Supplementary information supporting the paper: Warnatzsch and Reay (2019) Assessing Climate Change Projections and Impacts on Central Malawi’s Maize Yield: The Risk of Maladaptation.

1. Supplementary Tables and Figures

Table 1: Regional Climate Models (RCM) sources. All of the models other than CanRCM4_r2 were accessed through The Earth System Grid Federation (ESGF) data index (ESGF, 2017). The CanRCM4_r2 model was accessed through the Canadian Centre for Climate Modelling and Analysis website (CCCma, 2017).

RCM	Institution	Lateral Boundary Conditions	Original Calendar	Reference
CCLM4-8-17_v1	Climate Limited-area Modelling Community (CLMcom)	CNRM-CM5 r1i1p1	365-days	(COSMO, 2017)
		HadGEM2-ES r1i1p1	360-days	
		EC-EARTH r12i1p1	366-days	
		MPI-ESM-LR r1i1p1	366-days	
HIRHAM5_v2	Danmarks Meteorologiske Insitut (DMI)	EC-EARTH r3i1p1	366-days	(Christensen et al., 2007)
RACMO22T_v1	Koninklijk Nederlands Meteorologisch Instituut (KNMI)	HadGEM2-ES r1i1p1	360-days	(van Meijgaard et al., 2008)
		EC-EARTH r1i1p1	366-days	
RCA4_v1	Sveriges Meteorologiska och Hydrologiska Institut (SMHI)	CanESM2 r1i1p1	366-days	(Samuelsson et al., 2015)
		CNRM-CM5 r1i1p1	366-days	
		CSIRO-MK3-6-0 r1i1p1	365-days	
		GFDL-ESM2M r1i1p1	365-days	
		IPSL-CM5A-MR r1i1p1	365-days	
		HadGEM2-ES r1i1p1	360-days	
		EC-EARTH r12i1p1	366-days	
		MIROC5 r1i1p1	365-days	
		MPI-ESM-LR r1i1p1	366-days	
		NORESM1-M r1i1p1	365-days	
REMO2009_v1	Climate Service Centre Germany (CSC) and Max Planck Institut (MPI)	EC-EARTH r12i1p1	366-days	(Jacob et al., 2012)
		MPI-ESM-LR r1i1p1	366-days	
CanRCM4_r2	Canadian Centre for Climate Modelling and Analysis (CCCma)	CanESM2 r1i1p1	365-days	(Scinocca et al., 2016)

Table 2: Observed data sources

Dataset	Variable Used	Resolution	Time-Period Available	Source	Reference
Climate Research Unit (CRU) version 4.0	Tas, TasMin, TasMax and Pr	0.5° Monthly Land Only	1901-2015	Gridded Station Data	(Harris et al., 2014)
University of Delaware (UDel) version 4.01	Tas and Pr	0.5° Monthly Land Only	1901-2010	Gridded Station Data	(Willmott and Matsuura, 2001)
Global Precipitation Climatology Centre (GPCC) version 7	Pr	1.0° Monthly	1901-2010	Satellite and Station Data	(Schneider et al., 2015)

Table 3: List of data sources for the 13 climate files used in the crop models. Note that all RCMs referred to in this table are listed in Table 1 and the observed data referred to in this table are from the sources listed in.

<table>
<tr><th>File</th><th>Time Scale</th><th>RCP</th><th>Temperature</th><th>Evapotrasnpiration Rate</th><th>Precipitation Rate</th><th>CO_2 concentration</th></tr>
<tr><td>1</td><td>1971-2000</td><td>N/A</td><td>Mean of observed monthly data for minimum and maximum temperature</td><td rowspan="13">Calculated using methodology described in Section 2</td><td>Observed monthly data for precipitation rates</td><td>AquaCrop Mauna Loa CO_2</td></tr>
<tr><td>2</td><td rowspan="6">2020-2049</td><td rowspan="3">4.5</td><td rowspan="12">Projected ensemble mean daily minimum and maximum temperature</td><td>Projected ensemble minimum precipitation rate</td><td rowspan="3">AquaCrop IPCC RCP 4.5</td></tr>
<tr><td>3</td><td>Projected ensemble mean precipitation rate</td></tr>
<tr><td>4</td><td>Projected ensemble maximum precipitation rate</td></tr>
<tr><td>5</td><td rowspan="3">8.5</td><td>Projected ensemble minimum precipitation rate</td><td rowspan="3">AquaCrop IPCC RCP 8.5</td></tr>
<tr><td>6</td><td>Projected ensemble mean precipitation rate</td></tr>
<tr><td>7</td><td>Projected ensemble maximum precipitation rate</td></tr>
<tr><td>8</td><td rowspan="6">2040-2069</td><td rowspan="3">4.5</td><td>Projected ensemble minimum precipitation rate</td><td rowspan="3">AquaCrop IPCC RCP 4.5</td></tr>
<tr><td>9</td><td>Projected ensemble mean precipitation rate</td></tr>
<tr><td>10</td><td>Projected ensemble maximum precipitation rate</td></tr>
<tr><td>11</td><td rowspan="3">8.5</td><td>Projected ensemble minimum precipitation rate</td><td rowspan="3">AquaCrop IPCC RCP 8.5</td></tr>
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<tr><td>13</td><td>Projected ensemble maximum precipitation rate</td></tr>
</table>

Table 4: Absolute AquaCrop output data for historic 1971-2000 climate using three different soil types

Cultivar	Planting Date	AquaCrop Default Soil	AquaCrop Default Sandy Clay Loam Soil	Calibrated Sandy Clay Loam Soil
Slow-Development	15 Nov	12.293	12.05	12.052
	10 Dec	12.861	12.861	12.861
	30 Dec	13.323	12.834	12.249
Fast-Development	15 Nov	7.727	7.384	7.383
	10 Dec	7.961	7.961	7.961
	30 Dec	8.243	8.243	8.243

Table 5: Absolute AquaCrop output data for projected climates under RCP 4.5 using three different soil types

Cultivar	Soil Type	Planting Date	2020-2049			2040-2069		
			Min. Rain	Ave. Rain	Max. Rain	Min. Rain	Ave. Rain	Max. Rain
Slow-Development	AquaCrop Default Soil	15 Nov	9.781	12.15	12.229	8.142	12.197	12.284
		10 Dec	9.024	12.958	12.958	7.615	12.324	12.324
		30 Dec	4.682	13.699	13.699	4.324	13.299	13.299
Fast-Development		15 Nov	6.162	7.844	7.947	5.691	7.683	7.81
		10 Dec	7.894	8.065	8.065	7.613	7.901	7.901
		30 Dec	8.388	8.388	8.388	8.093	8.157	8.157
Slow-Development	AquaCrop Default Sandy Clay Loam Soil	15 Nov	5.502	11.985	12.229	4.628	12.021	12.284
		10 Dec	3.031	12.958	12.958	2.994	12.324	12.324
		30 Dec	0.995	13.699	13.699	1.004	13.299	13.299
Fast-Development		15 Nov	1.716	7.611	7.947	1.431	7.435	7.81
		10 Dec	7.419	8.065	8.065	6.344	7.901	7.901
		30 Dec	7.391	8.388	8.388	6.957	8.157	8.157
Slow-Development	Calibrated Sandy Clay Loam Soil	15 Nov	5.497	11.984	12.229	4.800	12.025	12.284
		10 Dec	2.683	12.958	12.958	2.725	12.324	12.324
		30 Dec	0.792	13.699	13.699	0.804	13.299	13.299
Fast-Development		15 Nov	1.675	7.601	7.947	1.344	7.433	7.810
		10 Dec	7.410	8.065	8.065	6.060	7.901	7.901
		30 Dec	7.032	8.388	8.388	6.596	8.157	8.157

Table 6: Absolute AquaCrop output data for projected climates under RCP 8.5 using three different soil types

Cultivar	Soil Type	Planting Date	2020-2049			2040-2069		
			Min. Rain	Ave. Rain	Max. Rain	Min. Rain	Ave. Rain	Max. Rain
Slow-Development	AquaCrop Default Soil	**15 Nov**	8.337	12.317	12.423	4.884	11.962	12.077
		10 Dec	8.44	12.863	12.863	8.615	12.186	12.186
		30 Dec	5.013	13.324	13.324	5.191	12.667	12.667
Fast-Development		**15 Nov**	5.604	7.749	7.891	4.218	7.284	7.433
		10 Dec	7.635	7.962	7.962	7.15	7.527	7.527
		30 Dec	8.206	8.244	8.244	7.775	7.819	7.819
Slow-Development	AquaCrop Default Sandy Clay Loam Soil	**15 Nov**	3.771	12.112	12.423	3.548	11.747	12.077
		10 Dec	2.91	12.863	12.863	3.299	12.186	12.186
		30 Dec	1.112	13.324	13.324	1.509	12.667	12.667
Fast-Development		**15 Nov**	1.413	7.448	7.891	1.107	6.963	7.433
		10 Dec	6.602	7.962	7.962	5.6	7.527	7.527
		30 Dec	7.249	8.244	8.244	7.172	7.819	7.819
Slow-Development	Calibrated Sandy Clay Loam Soil	**15 Nov**	3.799	12.121	12.423	4.352	11.759	12.077
		10 Dec	2.816	12.863	12.863	3.402	12.186	12.186
		30 Dec	0.878	13.324	13.324	1.275	12.667	12.667
Fast-Development		**15 Nov**	1.358	7.449	7.891	1.029	6.970	7.433
		10 Dec	6.473	7.962	7.962	5.421	7.527	7.527
		30 Dec	6.895	8.244	8.244	6.905	7.819	7.819

Table 7: Absolute AquaCrop output data for historic (1971-2000) and projected climate under RCP 4.5 and 8.5 using the default Maize crop file and calibrated sandy clay loam soil file.

Soil Type	Planting Date	1971-2000	RCP	2020-2049			2040-2069		
				Min. Rain	Ave. Rain	Max. Rain	Min. Rain	Ave. Rain	Max. Rain
Calibrated Sandy Clay Loam Soil	**15 Nov**	14.24	4.5	13.92	14.27	14.33	13.88	14.27	14.33
			8.5	13.90	14.25	14.33	13.72	14.24	14.33
	10 Dec	14.33	4.5	14.26	14.33	14.33	14.22	14.33	14.33
			8.5	14.21	14.33	14.33	14.18	14.33	14.33
	30 Dec	14.49	4.5	14.49	14.49	14.49	14.48	14.49	14.49
			8.5	14.49	14.49	14.49	14.49	14.49	14.49

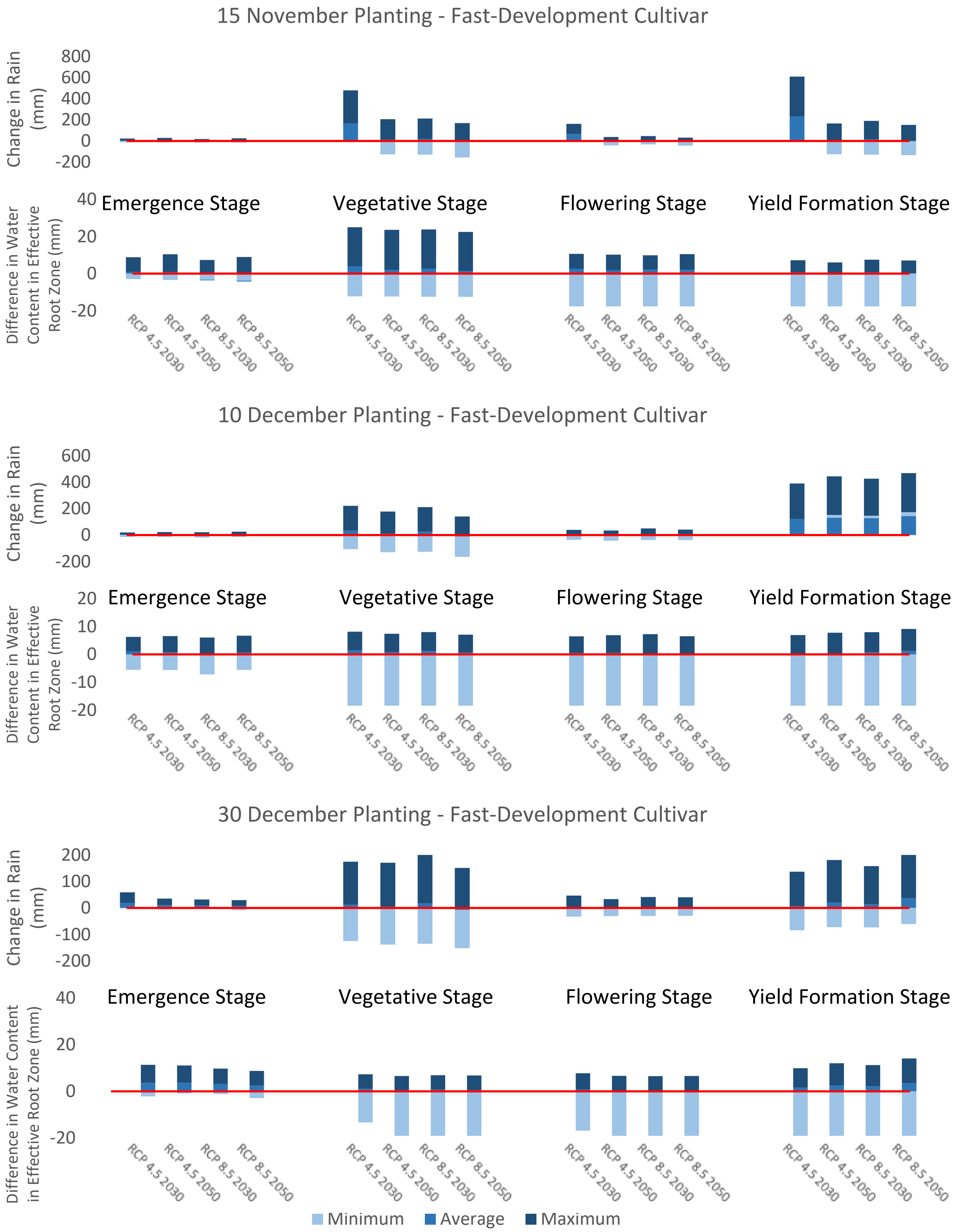

Figure 1: Change in total precipitation (mm) and water content in the effective root zone (mm) by developmental stage of the fast-development cultivar maize grown in Central Malawi for the three planting dates as compared to the baseline 1971-2000 period (red line). This data is shown for the three precipitation scenarios: minimum (palest), average (medium shade) and maximum (darkest) precipitation, for the two RPC scenarios and time periods.

Table 8: Number of days exceeding the maximum temperature threshold (32 degrees Celsius) by development stage for each cultivar

	Planting Date	Stage	Historic	RCP4.5		RCP8.5	
				2030	2050	2030	2050
Slow-Development Cultivar	Nov. 15	Emergence	8	6	8	8	7
		Vegetative	1	0	2	1	10
		Flowering	0	0	0	0	0
		Yield Formation	0	0	0	0	0
		Total	**9**	**6**	**10**	**9**	**17**
	Dec. 10	Emergence	0	0	0	0	0
		Vegetative	0	0	0	0	0
		Flowering	0	0	0	0	0
		Yield Formation	0	0	0	0	0
		Total	**0**	**0**	**0**	**0**	**0**
	Dec. 30	Emergence	0	0	0	0	0
		Vegetative	0	0	0	0	0
		Flowering	0	0	0	0	0
		Yield Formation	0	0	0	0	0
		Total	**0**	**0**	**0**	**0**	**0**
Fast-Development Cultivar	Nov. 15	Emergence	5	5	5	5	5
		Vegetative	4	1	5	4	12
		Flowering	0	0	0	0	0
		Yield Formation	0	0	0	0	0
		Total	**9**	**6**	**10**	**9**	**17**
	Dec. 10	Emergence	0	0	0	0	0
		Vegetative	0	0	0	0	0
		Flowering	0	0	0	0	0
		Yield Formation	0	0	0	0	0
		Total	**0**	**0**	**0**	**0**	**0**
	Dec. 30	Emergence	0	0	0	0	0
		Vegetative	0	0	0	0	0
		Flowering	0	0	0	0	0
		Yield Formation	0	0	0	0	0
		Total	**0**	**0**	**0**	**0**	**0**

Table 9: Average annual precipitation rate (mm) for each RCM in 2030 (2020-2049) and 2050 (2040-2069) and a comparison to the 1971-2000 average precipitation rate of 1081.4mm

RCM	RCP 4.5				RCP 8.5			
	Average Annual Projected Precipitation (mm)		Change from 1971-2000 Average		Average Annual Projected Precipitation (mm)		Change from 1971-2000 Average	
	2030	2050	2030	2050	2030	2050	2030	2050
CCCmaCanRCM	1117.1	1160.3	3%	7%	1155.9	1215.2	7%	12%
CCCmaSMHI	994.7	991.5	-8%	-8%	969.1	1047.6	-10%	-3%
CNRM	1104.6	1070.1	2%	-1%	1170.0	1101.1	8%	2%
CNRMSMHI	1009.7	1020.2	-7%	-6%	1098.7	1083.0	2%	0%
CSIRO	1056.7	961.1	-2%	-11%	1117.5	1002.1	3%	-7%
ICHECDMI	1001.1	920.5	-7%	-15%	943.0	904.9	-13%	-16%
ICHECCCLM	1010.7	974.3	-7%	-10%	932.9	933.0	-14%	-14%
ICHECKNMI	1063.5	1025.2	-2%	-5%	1047.0	1073.2	-3%	-1%
ICHECMPI	996.6	976.4	-8%	-10%	934.0	907.4	-14%	-16%
ICHECSMHI	1065.9	1077.9	-1%	0%	1066.9	1077.4	-1%	0%
IPSL	1089.4	1160.3	1%	7%	1139.6	1205.3	5%	11%
MIROC	1039.6	1028.0	-4%	-5%	1068.3	1034.2	-1%	-4%
MOHCCCLM	1002.0	986.1	-7%	-9%	982.5	990.6	-9%	-8%
MOHCKNMI	1015.5	1006.9	-6%	-7%	1045.8	1015.1	-3%	-6%
MOHCSMHI	1062.8	1096.8	-2%	1%	1098.7	1049.4	2%	-3%
MPICCLM	980.4	971.4	-9%	-10%	995.3	959.2	-8%	-11%
MPIREMO	1037.5	1019.9	-4%	-6%	1031.0	1021.9	-5%	-6%
MPISMHI	1080.4	1052.6	0%	-3%	1089.9	1039.3	1%	-4%
NCCSMHI	1088.3	1105.9	1%	2%	1121.6	1109.0	4%	3%
NOAA	1075.7	1114.4	-1%	3%	1100.5	1048.2	2%	-3%

2. Methodology for Calculating Evapotranspiration for Central Malawi

To calculate evapotranspiration for Central Malawi, the FAO Penman Monteith (FPM) model was applied (Allen et al., 1998a).

Equation 1 $$ETo = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Where:

- ETo is the reference evapotranspiration (mm day^{-1})
- R_n is the net radiation at the crop surface (MJ m2 day^{-1}),
- G is the soil heat flux density (MJ m-2 day^{-1})
- T is the mean daily air temperature (°C)
- u_2 is wind speed at 2 m height (m s^{-1})
- e_s is the saturation vapour pressure (kPa)
- e_a is the actual vapour pressure (kPa), see Equation 10
- $e_s - e_a$ is the saturation vapour pressure deficit (kPa)
- Δ is the slope vapour pressure curve (kPa$°C^{-1}$)
- γ is the psychrometric constant (kPa $°C^{-1}$)

It is not possible to get data for all of the above variables for Central Malawi, either from observed data of the past, or from climate models used to hindcast the past or forecast future climates. Therefore, temperature-based calculation methods were applied for climatic variables with no primary data available (Allen et al., 1998b). This methodology has been tested for Malawi by Wang et al. (2011), and for South Malawi by Ngongondo et al. (2012) and deemed to be appropriate for use.

2.1. Net Radiation at the Crop Surface

R_n is the net radiation at the crop surface (MJ m2 day^{-1}) and can be calculated as follows:

Equation 2 $$R_n = R_{ns} - R_{nl}$$

Where:

- R_{ns} is the net incoming shortwave radiation (MJm-2 day-1) and can be calculated as follows:

  Equation 3 $$R_{ns} = (1 - \propto)R_s$$

  Where:

  - ∝ is the albedo or canopy reflection coefficient, which is 0.23 for the hypothetical grass reference crop
  - R_s is the fraction of the solar radiation not reflected from the surface (MJm-2 day-1) and can be calculated as follows:

    Equation 4 $$R_s = k_{Rs}\sqrt{T_{max} - T_{min}}\,R_a$$

    Where:

    - K_{RS} is adjustment coefficient. For inland regions not influenced by large bodies of water, K_{RS} = 0.16 ; for coastal regions, or regions where the air mass is influenced by a large nearby water body, K_{RS} = 0.19. Since Central Malawi is highly influenced by the presence of a large water body (Lake Malawi). K_{RS} is considered to be 0.19 in this study.
    - T_{max} is the maximum air temperature (ºC)
    - T_{min} is the minimum air temperature (ºC)
    - R_a is extra-terrestrial radiation (MJm-2 day-1) and can be calculated as follows:

      Equation 5 $$R_a = \frac{24(60)}{\pi}G_{sc}d_r[\omega_s\, sin(\varphi)\, sin(\delta) + cos(\varphi)\, cos(\delta)\, sin(\omega_s)]$$

Where:

- G_{Sc} is the solar constant = 0.0820 $MJm^{-2}min^{-1}$
- d_r is the inverse relative since earth-Sun (rad) which can be calculated as follows:

  Equation 6 $d_r = 1 + 0.033\cos\left(\frac{2\pi}{365}J\right)$

  Where:
  - J is the number of days in the year between 1 (1 January) and 365 or 266 (31 December). J at the middle of each month = 30.4M-15 where M is the month number
- ω_s is the sunset hour angle (rad) which can be calculated as follows:

  Equation 7 $\omega_s = arccos[-tan(\varphi)\,tan(\delta)]$

  Where:
  - φ is the latitude (rad)
  - δ is the solar declination (rad) which can be calculated as follows:

    Equation 8 $\delta = 1 + 0.409\,sin\left(\frac{2\pi}{365}J - 1.39\right)$

- R_{nl} is in the net outgoing longwave radiation (MJm-2 day-1) and can be calculated as follows:

Equation 9 $$R_{nl} = \sigma\left[\frac{T_{maxK}{}^4 + T_{minK}{}^4}{2}\right]\left(0.34 - 0.14\sqrt{e_a}\right)\left(1.35\frac{R_s}{R_{so}} - 0.35\right)$$

Where:

- σ is the Stefan-Boltzmann constant [4.903 x 10^{-9} MJ K^{-4} m^{-2} day^{-1}
- $T_{max,K}$ is the maximum absolute temperature during the 24-hour period [K = °C + 273.16],
- $T_{min,K}$ minimum absolute temperature during the 24-hour period [K = °C + 273.16],
- e_a actual vapour pressure [kPa], which can be calculated as follows:

  Equation 10 $e_a = e^o(T_{dew}) = 0.6108exp\left(\frac{17.27T_{dew}}{T_{dew}+237.3}\right)$

  Where:
  - T_{dew} is the dew point temperature. T_{dew} is near the minimum temperature (T_{min}) when the relative humidity is nearly 100%. In semi-arid regions, T_{dew} is estimated by subtracting 2°C from T_{min}. As Central Malawi's humidity is typically under 90%, the T_{dew} can be calculated as follows:

    Equation 11 $T_{dew} = T_{min} - 2$

- R_s is the solar radiation [MJ m-2 day-1], see Equation 4.
- R_{so} is the clear-sky solar radiation [MJ m-2 day-1], which can be calculated as follows:

  Equation 12 $R_{SO} = (0.75 + 0.00002(h))R_a$

  Where:
  - h is the elevation above sea level (m)
  - R_a is extra-terrestrial radiation, (MJm-2 day-1), see Equation 5.

2.2. Soil Heat Flux Density

G is the soil heat flux density (MJ m-2 day^{-1})

- For daily assessment, G is assumed to be zero (0) as the soil heat flux is relatively small
  Equation 13: $G_{day} = 0$

- For monthly assessments,
  Equation 14: $G = 0.07\ (T_{month,i+1} - T_{month,i-1})$

  Where:
  - $T_{mon,\ i-1}$ is the mean air temperature of the previous month (°C)
  - $T_{mon,\ i+1}$ is the mean air temperature of the next month (°C)

2.3. Mean Temperature

T is the mean daily air temperature (°C), which can be calculated as follows:
Equation 15: $T_{mean} = \frac{T_{min}+T_{max}}{2}$

Where:
- T_{max} is the maximum air temperature (ºC)
- T_{min} is the minimum air temperature (ºC)

2.4. Wind Speed at 2m height

u_2 is wind speed at 2 m height (m s^{-1}). We can use a default value of 172 km day^{-1} which is the average value over different weather stations around the globe. This was recommended by Allen et al. (1998). To convert to the correct units for the equation above (m s^{-1}) we can do the following:
Equation 16: $\frac{172km}{day}\ x\ \frac{day}{24\ hours}\ x\ \frac{hour}{60\ minutes}\ x\ \frac{minute}{60\ seconds}\ x\ \frac{1000\ meters}{km} = \frac{172{,}000\ meters}{86{,}400\ seconds}$

2.5. Vapour Pressure

To calculate ETO, various vapour pressure variables are required, including the saturation vapour pressure (e_s), the actual vapour pressure (e_a) and the slope vapour pressure curve (Δ).

- e_s is the saturation vapour pressure (kPa), it can be calculated as follows:
  Equation 17: $e_s = \frac{e^o(T_{max})+e^o(T_{min})}{2}$

  Where:
  - $e^0(T_{max})$ is the vapour pressure at maximum temperature, and can be calculated as follows:
    Equation 18: $e^o(T_{max}) = 0.6108exp\left(\frac{17.27T_{max}}{T_{max}+237.3}\right)$

    Where:

    - T_{max} is the maximum air temperature (ºC)
  - $e^0(T_{min})$ is the vapour pressure at minimum temperature, and can be calculated as follows:
    Equation 19: $e^o(T_{min}) = 0.6108exp\left(\frac{17.27T_{min}}{T_{min}+237.3}\right)$

    Where:

    - T_{min} is the minimum air temperature (ºC)

- e_a is the actual vapour pressure (kPa), see Equation 10
- Δ is the slope vapour pressure curve (kPa°C^{-1})

Equation 20: $\Delta = \frac{4098\left[0.6108exp\left(\frac{17.27T}{T+237.3}\right)\right]}{(T+237.3)^2}$

Where:

- T is the mean air temperature (°C), see Equation 15
- exp[…] 2.7183 (base of natural logarithm) raised to the power […]

2.6. Psychrometric Constant

γ is the psychrometric constant (kPa $°C^{-1}$), it can be calculated as follows:

Equation 21: $\gamma = \frac{C_P P}{\varepsilon\lambda}$

Where:

- C_P is the specific heat at a constant pressure, C_P = 1.013 x 10^{-3} MJ kg^{-1} $°C^{-1}$
- P is atmospheric pressure (kPa), which can be calculated as follows:

  Equation 22: $P = 101.325(293 - 0.0065(h))^{5.25588}$

  Where:

    - h is the altitude above sea level in meters (m)
        - For Central Malawi, the average altitude above sea level (h) is 948.1944444m (determined using data from JISAO (2014))
    - ε is the ratio molecular weight of water vapour / dry air, ε = 0.622
    - λ is the latent heat of vaporization, λ = 2.45 MJ kg^{-1}

3. References

ALLEN, R. G., PEREIRA, L. S., RAES, D. & SMITH, M. 1998a. FAO Penman-Monteith Equation. *Crop evapotranspiration - Guidelines for computing crop water requirements.*

ALLEN, R. G., PEREIRA, L. S., RAES, D. & SMITH, M. 1998b. Meteorological Data. *Crop evapotranspiration - Guidelines for computing crop water requirements.* Rome: FAO.

CCCMA. 2017. *Canadian Regional Climate Model Output* [Online]. Government of Canada. Available: http://climate-modelling.canada.ca/climatemodeldata/canrcm/CanRCM4/index.shtml [Accessed 26 June 2017].

CHRISTENSEN, O. B., DREWS, M., CHRISTENSEN, J. H., DETHLOFF, K., KATELSEN, K., HEBESTADT, I. & RINKE, A. 2007. Technical report 06-17. The HIRHAM Regional Climate Model

Version 5 (β). Copenhagen.

COSMO. 2017. *Core Documentation of the COSMO-model* [Online]. Available: http://www.cosmo-model.org/content/model/documentation/core/default.htm#p1 [Accessed 20 October 2017].

ESGF. 2017. *ESGF@LiU/CORDEX* [Online]. Available: https://esg-dn1.nsc.liu.se/projects/cordex/ [Accessed 26 June 2017].

HARRIS, I., JONES, P. D., OSBORN, T. J. & LISTER, D. H. 2014. Updated high-resolution grids of monthly climatic observations - the CRU TS3.10 Dataset. *International Journal of Climatology,* 34**,** 623-642.

JACOB, D., ELIZALDE, A., HAENSLER, A., HAGEMANN, S., KUMAR, P., PODZUN, R., RECHID, D., REMEDIO, A. R., SAEED, F., SIECK, K., TEICHMANN, C. & WILHELM, C. 2012. Assessing the

Transferability of the Regional Climate Model REMO to Different Coordinated

Regional Climate Downscaling Experiment (CORDEX) Regions. *Atmosphere,* 3**,** 181-199.

JISAO 2014. Elevation data in netCDF. 0.25-degree latitude-longitude resolution elevation (TBASE).

NGONGONDO, C., XU, C.-Y., TALLAKSEN, L. M. & ALEMAW, B. 2012. Evolution of the FAO Penman-Monthith, Preistley-Taylor and Hargreaves models for estimating reference evapotranspiration in southern Malawi. *Hydrology Research,* 44**,** 706-722.

SAMUELSSON, P., GOLLVIK, S., JANSSON, C., KUPIAINEN, M., KOURZENEVA, E. & JAN VAN DE BERG, W. 2015. The surface processes of the Rossby Centre

regional atmospheric climate model (RCA4). Norrköping, Sweden.

SCHNEIDER, U., BECKER, A., FINGER, P., MEYER-CHRISTOFFER, A., RUDOLF, B. & ZIESE, M. 2015. GPCC Full Data Reanalysis Version 7.0 at 1.0 °: Monthly Land-Surface Precipitation from Rain-Gauges built on GTS-based and Historic Data.

SCINOCCA, J. F., KHARIN, V. V., JIAO, Y., QIAN, M. W., LAZARE, M., SOLHEIM, L., FLATO, G. M., BINER, S., DESGAGNE, M. & DUGAS, B. 2016. Coordinated Global and Regional Climate Modeling. *Journal of Climate,* 29**,** 17-35.

VAN MEIJGAARD, E., VAN ULFT, L. H., VAN DE BERG, W. J., BOSVELD, F. C., VAN DEN HURK, B. J. J. M., LENDERINK, G. & SIEBESMA, A. P. 2008. Technical report ; TR - 302. The KNMI regional atmospheric climate model RACMO version 2.1. De Bilt.

WANG, Y.-M., NAMAONA, W., GLADDEN, L. A., TRAORE, S. & DENG, L.-T. 2011. Comparative study on estimating reference evapotranspiration under limited climate data condition in Malawi. *International Journal of the Physical Sciences,* 6**,** 2239-2248.

WILLMOTT, C. J. & MATSUURA, K. 2001. *Terrestrial Air Temperature and Precipitation: Monthly and Annual Time Series (1950-1999)* [Online]. Available: http://climate.geog.udel.edu/~climate/html_pages/README.ghcn_ts2.html. [Accessed 30 August 2017].