low-lying areas where productivity is inherently high affected almost the whole country in terms of food availability stability and accessibility. The alternation with droughts in the high areas complicates crop productivity. Floods wash away livestock in the low-lying areas. |

| Metadata identifier | 1 |
|---|---|
| **Explanation for confidence rating** | **High:** Spatial coverage of floods responsible for economic losses are generally localized in watershed areas. This limited coverage creates localized impacts such as crop and soil losses; hence the rating is medium. However, the impacts are felt on the national economy hence the rating is high. For example, on average, Malawi loses US$9 million or 0.7% of the GDP each year due to floods in the southern region of the country. Taken together, drought and floods cost the Malawian economy about 1.7% of its GDP every year. This is equivalent to almost US$22 million. |
| **Climate projections, emissions scenarios, or models used** | We have not employed any modelling. All impacts are synthesized from the literature. Where the predictions are used in the literature, the major models used are CMIP5 models and their ensemble for the period 1950-2099. |
| **Dataset(s)** | No datasets have been accessed |
| **Additional assumptions** | None |
| **Additional limitations** | Yield reduction observed in crops across the country are associated with many compounding factors besides climate change. The factors include soil erosion, poor soil fertility and poor farming practices. These factors are not fully accounted for. |

| Metadata identifier | 1.1 |
|---|---|
| **Source(s)** | **See Metadata Identifier 1** |
| **Explanation for impact rating** | **Medium-High:** Drought periodically occurs, and the 2001 drought resulted in crop output decline by a third. Maize operation equivalent to 3% of GDP in fiscal year 2002/03 budget declined. In 1992 severe drought occurred which hit the country, 67% decline in maize output was experienced compared with previous year. The country experienced heavy floods in 2015 followed by drought. Alternating between drought and floods gives high rating on the impacts but medium impact for individual event. The pattern of maize is not currently resilient to the current climate and high levels of climate variability. However, evidence does not reveal consistent decreases (**Figure 1.1**).<br><br>**Figure 1.1 Maize production**<br>  <br><br><br>On the other hand, tea the second largest export crop, decreased by 23%, cotton and Sugar production fell by 54% and 21% respectively. Agriculture, which accounts for **28% of GDP**, contracted by an estimated |

| Metadata identifier | 1.1 |
|---|---|
| | 2%, on the back of a 1.6% decline in 2015 (Bhatia and Mwanakatwe, 2017).[1] This explains the rating of the impact as **medium-high as most cash crops are affected.** |
| **Explanation for confidence rating** | **Medium-High:** Spatial coverage of floods responsible for economic losses are generally localized in watershed areas. This limited coverage creates localized impacts such as crop and soil losses; hence the rating is medium. However, the impacts are felt on the national economy hence the rating is high. For example, on average, Malawi loses US$9 million or 0.7% of the GDP each year due to floods in the southern region of the country. Taken together, drought and floods cost the Malawian economy about 1.7% of its GDP every year. This is equivalent to almost US$22 million. |
| **Climate projections, emissions scenarios, or models used** | We have not employed any modelling. All impacts are synthesized from the literature. Where the predictions are used in the literature, the major models used are CMIP5 models and their ensemble for the period 1950-2099. |
| **Dataset(s)** | No data sets have been accessed |
| **Additional assumptions** | None |
| **Additional limitations** | Yield reduction observed in crops across the country are associated with many compounding factors besides climate change. The factors include soil erosion, poor soil fertility and poor farming practices. These factors are not fully accounted for. |

| Metadata identifier | 1.2 |
|---|---|
| **Source(s)** | Expert opinion and field experience |
| **Explanation for impact rating** | **Low-Medium:** Different agroecological zones are now receiving different weather patterns. E.g. northern areas of Malawi are becoming warmer. The creation of new agroecological zones holds only if changes in temperature and precipitation occur on a large temporal scale. |
| **Explanation for confidence rating** | **Low:** Not much research has been carried out on understanding the extent of this impact on a large spatial scale. These observations are confined to the Northern Region of the country. |
| **Climate projections, emissions scenarios, or models used** | Modelling in this area has not been comprehensive in terms of spatial coverage. Studies have been conducted on a local scale. |
| **Dataset(s)** | No datasets used |
| **Additional assumptions** | We assumed that temperature will continue rising and precipitation will increase in northern areas thereby creating new agroecological zones. |
| **Additional limitations** | Observed increased temperatures and rainfall in northern region has been on a short time scale. The observed impacts have not been comprehensively documented. |

[1] Bhatia, A. and Mwanakatwe, P. 2017. African Economic Outlook for Malawi

| Metadata identifier | 1.3 |
|---|---|
| **Source(s)** | Government of Malawi (2017). Strategic Program for Climate Resilience: Malawi Pilot Program on Climate Resilience (PPCR). Lilongwe.<br><br>Pauw, K., J. Thurlow, M. Bachu and D. E. Van Seventer, 2011, 'The Economic Costs of Extreme Weather Events: A Hydro-Meteorological CGE Analysis for Malawi', Environment and Development Economics, 16: pp. 177–98. |
| **Explanation for impact rating** | **Low:** The livestock sector in Malawi is one of the least developed and production is occurring in small areas mostly the northern and south tip of the country and along the lakeshores. The impacts at national level has been scored low as the significance of droughts and floods are also low at national level. However, the |
| **Explanation for confidence rating** | **Low:** Zulu (2017) reviewed existing research and knowledge on impacts of climate variability and change on Agriculture and Communities in Malawi. The review failed to find published studies on the livestock subsector, reflecting underdevelopment of the sub-sector in Malawi. However, the same study noted that selling livestock is a coping strategy to climate and other shocks. However, a recent study examining past impacts of drought on indigenous livestock production in Central Malawi based on social survey data finds highly significant decreases ($p<0.01$) in goat and pig production with increasing drought incidence (Oyekale 2012)[2]. Thus, we derive the basis for the confidence rating at least medium. Moreover, the study covered only districts of the country out of the 24 districts. |
| **Climate projections, emissions scenarios, or models used** | None |
| **Dataset(s)** | None |
| **Additional assumptions** | None |
| **Additional limitations** | None |

[2] Bhatia, A. and Mwanakatwe, P. 2017. African Economic Outlook for Malawi
Climate-related Income Shocks and Adaption Options in Central Malawi. Journal of Food, Agriculture and Environment 10: 1505-1510.

| Metadata identifier | 2 |
|---|---|
| **Source(s)** | ○ Government of Malawi (2017). Strategic Program for Climate Resilience: Malawi Pilot Program on Climate Resilience (PPCR). Lilongwe.<br>○ Government of Malawi (2017). Strategic Program for Climate Resilience: Malawi Pilot Program on Climate Resilience (PPCR). Lilongwe.<br>○ Pauw, K., J. Thurlow, M. Bachu and D. E. Van Seventer, 2011, 'The Economic Costs of Extreme Weather Events: A Hydro-Meteorological CGE Analysis for Malawi', Environment and Development Economics, 16: pp. 177–98.<br>○ MoFEPD, 2011, Economic Valuation of Sustainable Natural Resource Use in Malawi. Poverty and Environment Initiative. UNDP/UNEP, Ministry of Finance and Development Planning, Lilongwe. |
| **Explanation for impact rating** | **High: Over 98% of Malawi's grid electricity is from hydro power which is under threat and vulnerable to droughts.** We have scored high on energy for several reasons. Firstly, observation shows that all of Malawi's hydropower generation capacity is located on the Shire River. Continuity of electricity supplies from the Shire River power stations is essential for Malawi and is dependent on the sufficiency of water in the river. Increases in the frequency of droughts has once diminished water supplies. This in turn affected hydropower generation and power has been often rationed at the end of the dry season because of low water levels. Even if climate change brings an increase in wet season surface water yields, this will be more than offset by dry season decreases. During the 2016 drought, Lake Malawi was at its lowest level for over a decade and electricity was rationed throughout the country. Second, Intense rainstorms combined with ongoing degradation of upstream catchments also contributes to a rise in siltation and sedimentation, adversely affecting the country's hydropower energy generation. |
| **Explanation for confidence rating** | **High:** Hydropower generation capacity in the Shire River has been observed year after year since 1992. Many studies agree on the observed reduction of hydropower generation. However, one study has suggested climate change will have only a small effect on hydropower production in Malawi. Based on expert judgement, the impacts of climate change on hydropower generation although not documented is very high since they direct affect national economic growth. |
| **Climate projections, emissions scenarios, or models used** | Although one study has suggested climate change will have only a small effect on hydropower production in Malawi, the study used used projections which predominantly predicted an increase in rainfall (which may or may not hold true) and assumed that Malawi will reduce domestically produced hydropower as a share of total generation because of a paucity of good locations. |
| **Dataset(s)** | None |
| **Additional assumptions** | None |
| **Additional limitations** | None |

| Metadata identifier | 3 |
|---|---|
| **Source(s)** | ○ Government of Malawi (2017). Strategic Program for Climate Resilience: Malawi Pilot Program on Climate Resilience (PPCR). Lilongwe.<br>○ Government of Malawi (2017). Strategic Program for Climate Resilience: Malawi Pilot Program on Climate Resilience (PPCR). Lilongwe.<br>○ IPCC, 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press.<br>○ Pauw, K., J. Thurlow, M. Bachu and D. E. Van Seventer, 2011, 'The Economic Costs of Extreme Weather Events: A Hydro-Meteorological CGE Analysis for Malawi', Environment and Development Economics, 16: pp. 177–98.<br>○ MoFEPD, 2011, Economic Valuation of Sustainable Natural Resource Use in Malawi. Poverty and Environment Initiative. UNDP/UNEP, Ministry of Finance and Development Planning, Lilongwe. |
| **Explanation for impact rating** | **Medium-High:** Rising temperatures have been documented across the country. The observed frequency of droughts coupled with land degradation in the watershed have both affected water quality and quantity. Extreme rises in water temperature can contribute to water quality degradation and may have a negative impact on the quality of drinking water. However, Malawi has fresh water supply proposed projects which may avert the impacts of rising temperatures, hence the score is medium – high. |
| **Explanation for confidence rating** | **Medium-High:** Risk of reduced water supply and quality for household use has already been felt in many parts of the country. However, not all parts of the country do experience drought conditions. Other areas are becoming wetter – a situation which averts the impacts on water supply. |
| **Climate projections, emissions scenarios, or models used** | None |
| **Dataset(s)** | Literature |
| **Additional assumptions** | None |
| **Additional limitations** | None |

| Metadata identifier | 4 |
|---|---|
| **Source(s)** | ○ Government of Malawi (2017). Strategic Program for Climate Resilience: Malawi Pilot Program on Climate Resilience (PPCR). Lilongwe.<br>○ Government of Malawi (2017). Strategic Program for Climate Resilience: Malawi Pilot Program on Climate Resilience (PPCR). Lilongwe.<br>○ IPCC, 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press.<br>○ Pauw, K., J. Thurlow, M. Bachu and D. E. Van Seventer, 2011, 'The Economic Costs of Extreme Weather Events: A Hydro-Meteorological CGE Analysis for Malawi', Environment and Development Economics, 16: pp. 177–98. |
| **Explanation for impact rating** | **Medium-High:** The impacts on infrastructure have been observed for the past decade but the frequency of flooding has increased in recent years. Both rural and urban areas are impacted although spatial coverage is confined to low lying areas, but the magnitude of economic disruptions is high. The World Bank's Malawi Drought Recovery and Resilience Project and the Malawi Floods Emergency Recovery Project (IDA, US$104 million and US$80 million respectively) have large investments in climate proofing infrastructures such as roads and bridges. This is similarly the case with resilience investments in other areas of infrastructure, such as schools and transport. Hence the rating is medium. |
| **Explanation for confidence rating** | **High:** Climate change has affected the road network and is projected to slightly reduce the growth rate of GDP. Severe flooding causes considerable damage to infrastructure, including roads, bridges, schools and health facilities. Costs for repair and restoration of infrastructure place an added burden on over-stretched public expenditure budgets. For example, the 2015 floods highlighted the vulnerabilities of the transport sector with serious damage caused to the infrastructure. For the transport sector, the total disaster effects of damages and losses were approximately US $60 million while the cost of recovery was almost US $130 million– the highest among all the sectors. |
| **Climate projections, emissions scenarios, or models used** | Based on a broad analysis using median climate scenarios directly related to temperature and precipitation changes through to 2050 it has been estimated that, without adaptation measures applied to the planning, construction and maintenance of road infrastructure, Malawi is facing a potential total annual average cost of US $165 million. |
| **Dataset(s)** | None |
| **Additional assumptions** | The ongoing projects on building resilience of infrastructure will continue. |
| **Additional limitations** | None |

| Metadata identifier | 5 |
|---|---|
| **Source(s)** | ○ Government of Malawi (2017). Strategic Program for Climate Resilience: Malawi Pilot Program on Climate Resilience (PPCR). Lilongwe.<br>○ Government of Malawi (2017). Strategic Program for Climate Resilience: Malawi Pilot Program on Climate Resilience (PPCR). Lilongwe.<br>○ IPCC, 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press.<br>○ Pauw, K., J. Thurlow, M. Bachu and D. E. Van Seventer, 2011, 'The Economic Costs of Extreme Weather Events: A Hydro-Meteorological CGE Analysis for Malawi', Environment and Development Economics, 16: pp. 177–98. |
| **Explanation for impact rating** | **Low-Medium:** High temperatures are known to affect aquatic ecosystems. However, there has not been detailed research on the impacts of water temperature on Malawi's lakes to infer warming water temperature's impacts on aquatic ecosystems and fisheries. On the other hand, terrestrial ecosystems such as Lengwe National Park are in semiarid areas whereby the rising temperatures limit the value of water resources to species such as nyala (*Tragilaphus angus*). The low rating can therefore be explained due to limited coverage of previous assessments as well as the limited number of species that are sensitive to reduced precipitation. |
| **Explanation for confidence rating** | **Low:** All in all, the impacts of climate change on ecosystems exist but detailed there is limited evidence on both terrestrial and aquatic ecosystems. |
| **Climate projections, emissions scenarios, or models used** | Rising temperatures will negatively affect the production of phytobiomass and, thus, limit forage production. |
| **Dataset(s)** | None |
| **Additional assumptions** | The ongoing projects on building resilience of infrastructure will continue. |
| **Additional limitations** | None |

| Metadata identifier | 6 |
|---|---|
| **Source(s)** | **Government of Malawi (2017):** Strategic Program for Climate Resilience: Malawi Pilot Program on Climate Resilience. Minister of Natural Resources, Energy And Mining, Lilongwe. |
| **Explanation for impact rating** | **Medium:** It is projected, that by 2030, an additional 10,900 people may be at risk of river floods annually because of climate change and 12,400 owing to socio economic change above the estimated 14,400 annually affected population in 2010 (WHO and UNFCCC, 2015). |

| Metadata identifier | 6 |
|---|---|
| **Explanation for confidence rating** | **Low-Medium**: There is contradiction on the outcome of the impacts of projected climate change on maize production in Malawi. Recent crop modelling projections suggest that climate change will increase maize production in the Mzimba district over the period 2040-2070, with the model suggesting that 56% of farmers will register gains. However, one study suggests a possibility that rainy seasons will grow shorter, potentially leading to more frequent failures in maize cultivation, which in turn has significant implications on yield. |
| **Climate projections, emissions scenarios, or models used** | Projected Mean Annual Precipitation by 2050 compared to the reference period (1986-2005) under RCP 8.5 of CIMP5 ensemble modelling. |
| **Dataset(s)** | Not available. |
| **Additional assumptions** | None |
| **Additional limitations** | None |

| Metadata identifier | 7 |
|---|---|
| **Source(s)** | Government of Malawi (2017): Strategic Program for Climate Resilience: Malawi Pilot Program on Climate Resilience. Minister of Natural Resources, Energy and Mining, Lilongwe. |
| **Explanation for impact rating** | **Medium**: Increases in the occurrence of extreme weather events such as rainstorms, combined with land degradation and deforestation, are likely to result in increased flooding which can damage hydropower generation infrastructure. Intense rainstorms combined with ongoing degradation of upstream catchments also contributes to a rise in siltation and sedimentation, adversely affecting the country's hydropower energy generation. Shire River flows are largely dependent on water levels in Lake Malawi hence management of Lake Malawi catchment and ecosystem is key for the energy security of the country, and this can lead to significant worries about energy security based on reliability of flow into the river dependent on lake levels |
| **Explanation for confidence rating** | **Medium**: One study has suggested climate change will have only a small effect on hydropower production in Malawi, this was because they used projections which predominantly predicted an increase in rainfall (which may or may not hold true) and also assumed that Malawi will reduce domestically produced hydropower as a share of total generation because of a paucity of good locations.[3] |
| **Climate projections, emissions scenarios, or models used** | Projected Mean Annual Precipitation by 2050 compared to the reference period (1986-2005) under RCP 8.5 of CIMP5 ensemble modelling. |
| **Dataset(s)** | Not available. |
| **Additional** | None |

[3] Arndt, C., Schlosser, A., Strzepek, K. and Thurlow, J. (2014) Climate Change and Economic Growth Prospects for Malawi: An Uncertainty Approach. Journal of African Economies, Vol. 23, AERC Supplement 2, pp. ii83–ii107.

| Metadata identifier | 7 |
|---|---|
| **assumptions** | |
| **Additional limitations** | None |

| Metadata identifier | 8 |
|---|---|
| **Source(s)** | **Government of Malawi (2017):** Strategic Program for Climate Resilience: Malawi Pilot Program on Climate Resilience. Minister of Natural Resources, Energy and Mining, Lilongwe. |
| **Explanation for impact rating** | **Medium**: studies on the future impacts of climate change on water quality are scanty. However, projection indicate high variability in climate with droughts and floods occurring frequently in many parts of the country. With reductions in rainfall, reductions in surface runoff are likely to impact negatively on groundwater recharge and consequently contribute to drying of boreholes across the country |
| **Explanation for confidence rating** | **Low:** There are no studies on climate modeling and the impacts on water at the country level. |
| **Climate projections, emissions scenarios, or models used** | None |
| **Dataset(s)** | Not available. |
| **Additional assumptions** | None |
| **Additional limitations** | None |

| Metadata identifier | 9 |
|---|---|
| **Source(s)** | **Government of Malawi (2017):** Strategic Program for Climate Resilience: Malawi Pilot Program on Climate Resilience. Minister of Natural Resources, Energy And Mining, Lilongwe. |
| **Explanation for impact rating** | **High:** Based on a broad analysis using median climate scenarios directly related to temperature and precipitation changes through to 2050 it has been estimated that, without adaptation measures applied to the planning, construction and maintenance of road infrastructure, Malawi is facing a potential total annual average cost of US $165 million[4]. |
| **Explanation for confidence rating** | **High**: There is not contradiction among studies on the future variability of climate cage in terms of floods and drought occurrences that will seriously affect the infrastructure. Severe flooding in particular causes considerable damage to infrastructure, including roads, bridges, schools and health facilities. Costs for |

[4] Chinowsky, P.S. et al. (2015). Infrastructure and climate change: a study of impacts and adaptations in Malawi, Mozambique, and Zambia. Climatic Change (2015) 130:49–62. DOI 10.1007/s10584-014-1219.

| Metadata identifier | 9 |
|---|---|
| | repair and restoration of infrastructure place an added burden on over-stretched public expenditure budgets. |
| **Climate projections, emissions scenarios, or models used** | Projected Mean Annual Precipitation by 2050 compared to the reference period (1986-2005) under RCP 8.5 of CIMP5 ensemble modelling. |
| **Dataset(s)** | Not available. |
| **Additional assumptions** | None |
| **Additional limitations** | None |

| Metadata identifier | 10 |
|---|---|
| **Source(s)** | **Government of Malawi (2017):** Strategic Program for Climate Resilience: Malawi Pilot Program on Climate Resilience. Minister of Natural Resources, Energy and Mining, Lilongwe. |
| **Explanation for impact rating** | **Medium**: Terrestrial habitats will lose the quality and quantity of forage because of increased intensity of droughts. The semiarid arid areas of Malawi such as the lower Shire Valley where nyala species occur will become dry and forage quality will reduce (Nkanda, 1996). |
| **Explanation for confidence rating** | **Low**: While only one study has been carried out to understand the future impacts of climate change wildlife, the study comprehensive. |
| **Climate projections, emissions scenarios, or models used** | None |
| **Dataset(s)** | Not available. |
| **Additional assumptions** | None |
| **Additional limitations** | None |