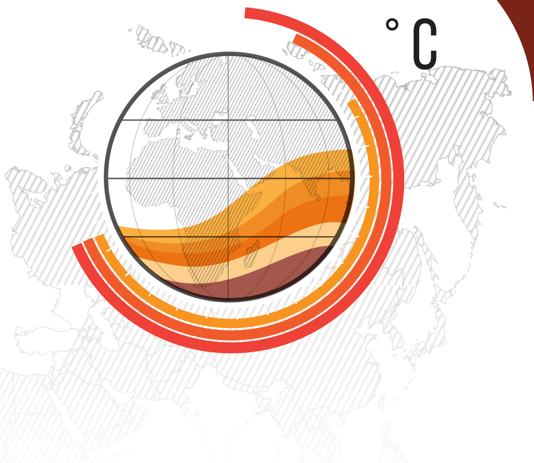
WHAT GLOBAL WARMING OF 1.5°C AND HIGHER MEANS FOR KENYA



The Paris Agreement has a goal of limiting global warming well below 2°C, ideally 1.5°C. Understanding the local-level impacts of these global temperature targets is crucial for informing climate change adaptation needs and actions. To date, mitigation pledges by nations fall far short of what is needed, with the world on track to warm by 3.2°C by the end of the century[1].

For Kenya, local warming will be greater than the global average, with significant impacts for the already-warm climate. Even a 1.5°C increase in global temperature will severely affect agriculture, health, and other vulnerable sectors. Under an increasing emissions trajectory, the 1.5°C threshold could be breached within the next decade, and the 2°C threshold the decade after[2]. As impacts on climate extremes and vulnerable sectors will worsen with each half degree increment, and compromise Kenya's development agenda, there is an urgent need to accelerate the country's adaptation responses.

LOCAL IMPACTS IN KENYA — GLOBAL WARMING ABOVE PRE-INDUSTRIAL LEVELS

	LOCAL IMPACTS IN KENYA		1.5°C	vs 2°C	vs 2.5°C	vs 3°C
Projected climate changes[3]	CLIMATE	Mean temperature (°C)	▲ 1.7	▲ 2.2	▲ 2.8	▲ 3.3
		Heat waves (days)	▲ 92	▲ 155	▲ 201	▲ 226
		Annual rainfall	▲ 5%	▲ 8%	▲ 11%	▲ 12%
		Heavy rainfall (days)	▲ 1	▲ 2	▲ 2	▲ 3
		Percentage of total rainfall falling within heavy downpours[4]	21%	23%	24%	25%
Estimated impacts[5]	WATER	Lake Victoria Basin[6] (runoff)	▲ 46%	▲ 50%[7]	▲ 88%	▲ 91%[7]
		Country-wide streamflow[8]			▲ 50%	
	AGRICULTURE	Wheat and groundnuts[9] (yield)	▼ 14%[7]	▼ 24%[7]	▼ 34%[7]	▼ 43%[7]
		Maize[10] (yield)	▲ 4%	▲ 7%	▲ 7%	▲ 7%
	LIVESTOCK	Small livestock farms[11] (income)	▼ 6%[7]	▼ 9%[7]	▼ 13%	▼ 17%[7]
		Large livestock farms[11] (income)	▼ 11%[7]	▼ 19%[7]	▼ 26%	▼ 35%[7]
	HEALTH	Child malnutrition[9] (increased prevalence linked to climate change)	▲ 2%	▲ 2.5%[7]	▲ 3%	▲ 3.5%[7]
		Malaria[12] (months of risk)	▲ 32%[7]	▲ 47%[7]	▲ 70%	▲ 78%[7]
		Diarrheal death linked to climate change[13] (% of all diarrheal deaths)	9%	10%[7]	12%[7]	13%

[1] Climate Action Tracker. https://climateactiontracker.org/global/cat-thermometer.
[2] Nkemelang, T. et al. 2018. Determining what global warming of 1.5°C and higher means for the semi-arid regions of Botswana, Namibia, Ghana, Mali, Kenya and Ethiopia: A description of ASSAR's methods of analysis. https://bit.ly/2yHbWPf.
[3] Based on climate modelling by T. Nkemelang. University of Cape Town, South Africa.
[4] As an indicator of flood risk.
[5] Based on data analysis by R. Bouwer. University of Cape Town, South Africa. Empty blocks indicate a lack of available information.
[6] Githui, F., Gitau, W., Mutua, F., and Bauwens, W. 2009. Climate change impact on SWAT simulated streamflow in western Kenya. *International Journal of Climatology*. https://doi.org/10.1002/joc.1828.
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ASSAR
Adaptation at Scale in Semi-Arid Regions

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TABLE 1: IMPACTS OF GLOBAL WARMING THRESHOLDS ON KENYA'S CLIMATIC ZONES

	ARID NORTH EAST				ARID NORTH WEST				SEMI-ARID NORTH				SEMI-ARID NORTH EAST			
	1.5°C	2°C	2.5°C	3°C	1.5°C	2°C	2.5°C	3°C	1.5°C	2°C	2.5°C	3°C	1.5°C	2°C	2.5°C	3°C
Annual rainfall (%)	+6	+10	+12	+15	+9	+18	+21	+24	+10	+12	+16	+16	+7	+12	+14	+17
Duration of dry spells (days)	+2	+1	0	+2	-4	-5	-6	-7	+2	+2	+2	+5	-3	-2	-3	-4
Duration of wet spells (days)	+1	+1	+1	0	0	0	+1	+1	0	0	+1	+1	+1	+1	+1	+1
Heavy rainfall days (>10mm/day)	+1	+2	+2	+3	+1	+2	+3	+3	+2	+1	+2	+3	+2	+2	+3	+4
Extreme heavy rainfall days (>20mm/day)	0	0	+1	+1	+1	+1	+1	+1	0	+1	+1	+1	+1	+1	+1	+1
Amount of rain in heavy rainfall events (%)	+28	+38	+48	+54	+43	+53	+60	+79	+18	+27	+39	+44	+26	+41	+45	+66
Amount of rain in extremely heavy rainfall events (%)	+36	+51	+64	+92	+54	+76	+92	+121	+44	+61	+61	+83	+58	+66	+91	+117
Amount of rain in highest rainfall day (%)	+8	+14	+16	+17	+12	+16	+16	+19	+10	+12	+14	+16	+12	+13	+18	+19
Amount of rain in highest five consecutive rainfall days (%)	+8	+11	+14	+18	+9	+13	+18	+18	+7	+10	+14	+17	+7	+11	+13	+15
Temperature change (°C)	+1.7	+2.2	+2.7	+3.3	+1.7	+2.4	+2.9	+3.5	+1.7	+2.3	+2.9	+3.4	+1.7	+2.3	+3.0	+3.5
Number of hot days (>90th percentile)	+156	+208	+233	+248	+132	+173	+205	+222	+146	+204	+232	+250	+128	+172	+203	+221
Number of hot nights (>90th percentile)	+150	+212	+276	+306	+127	+189	+243	+279	+127	+186	+248	+285	+125	+191	+244	+281
Number of cold days (<10th percentile)	-36	-39	-43	-45	-28	-34	-37	-38	-31	-35	-38	-40	-30	-33	-38	-40
Number of cold nights (<10th percentile)	-63	-65	-66	-66	-55	-57	-60	-62	-58	-60	-61	-61	-60	-62	-64	-65
Duration of heat waves (days)	+112	+182	+236	+253	+96	+145	+184	+212	+92	+153	+207	+235	+90	+141	+185	+215

	SEMI-ARID SOUTH				HUMID: MOUNTAINS				HUMID: COAST				KENYA OVERALL			
	1.5°C	2°C	2.5°C	3°C	1.5°C	2°C	2.5°C	3°C	1.5°C	2°C	2.5°C	3°C	1.5°C	2°C	2.5°C	3°C
Annual rainfall (%)	+4	+6	+8	+8	+6	+6	+9	+10	+1	+1	+2	+1	+5	+8	+11	+12
Duration of dry spells (days)	-3	-4	-5	-6	-2	-2	-1	-2	+3	+4	+4	+5	0	-1	0	0
Duration of wet spells (days)	0	0	0	-1	+1	+1	0	0	0	-1	-1	-1	0	+1	+1	0
Heavy rainfall days (>10mm/day)	+1	+1	+2	+2	+2	+2	+3	+3	+1	+1	+1	+1	+1	+2	+2	+3
Extreme heavy rainfall days (>20mm/day)	0	+1	+1	+1	+1	+1	+2	+2	0	0	0	0	+1	+1	+1	+1
Amount of rain in heavy rainfall events (%)	+31	+34	+50	+57	+32	+42	+55	+66	+13	+17	+24	+25	+25	+38	+49	+59
Amount of rain in extremely heavy rainfall events (%)	+30	+43	+69	+72	+32	+35	+51	+138	+25	+31	+47	+52	+47	+64	+83	+96
Amount of rain in highest rainfall day (%)	+6	+10	+16	+16	+11	+15	+18	+25	+6	+10	+13	+14	+9	+11	+16	+17
Amount of rain in highest five consecutive rainfall days (%)	+8	+12	+14	+15	+9	+12	+14	+18	+5	+7	+11	+10	+7	+10	+12	+16
Temperature change (°C)	+1.6	+2.1	+2.6	+3.2	+1.7	+2.2	+2.8	+3.3	+1.5	+2.0	+2.8	+3.4	+1.7	+2.2	+2.8	+3.3
Number of hot days (>90th percentile)	+129	+176	+211	+235	+106	+147	+182	+208	+149	+201	+237	+264	+133	+181	+208	+227
Number of hot nights (>90th percentile)	+156	+216	+271	+308	+125	+186	+237	+272	+194	+261	+299	+326	+136	+204	+261	+294
Number of cold days (<10th percentile)	-37	-41	-45	-47	-32	-36	-38	-40	-51	-55	-56	-57	-34	-38	-41	-43
Number of cold nights (<10th percentile)	-64	-66	-68	-68	-58	-61	-62	-63	-72	-74	-77	-78	-63	-65	-66	-66
Duration of heat waves (days)	+85	+147	+198	+227	+68	+115	+153	+188	+111	+109	+225	+257	+92	+155	+201	+226

Anticipating a 1.5°C+ world

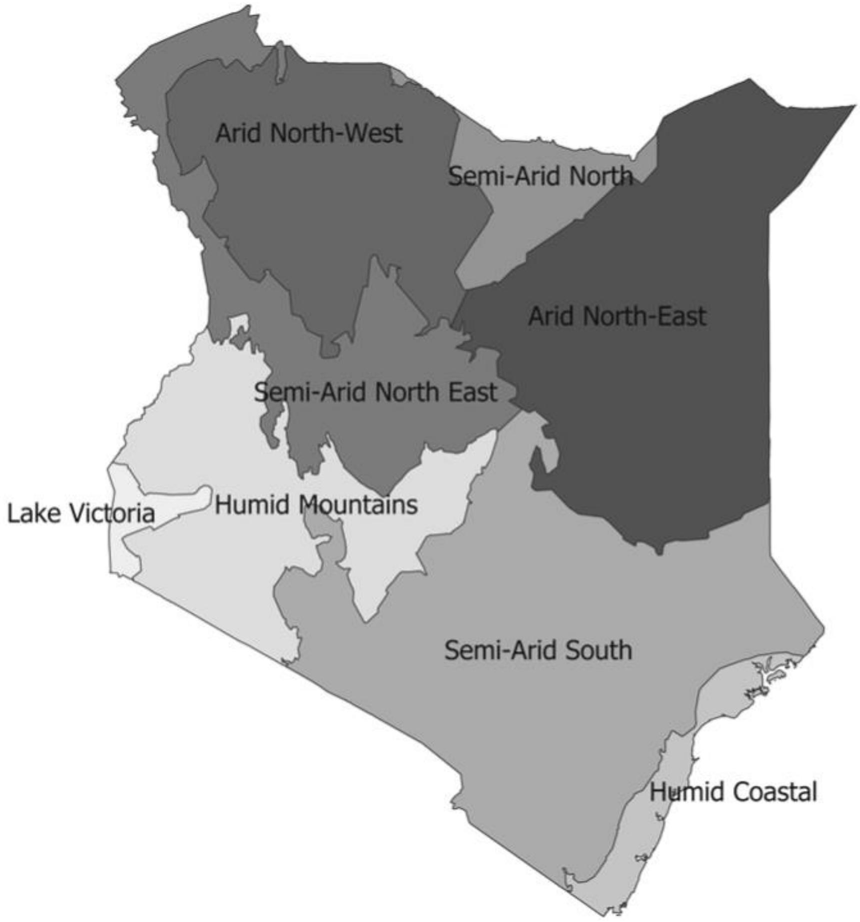
The Paris Agreement has a goal of limiting global warming to below 2°C (and ideally below 1.5°C) above pre-industrial levels. Current emissions reduction promises by nations fall short of what is needed to meet this target. Instead, global average temperatures could exceed the 1.5°C warming mark by as early as the next decade and the 2°C threshold the decade after (Nkemelang *et al*., 2018). The world is on track for a warming of 3.2°C by 2100 (Climate Action Tracker).

For Kenya, these seemingly small increments in global temperature can lead to marked local changes in climate, which can interact with, or worsen, existing vulnerabilities.

As this brief highlights, Kenya needs to anticipate and plan for quite rapid changes in local weather and climate. To adapt to a 1.5°C+ world, Kenya should carry forward the momentum gained through the development of its National Adaptation Plan and Climate Change Action Plans.

With these instruments in place, and aware of the near-term risks of 1.5°C and above, Kenya will be in a position to intensify its adaptation planning and actions, as well as efforts to finance these, so it is prepared to respond to the impacts associated with global warming.

Kenya



Kenya can be divided into three main climate types: arid, semi-arid and humid. These types are spread across different geographic regions, and so we assessed seven different climate zones: arid north-east, arid north-west, semi-arid north, semi-arid north-east, semi-arid south, humid mountainous, and humid coast.

The arid and semi-arid zones are characterised by hot and dry climates. The humid zones are characterised by wetter climates and milder temperatures in the mountain region, and high temperatures in the coastal region.

As the global temperatures rise by 1.5°C, 2°C and higher, the local impacts will have significant impacts on the climate conditions within these zones.

Anticipated changes in Kenya's climate and its extremes

Increasingly warm temperatures

Kenya already has high mean temperatures across most of the country, with only the highlands in the humid mountainous zone having relatively cool conditions. Increasing global temperatures will result in further warming in Kenya with an country average increase of 1.7° C at a global warming of 1.5°C, and a 3.3°C increase at a global warming of 3°C.

Temperature increases vary across climate zones by between 1.5-1.8°C at 1.5°C global warming. At 2.0°C and 3.0°C these increases will be as much as 2-2.4°C and 3.2-3.5°C, respectively (see Table 1).

These temperature changes will result in significant increases in extremely hot days and nights, while the number of cold days and nights will decrease. Warm spells and heat waves will become more frequent and intense across all zones, and the duration of warm spells will increase by 68-112 days across the different climatic zones at 1.5°C global warming (Table 2). This will be even greater at 2°C with increases of 115 and 182 days respectively. By 3°C more than half the year will be dominated by what are considered heat waves today, as the total duration of warm spells will range from 193-261 days with the humid coast experiencing the longest heat waves.

Table 2: Local changes to Kenya's temperature, heat waves and rainfall

	Local temperature increases	Duration of heat waves	Local rainfall decreases
1.5°C	+ 1.5 - 1.7°C	+ 68 - 112	+ 1 - 10%
2°C	+ 2.0 - 2.4°C	+ 109 - 182	+ 1 - 18%
2.5°C	+ 2.6 - 3.0°C	+ 154 - 236	+ 2 - 21%
3°C	+ 3.2 - 3.5°C	+ 188 - 257	+ 1 - 24%

Increasing rainfall

As local temperatures rise in Kenya, the total annual precipitation is expected to increase by 5% at 1.5°C global warming, 8% at 2.0°C, and up to 12% at 3°C (Table 2).

The changes in rainfall will vary across zones, with the humid coast having the smallest rainfall increase of approximately 1% as global temperatures increase from 1.5°C to 3°C (see Table 1). At 1.5°C the semi-arid north will receive as much as a 10% rainfall increase, while at 2°C and 3°C global warming the arid north-west will receive the largest rainfall increases (18-24%, respectively).

The duration of wet spells is expected to have either no change or an increase of one day in most zones. However, the change in duration of dry spells is expected to vary with some zones experiencing increases while others experience decreases (see Table 1).

More frequent and intense heavy rainfall events

The increase in rainfall will also correlate with an increasing intensity of rainfall events. Across all zones, the number of heavy and extreme heavy rainfall days will increase, with the biggest increases in the semi-arid north-east and humid mountainous zones.

The largest rainfall events will increase in intensity and frequency. All regions will experience large increases in the amount of total annual rainfall which falls within heavy and extremely heavy rainfall events.

The intensity of the largest events will also increase in terms of the amount of rainfall falling within these events. Some of the highest increases are expected within the humid mountain and arid north-west zones (see Table 1 for details on each zone).

Mark Tebboth

1.5°C + impacts on Kenya's vulnerable sectors

The increasing frequency and intensity of climate extremes in Kenya will have significant impacts on the country's vulnerable sectors, creating various challenges to the achievement of President Kenyatta's "Big Four Agenda" (Presidency, Republic of Kenya, 2018). The local impacts of global temperature increases are expected to be particularly hard felt on the country's water resources, agriculture and human health sectors.

WATER: Depleting resources and an increase in disasters

Changes in temperature and rainfall in Kenya at 1.5°C global warming and higher will result in an increasing severity of climate-related risks, especially flooding and droughts, to which Kenya is already highly vulnerable.

Stream flow: The projected increases in rainfall across Kenya will result in a higher discharge from rivers within the country. At 2°C, surface runoff is projected to increase by more than 50% across the country (Schewe *et al.*, 2014). While increased rainfall will influence streamflow, the largest increase will likely be in surface runoff into the river systems as increasing rainfall intensity generates excess water that cannot be easily or quickly absorbed by the land. This means runoff will be high during rainfall events, but will not necessarily translate to large increases in streamflows or water availability.

At 1.5°C global warming, the Lake Victoria Basin in the humid mountainous zone, will experience a 46% increase in surface runoff, and 5% increase in streamflow (Githui *et al.*, 2009). These will increase to 50% for surface runoff and 9% for streamflow 2°C, and to 91% for surface runoff and 16% for streamflow 3°C, respectively.

Table 3: Changes to Kenya's water resources

	Lake Victoria Basin (Runoff)	Lake Victoria Basin (Streamflow)
1.5°C	+ 46%	+ 5%
2°C	+ 50%	+ 9%
2.5°C	+ 88%	+ 13%
3°C	+ 91%	+ 16%

Floods: Flood risks already have significant impact in Kenya**.** In 2018, flash floods affected 800,000 people, displacing communities and causing 186 deaths (OCHA, 2018). The projected increased rainfall and rainfall intensity, will lead to increased flood risks across the country.

The Kenyan government has identified 11 flood prone areas in the country (Republic of Kenya, 2018), of which:

- **Two are located within the arid north-west and two within the arid north-east zones.** These zones will receive increased heavy rainfall days and increased intensity of rainfall events. The arid north-west in particular will receive the largest increase in the amount of rainfall falling within heavy and extremely heavy rainfall events.
- **Three are located in the semi-arid south zone (and partly humid coast), and one within the semi-arid north east zone.** Rainfall and heavy rainfall events will increase in these zones, particularly in the semi-arid north-east which (at 1.5°C global warming) will experience some of the highest increases in the amount of rain falling within heavy events.
- **One is located in the humid mountainous zone.** This zone already has relatively high rainfall, and while the increase in total rainfall will be lower than for other zones, the increase in intensity and frequency of heavy rainfall events will be one of the highest in the country.

At 1.5°C global warming, flooding will likely cause more damage in these hotspots, as an estimated increase of 20-40% in damages and losses could occur (Alfieri *et al.*, 2016). This vulnerability will worsen at 2°C with an additional 20-40% increase in the population affected by flooding, suggesting the emergence of new flood-prone areas.

Droughts: Droughts are a common occurrence in Kenya, and will likely be exacerbated by increasing temperatures, and perhaps more variable rainfall. Since 2014, a persistent drought has doubled food insecurity, led to a 99% decline in maize production along coastal areas, and exacerbated water scarcity in semi-arid regions (Reliefweb, 2018a). Increasing temperatures and changing rainfall patterns may result in more intense drought periods. The arid and semi-arid zones already have the highest temperatures and lowest rainfall and therefore are especially vulnerable. These zones will experience some of the highest temperature increases, as well as significant increases in the duration of heat waves. The hotter conditions will likely increase evapotranspiration placing strain on water resources. However, the increasing precipitation may offset drought vulnerabilities somewhat.

In most zones, the duration of dry spells is expected to decrease at 1.5°C and 2°C global warming, except in the arid north-east, semi-arid south, and humid coastal zones, which all see an increase in dry spell duration. It is projected that at 1.5°C drought severity (according to the Palmer Drought Index (PDSI) will decrease from -4 to -5, but increase to -3 at 2°C. This suggests that drought severity will increase slightly at 1.5°C, but will be offset by increased rainfall at 2°C.

Sea-level rise: Coastal flooding and the inundation of coastal land are expected to become an increasing threat to Kenya as global temperatures increase and sea levels rise. At 1.5°C global warming, roughly 250,000 Kenyans will be at risk of coastal flooding (Republic of Kenya, 2018).

At 1.5°C and 3°C sea levels will rise by 15 and 55cm respectively (Climate Analytics, 2018). This amount of sea level rise will have significant impacts within the humid coast zone, with 10% and 30% of land in Mombasa at risk of being submerged by rising waters.

Table 4: Sea level rise in Kenya

	Sea level rise (Lamu)	Land at risk of coastal flooding (Mombasa)
1.5°C	15cm	10%
2°C	28cm	17%
2.5°C	42cm	24%
3°C	55cm	30%

Daniel McGahey

AGRICULTURE: Reduced productivity and worsening food security

Kenya's agricultural sector is a mainstay of the economy. It accounts for approximately 25% of GDP, 65% of exports, and 75% of employment in the country (Republic of Kenya, 2017). The majority of crop production and commercial livestock rearing occurs in the humid mountainous region, while livestock pastoralism is concentrated in the arid regions. Global temperature rise of 1.5°C and higher is likely to result in agricultural losses and place strain on food security in Kenya.

Table 5: Changes to Kenya's growing seasons

	Arid north-west	Arid north-east	Semi-arid zones	Humid mountainous	Humid coastal
1.5°C	+ 22%	- 9%	+ 4%	- 3%	- 8%
2°C	+ 32%	- 18%	+ 3%	- 6%	- 14%
2.5°C	+ 44%	- 28%	+ 2%	- 9%	- 20%
3°C	+ 53%	- 37%	+ 1%	- 12%	- 25%

Kenya's growing seasons: Changes in temperature and rainfall are expected to have an impact on the agricultural areas and the amount of suitable growing days in different zones of Kenya. The length of growing periods may decrease (loss) as a result of increased heat stress, or may increase (gain) due to increasing rainfall.

Each zone is expected to be affected as follows (Herrero *et al*., 2010):

At 1.5°C

- Arid north-west will experience a 22% gain, while the arid north east will experience a 9% loss.
- Semi-arid zones will experience a gain of 4%.
- Humid mountainous and humid coast will experiences losses of 3% and 8% respectively.

At 2°C

- Arid north-west will experience a gain of 32%, while the arid north east will experience a loss of 18%.
- Semi-arid zones will experience a gain of 3%.
- Humid mountainous and humid coast will experience losses of 6% and 14%.

At 3°C

- Arid north-west will experience a gain of 53% while the arid north-east will experience a loss of 37%.
- Semi-arid zones will experience a loss of 1%.
- Humid mountainous and humid coast will experience a loss of 12 and 25% respectively.

Crop yields: Global temperature increases of 1.5°C and above will result in decreased yields in wheat and groundnut, and increased maize yields across Kenya.

The changing suitable crop-growing regions will have varying impacts on the yields of crops in different climate regions (Herrero *et al*., 2010):

At 1.5°C and 2°C

- The humid zones will experience a loss of approximately 16% and 26% in both wheat and irrigated rice yields, but will experience increases of approximately 6% and 9% in maize and groundnut yields.
- The semi-arid zones will experience losses of approximately 9% and 15% in maize and -16% and -265% in groundnuts, but will experience gains of approximately 6% and 9% in wheat and irrigated rice yields.
- The arid zones will experience losses of approximately 16-26% in both maize and groundnut yields.

At 3°C

- Losses across all zones are expected to amount to approximately 2% for maize, and up to 43% for groundnuts, wheat and irrigated rice.

Table 6: Changes to Kenya's agricultural yields

	Maize (yield) *humid mountainous zone*	Maize (yield) *arid zones*	Maize (yield) *semi-arid zones*	Groundnut (yield) *humid zones*	Groundnut (yield) *arid and semi-arid zones*	Wheat and rice (yield) *semi-arid zones*	Wheat and rice (yield) *humid mountainous zone*	Small livestock farms (income)	Large livestock farms (income)
1.5°C	+ 6%	- 16%	- 9%	+ 6%	- 16%	+ 6%	- 16%	- 6%	- 11%
2°C	+ 9%	- 26%	- 15%	+ 9%	- 26%	+ 9%	- 26%	- 9%	- 19%
2.5°C	+ 13%	- 37%	- 20%	+ 13%	- 37%	+ 13%	- 37%	- 13%	- 26%
3°C	+ 17%	- 47%	- 27%	+ 17%	- 47%	+ 17%	- 47%	- 17%	- 35%

Livestock: Increasing temperatures pose challenges to livestock production. At high temperatures, cattle-feed intake, milk production, fertility and longevity decline, while water intake increases drastically, all of which affect livestock productivity (Thornton *et al.*, 2009). The concentration of pastoralism in Kenya's arid and semi-arid regions, where temperature increases will be among the largest in the country, means livestock will be particularly vulnerable to heat stress.

Drought will also have significant impacts on livestock. At 1.5°C the livestock sector could lose as many as 1.8 million cattle due to increased variability and associated droughts (Herrero *et al.*, 2010). The level of impact will also be determined by the type of livestock farming, as large farms focusing on intensive cattle farming could experience income losses of 11% and 19% at 1.5°C and 2°C respectively (Mendelsohn and Seo, 2007). Small farmers with more diversified and adaptable practices will be less hard hit with income losses of 6% and 9% at 1.5°C and 2°C respectively.


Daniel McGahey

HUMAN HEALTH: Worsening malnutrition, heat stress and disease

The increasing temperatures and changing rainfall patterns projected to occur at warming of 1.5°C and above are set to alter the prevalence of disease. This is likely to increase the number of deaths attributed to climate change, due to illnesses such as malaria, dengue fever, heat stress, and diarrheal diseases (WHO, 2016).

Table 7: Impacts on human health in Kenya

	Child malnutrition linked to climate change	Diarrheal deaths linked to climate change	Malaria (persons exposed per month)	Heat stress: caution days* *humid mountainous*	Heat stress: extreme caution days* *humid coast and arid zones*	Heat stress: danger days* *humid coast and arid zones*
1.5°C	+ 2%	9%	+ 22%	+ 124	+ 18-52 days	+ 32-52 days
2°C	+ 3%	10%	+ 44%	+ 143	+ 27-78 days	+ 48-76 days
2.5°C	+ 4%	12%	+ 70%	+ 163	+ 37-78 days	+ 65-102 days
3°C	+ 6%	13%	+ 94%	+ 182	+ 46-131 days	+ 81-128 days

**see Table 8*

Child malnutrition: The impacts of climate change on the agricultural sector and food security will worsen malnutrition in the country. While Kenya is likely to make progress in combating child malnutrition, at 1.5°C and 2°C global warming, the portion of children suffering from malnutrition will be 17% and 16% respectively (without climate change this would be 15% and 13% respectively; Herrero *et al.*, 2010).

Diarrheal Diseases: Increasing rainfall and flooding events will result in a greater prevalence of water-borne diseases, especially diarrheal diseases. At 1.5°C and 2°C global warming, the portion of deaths due to diarrheal diseases attributed to climate change is 9% and 10% respectively (WHO, 2016).

Malaria: Higher temperatures and increasing rainfall is also expected to positively affect mosquito-borne diseases such as malaria. However, the development of the malaria parasite and vector is slow and requires wet conditions. In hot climates, a rainfall season of 3 months is sufficient to support a malaria season, while in milder climates at least 5 months of rainfall are needed (Craig *et al.*, 1999). At 1.5°C and 2°C global warming, the population exposed to malaria months will increase by 28% and 44% respectively (Tanser *et al.* 2003). The increase will be particularly significant in the humid mountainous zone as new areas in the highlands, which were previously too cold, will become suitable for malaria.

Heat stress: As temperatures rise so too does the prevalence of heat stress. This condition can result in heavy sweating, leg cramps, intense thirst, fatigue, disorientation and feelings of paranoia. In severe cases, people may experience hallucinations, fainting and vomiting. If people experience heatstroke and don't receive treatment they can die (Bosworth and Zade, 2018). Heat stress exposure can be categorised into four levels: caution days, extreme caution days, danger days, and extreme danger days (Garland et al., 2015; see Tables 7 and 8):

- **Caution days:** Currently most of Kenya already experiences exposure to caution days through the year, with the exception of the humid mountainous zone. At 1.5°C and 2°C global warming, the humid mountainous region will experience an increase of 124 and 143 additional days of exposure respectively.
- **Extreme caution days:** At 1.5°C and 2°C exposure to extreme caution days will increase by 18 and 27 days in the humid coast zone, 31 and 47 days in the arid north east region, and 52 and 78 days in the arid north west region.
- **Danger days:** At 1.5°C and 2°C the exposure to danger days will increase by 51 and 76 days in the humid coast and arid north-east regions, and 32 and 48 days in the arid north-west region.

Table 8: Heat Index (National Weather Service Weather Forecast Office).

Apparent temperature range	Classification	Effect on body
27°C – 32°C	Caution	Fatigue possible with prolonged exposure and/ or physical activity
32°C – 39°C	Extreme caution	Heat stroke, heat cramps, or heat exhaustion possible with prolonged exposure and/or physical activity
39°C – 51°C	Danger	Heat cramps or heat exhaustion likely, and heat stroke possible with prolonged exposure and/ or physical activity
51°C	Extreme danger	Heat stroke highly likely


Mark Tebboth

1.5°C+: Implications for Kenya's policies and development agenda

Global warming of 1.5°C and higher will likely have a significant impact on Kenya's vulnerable sectors and the country's ability to achieve its long-term development goals, along with the short- and medium-term ambitions of President Kenyatta's "Big Four Agenda" (Presidency, Republic of Kenya, 2018).

The Big Four Agenda defines Kenya's ambition to make significant strides in food security, affordable health care, affordable housing and manufacturing. The increasing occurrence and strength of climate extremes and their impacts on the livelihoods and wellbeing of Kenya's population will pose various challenges to the achievement of these goals. For example, agricultural losses will challenge the ability of the country to secure food. With the 1.5°C global warming threshold likely to be crossed in the coming decade, the urgency for Kenya to implement effective adaptation strategies is at an all-time high.

The Kenyan government has been proactive and taken onboard the seriousness of impending climate-related risks. It has the advantage of having a well-developed Climate Change Action Plan in place, but needs to further mainstream adaptation into all aspects of its development planning. There is a need to prioritise developing the capacity to design, roll-out, and maintain adaptation solutions to ensure a robust and sustainable development pathway. This will take time. As the government has recognised, adaptation to climate change is "a journey – and not a destination" (Republic of Kenya, 2013). It is time to speed up this journey to take on a sense of urgency.

Climate models, like those used for this brief, indicate the anticipated impacts of global warming on local climate at 1.5°C and higher. These projections, and their potential implications for the sectors that underpin sustainable development, can be used to inform the timing and importance of adaptation planning. By planning ahead, and factoring in worst-case scenarios, policymakers can best prepare to mitigate climate-related risks through early and well-informed adaptation planning.

APPENDIX: Methodology

Climate zones for climate analysis were created by dividing countries into distinct aridity zones using the Global Aridity Index (using mean annual precipitation and mean annual evapotranspiration). Mean annual surface temperature, precipitation and climate extremes were analysed using data obtained from the WorldClim Global Climate Dataset.

Climate models were obtained from the 5th version of the Coupled Model Intercomparison Project (CMIP5) program. 24 CMIP5 GCM outputs for RCP were used to focus on temperature and rainfall means, as well as indices of climatic extremes (rainfall and temperature extremes) that directly relate to local climate change vulnerabilities. Using 1861-1900 as a base period for pre-industrial conditions, the years at which RCP 8.5 reached 1.0°C, 1.5°C, 2.0°C, 2.5°C and 3.0°C global warming above pre-industrial levels were defined.

For each model ensemble member, a 31-year running mean was applied to the entire time-series. The climatology at a given global warming level is defined by the year the running mean reaches that global warming level and then stays consistently above it. For the climate indices within each subset, we calculated area-averaged climatological means at given global warming levels to determine the change relative to pre-industrial levels. The non-parametric Wilcoxon Paired Signed Rank test (WPSR) for RCP8.5 was used to test for significant differences between the distributions of ensembles of the indices at 1.0°C, 1.5°C, 2.0°C, 2.5°C and 3.0°C.

Impacts on vulnerable sectors were determined by examining previous studies where impacts could either be assigned to a specific increase in global temperature, or an emission scenario (SRES and RCP) and time frame could be attributed to a specific rise in global temperature. Impacts for each temperature interval were interpolated using a linear regression using the R software for statistical computing.

A more detailed description of this methodology can be viewed on the ASSAR Website.

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