# WHAT GLOBAL WARMING OF 1.5°C AND HIGHER MEANS FOR BOTSWANA

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 Botswana, local warming and drying will be greater than the global average. So, even a 1.5°C increase in global temperature will have severe local impacts, negatively affecting water supply, agriculture, health, and other vulnerable sectors. The 1.5°C threshold could be breached within the next decade, and the 2°C threshold the decade after[2]. This means there is an urgent need to accelerate Botswana's adaptation responses.

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LOCAL IMPACTS IN BOTSWANA

GLOBAL WARMING ABOVE PRE-INDUSTRIAL LEVELS
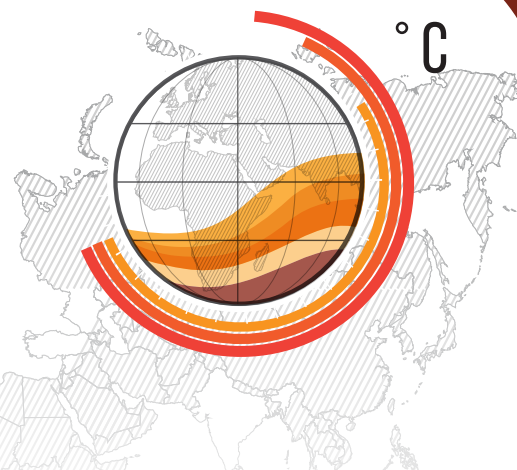
Projected climate changes[3]			1.5°C	vs	2°C	vs	2.5°C	vs	3°C
	CLIMATE	Mean temperature (°C)	▲ 2.2		▲ 2.8		▲ 3.5		▲ 4.2
		Heat waves (days)	▲ 43		▲ 72		▲ 105		▲ 136
		Annual rainfall	▼ 5%		▼ 9%		▼ 10%		▼ 11%
		Heavy rainfall (days)	▼ 2		▼ 3		▼ 3		▼ 4
		Dry days	▲ 10		▲ 17		▲ 24		▲ 28

Estimated impacts[4]

			1.5°C		2°C		2.5°C		3°C
WATER		Okavango River[5] (streamflow)	▼ 6%[6]		▼ 12%[6]		▼ 18%[6]		▼ 24%[6]
		Limpopo Catchment[7] (runoff)	▼ 26%		▼ 36%		▼ 46%		▼ 56%
AGRICULTURE		Maize[8] (yield)	▼ 23%		▼ 35%		▼ 46%[6]		▼ 58%[6]
		Sorghum[8] (yield)	▼ 11%		▼ 17%		▼ 23%[6]		▼ 29%[6]
		Water for livestock[9] (cost of pumping)	▲ 15%		▲ 19%		▲ 22%		▲ 24%
HEALTH		Malaria[10] (months of risk)	▼ 12%[6]		▼ 16%[6]		▼ 29%		▼ 29%[11]
		Heat stress[12] (number of days of exposure)	▲ 20		▲ 20		▲ 40		▲ 40

[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] Based on data analysis by R.Bouwer. University of Cape Town, South Africa.
[5] Andersson, L., Wilk, J., Todd, M.C., Hughes, D.A., Earle, A., Kniveton, D., Layberry, R. & Savenije, H.H. 2006. Impact of climate change and development scenarios on flow patterns in the Okavango River. *Journal of Hydrology*. https://doi.org/10.1016/j.jhydrol.2006.04.039.
[6] Extrapolated assuming a linear progression with no threshold being reached.
[7] Zhu, T. and Ringler, C. 2010. *Climate change implications for water resources in the Limpopo River Basin* (No. 961). International Food Policy Research Institute (IFPRI).
[8] Chipanshi, A.C., Chanda, R. and Totolo, O. 2003. Vulnerability assessment of the maize and sorghum crops to climate change in Botswana. *Climatic Change*. https://doi.org/10.1023/B:CLIM.0000004551.55871.eb.
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[11] Note: Interestingly, above 3°C a critical threshold is reached, and malaria risk increases by 36%.
[12] Garland, R.M., Matooane, M., Engelbrecht, F.A., Bopape, M.J.M., Landman, W.A., Naidoo, M., Merwe, J.V.D. and Wright, C.Y. 2015. Regional projections of extreme apparent temperature days in Africa and the related potential risk to human health. *International Journal of Environmental Research and Public Health*. https://dx.doi.org/10.3390%2Fijerph121012577.

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

	ARID SOUTH				ARID NORTH				SEMI-ARID SOUTH				SEMI-ARID NORTH				BOTSWANA 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	1.5°C	2°C	2.5°C	3°C
Annual rainfall (%)	-6	-8	-11	-15	-8	-10	-9	-11	-5	-9	-10	-11	-6	-9	-10	-11	-5	-9	-10	-11
Duration of dry spells (days)	+9	+15	+21	+27	+11	+18	+23	+30	+9	+16	+20	+25	+13	+19	+24	+29	+10	+17	+24	+28
Duration of wet spells (days)	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2	-2	-1	-1	-1	-1
Heavy rainfall days (>10mm/day)	-1	-2	-2	-3	-2	-3	-3	-3	-1	-2	-3	-3	-2	-3	-3	-3	-2	-3	-3	-4
Extreme heavy rainfall days (>20mm/day)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amount of rain in heavy rainfall events (%)	+4	-2	-4	-7	+3	0	+4	+6	+1	-1	+1	-3	+4	+2	+4	+7	+5	0	0	+1
Amount of rain in extremely heavy rainfall events (%)	+16	+8	+9	+3	+19	+19	+34	+32	+13	+16	+21	+21	+21	+20	+32	+35	+17	+15	+22	+20
Amount of rain in highest rainfall day (%)	+3	+3	+2	+2	+5	+5	+8	+9	+3	+5	+7	+7	+5	+7	+9	+9	+4	+4	+6	+8
Amount of rain in highest five consecutive rainfall days (%)	+1	0	0	-1	+2	+2	+7	+4	+2	+2	+4	+1	+3	+2	+5	+4	+2	+2	+3	+2
Temperature change (°C)	+2.1	+3.0	+3.6	+4.5	+2.2	+2.9	+3.5	+4.2	+2.2	+2.8	+3.4	+4.2	+2.1	+2.9	+3.6	+4.2	+2.2	+2.8	+3.5	+4.2
Number of hot days (>90th percentile)	+71	+105	+139	+168	+72	+105	+131	+161	+66	+98	+126	+156	+79	+116	+148	+180	+73	+108	+136	+169
Number of hot nights (>90th percentile)	+71	+107	+133	+163	+78	+116	+151	+185	+74	+109	+143	+177	+87	+128	+170	+203	+78	+119	+149	+182
Number of cold days (<10th percentile)	-27	-32	-35	-39	-27	-33	-36	-38	-25	-31	-35	-37	-30	-34	-38	-40	-28	-33	-36	-38
Number of cold nights (<10th percentile)	-37	-41	-45	-47	-37	-42	-44	-47	-37	-41	-44	-47	-40	-45	-46	-48	-39	-42	-45	-48
Duration of heat waves (days)	+39	+66	+97	+129	+42	+70	+101	+134	+40	+63	+90	+120	+48	+83	+121	+156	+43	+72	+105	+136

Preparing for 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 vulnerable countries like Botswana, these seemingly small increments in global temperatures can lead to distinct local climatological conditions, which can interact with and worsen existing vulnerabilities. Many communities in Botswana are dependent on natural resource-based livelihoods that are sensitive to the impacts of global temperature increases of 1.5°C+ and have little adaptive capacity to adjust to future changes (ASSAR, 2015). In the past, the livelihoods and wellbeing of these vulnerable communities have been adversely affected by extreme weather and climate events and declining ecosystem services. Global temperature increases of 1.5°C+ present serious additional adaptation challenges across nearly all socioeconomic sectors and communities, especially those most dependent on natural resources for livelihoods.

As this brief highlights, Botswana needs to anticipate and plan for quite rapid changes in local weather and climate. To adapt to a 1.5°C+ world, the country will have to accelerate the integration of climate change adaptation into all of its socioeconomic sectors under the framework of a National Adaptation Plan, and ensure that these measures are implemented from national to local levels. By accelerating adaptation action, Botswana will be far better positioned to respond to the impacts associated with 1.5°C and above, and ensure these impacts do not set the development agenda back.

Max Pixel

Botswana

Botswana is one of the most arid countries in southern Africa. The country is prone to hot and dry conditions with various challenges to water and food security.

For our analysis we assess the impacts of exceeding different global warming targets across four geoclimatic zones: semi-arid north, arid north, semi-arid south, and arid south.

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

Anticipated changes in Botswana's climate and its extremes

Botswana warms much faster than the global average

As global temperatures increase by 1.5°C and above, local temperature increases in Botswana will be even larger, and occur faster than the global rates of change. For example, at 1.5°C of global warming, temperature increases across the country will be between 2.1-2.2°C (Table 2). At 2°C and 3°C global warming the average temperature of Botswana is expected to increase by 2.8°C and 4.2°C respectively. The highest temperature increases are expected in the arid south zone which will increase by as much as 4.5°C at 3°C of global warming.

The rapid rate of warming in Botswana will result in the country having one of the highest increases in temperature in Africa.

These temperature changes will be accompanied by large increases in hot days and nights, and decreases in cold days and nights. Warm spells and heat waves will also become more frequent, last longer, and be more intense.

Across the different climatic zones heat wave durations will increase by 39-48 days at 1.5°C global warming, by 66-83 days at 2°C global warming, and by 120-156 days at 3°C global warming (Table 2). The semi-arid north zone will experience the most pronounced changes in all respects (see Table 1 for details for each zone).
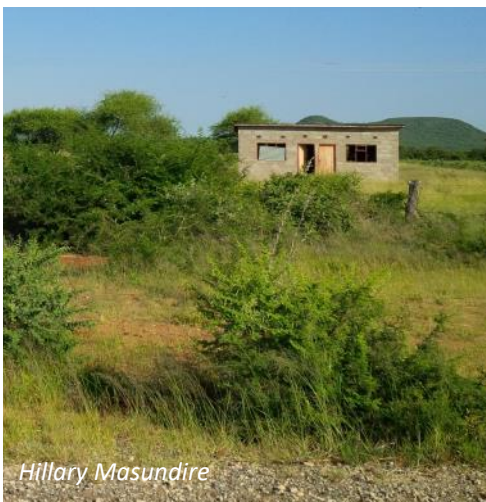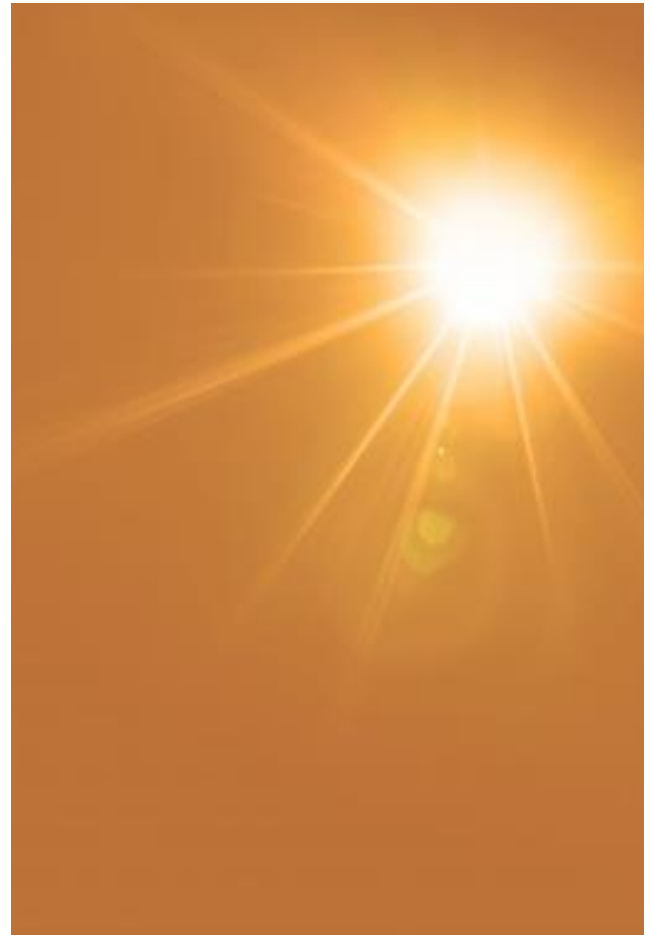
Hillary Masundire

Table 2: Local changes to Botswana's climate			
	Local temperature increases	Duration of heat waves	Local rainfall decreases
1.5°C	+ 2.1-2.2°C	+ 39-48 days	- 5-8%
2°C	+ 2.8-3.0°C	+ 66-83 days	- 8-10%
2.5°C	+ 3.4-3.6°C	+ 90-121 days	- 9-11%
3°C	+ 4.2-4.5°C	+ 120-156 days	- 11-15%

Decreasing rainfall

Botswana is expected to become progressively drier as the climate warms, with the country's average annual rainfall expected to drop by 5-11% between 1.5°C and 3°C (Table 2). At 1.5°C and 2°C the arid north zone will experience the largest decrease in rainfall; the arid south zone will experience the largest decrease at 3°C.

The decrease in rainfall will also mean that rain will fall less often, wet spells will become shorter and dry spells will become longer. In most regions, wet spells will last for one day less, however dry spells will be significantly longer. At 1.5°C dry spells will be 9-13 days longer, and at 2°C these dry spells will be 15-19 days longer with the biggest increase in the semi-arid north zone. At 3°C the duration of dry spells will increase by 25-30 days with the largest increase in the arid north zone (see Table 1 for details for each zone).

Increasing intensity of rainfall events

While rainfall will occur less often, the intensity of rainfall on days when it does rain is expected to increase.

The number of heavy and extremely heavy rainfall days will either decrease slightly or have no change, but the amount of rainfall falling within heavy events will increase. At 1.5°C the total rain falling in heavy and extremely heavy events will increase by 1-4% and 4-12%, respectively. The largest increases are expected in the arid south and semi-arid north zones. The largest rainfall events are also expected to increase slightly, with 4-8% more rain falling within the heaviest rainfall day between 1.5-3°C. The maximum five-day rainfall is also expected to increase by 2% at each interval of warming. The largest increase is expected in the semi-arid north zone.

These changes in rainfall across Botswana means rainy seasons will most likely be shorter and have less rain. However, when rain does fall, it will do so with more intensity, increasing the risks associated with heavy storms and floods, rather than relieving the country's water scarcity.
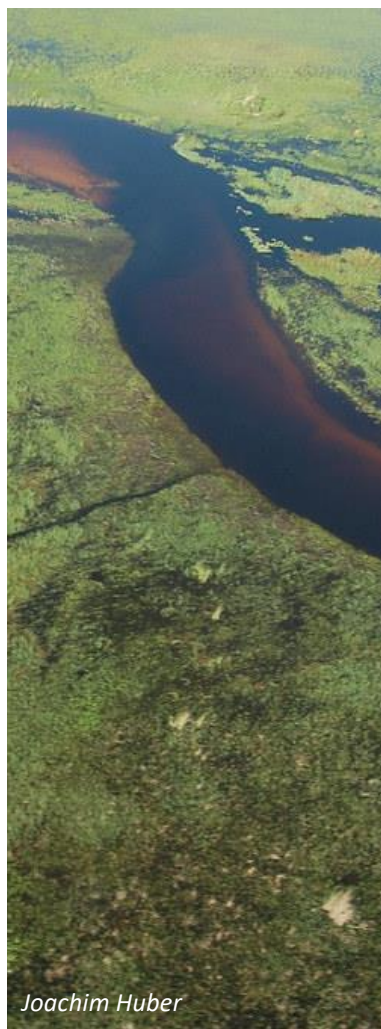

Hillary Masundire

1.5°C+: Impacts on Botswana's vulnerable sectors

WATER: Increasing pressure on an already-challenged system

At 1.5°C and higher of global warming, changes in temperatures and rainfall in Botswana will have significant impacts on water resources and water supply. Less rainfall and longer dry spells will mean Botswana is likely to experience more frequent and intense droughts. The increasing intensity of rainfall events will increase flood risk, while offering little relief to the often-stressed water resources of the country. Most of the vital sources of water for Botswana are expected to face increasing pressure with progressively declining water levels.

Table 3: Changes to Botswana's water resources

	Rainfall (Okavango Catchment)	Streamflow (Okavango River)	Rainfall (Limpopo Catchment)	Runoff (Limpopo Catchment)	Evaporation (Limpopo Catchment)	Rainfall (Chobe Catchment)	Streamflow (Zambezi Basin)
1.5°C	- 3%	- 6%	- 6%	- 26%	+ 8%	- 4%	- 5%
2°C	- 4%	- 12%	- 9%	- 36%	+ 12%	- 6%	- 7%
2.5°C	- 4%	- 18%	- 10%	- 46%	+ 16%	- 9%	- 9%
3°C	- 6%	- 24%	- 12%	- 56%	+ 20%	- 11%	- 11%

Joachim Huber

The Okavango Delta

The Okavango Delta is an inland delta located within the semi-arid north zone of Botswana. The delta plays an important role as a source of water for rural communities but its floodplains also provide fertile soils which support crops and livestock agriculture. Global warming of 1.5°C and higher will have significant impacts on the delta and the communities which depend on it.

Rainfall: The semi-arid north zone of Botswana is expected to have the greatest decrease in rainfall (Nkemelang *et al.*, 2018). The source region for the Okavango River – which spans northern Namibia and southern Angola, and that supplies the delta – is expected to experience a drop in annual rainfall of 3%, 4% and 6% at 1.5°C, 2°C, and 3°C of global warming respectively (Nkemelang unpubl.).

Streamflow: At 1.5°C global warming, streamflow in the Okavango River is expected to drop by approximately 6%. Between 2°C and 3°C global warming, the Okavango River could experience further streamflow decreases by between 12 and 24% respectively (Andersson *et al.*, 2006).

Floodplains: At each interval of global warming the Okavango region will become progressively warmer and drier. Rising temperatures will lead to increased evapotranspiration which will reduce water levels even further than declining streamflows. At 1.5°C floodplains in the Okavango Delta are expected to shrink, with seasonal flooding being the dominant form of flooding (rather than the permanent or regular flooding which has been observed). At 2°C, however, the extent of all floodplains will recede, with significant impacts on water availability and agricultural potential in this area (Murray-Hudson *et al.*, 2006).

Limpopo River Basin

The Limpopo River is an important source of water for the semi-arid south zone, with the catchment area supplying water to both the Gaborone area and the commercial agricultural sector.

Rainfall: At a 1.5°C increase in global temperatures, the section of the Limpopo River catchment area that falls within Botswana is expected to experience a 6% decrease in annual rainfall. Rainfall will continue to decrease at each interval of global temperature rise, with decreases of 9% and 12% at 2°C and 3°C respectively (Nkemelang, unpubl.).

Streamflow: The streamflow of the Limpopo River will be affected by changes in rainfall, evaporation and surface runoff. At 1.5°C global warming, the potential evaporation in the Botswana area of the Limpopo catchment will increase by 8%, which will increase progressively to 12% and 20% at 2°C and 3°C respectively (Zhu and Ringler, 2010). This means more water will be lost due to evaporation. This will coincide with reductions in surface runoff which is expected to decrease by 26% at 1.5°C, and by 36% and 56% at 2°C and 3°C respectively (Zhu and Ringler, 2010). The combined decrease in rainfall and runoff with the increase in evaporation will result in a progressively declining streamflow in the Limpopo River, having significant impacts on water availability for rainfed agriculture and dams such as the Gaborone Dam.

The Chobe River

Botswana already has plans to alleviate water stress in the country by drawing water from the Chobe River (in the Zambezi Basin) within the next decade (The Voice, 2013). However, this catchment may also be affected by progressive decreases in water availability at each interval of global warming.

Rainfall: Annual rainfall over the Chobe catchment is expected to decrease at 1.5°C and higher of global warming. At 1.5°C rainfall is expected to decrease by 4% over the catchment, by approximately 6% and 11% at 2°C and 3°C respectively (Nkemelang unpubl.).

Streamflow: Streamflow in the Zambezi basin is expected to decrease at each level of global temperature increase. At 1.5°C streamflow in the Zambezi is expected to decrease by 5%, with further decreases of 7% and 11% expected at 2°C and 3°C respectively (Hamududu & Killingtveit, 2016).

Tali Hoffman

AGRICULTURE: Decreases in crop and livestock productivity

Livestock rearing is a vital livelihood activity for nearly half of Botswana's population (Urquhart and Lotz-Sisitka, 2014). Most livestock rearing is communal, and communities rely heavily on rangelands for feeding animals. The impacts of increasing temperatures and progressive drying associated with 1.5°C and higher of global warming will result in less feed available and fewer palatable grass species, and reduce livestock productivity (Masike and Urich 2008).

During dry spells and droughts, the demand for water for livestock often makes it necessary for farmers to deepen boreholes and extend pumping hours (Masike and Urich 2009), hiking up costs for livestock rearing. At 1.5°C global warming the cost of pumping water is expected to increase by 15%, with further increases of 19% and 24% expected at 2°C and 3°C respectively.

Table 4: Changes to Botswana's crop and livestock agriculture					
	Maize yields (Hard velt)	Sorghum yields (Hard velt)	Maize yield (Sand velt)	Sorghum yield (Sand velt)	Cost of pumping water for livestock
1.5°C	- 24%	- 5%	- 22%	- 16%	+ 15%
2°C	- 34%	- 8%	- 35%	- 26%	+ 19%
2.5°C	- 46%	- 10%	- 47%	- 34%	+ 22%
3°C	- 58%	- 13%	- 59%	- 43%	+ 24%

Crop agriculture in Botswana takes two predominant forms: rainfed agriculture and 'molapo' or flood recession agriculture. Crop agriculture focuses primarily on maize, sorghum and millet production (Dougill *et al*., 2010). Food security is a major concern for Botswana, as the country is highly dependent on imports to fulfil its cereal needs, with increasing global temperatures expected to make the country more reliant on food imports (Schlenker and Lobell, 2010).

Rainfed crop agriculture occurs in two main agroclimatic zones, the hard velt located in the semi-arid south zone with more fertile soil and less harsh climate conditions, and the sand velt in the rest of the country with deep sand and little surface water (Chipanshi *et al*., 2003). Average yields across the country are expected to be impacted progressively at each level of global warming with yields projected to decrease by 23-58% for maize and 11-29% for sorghum.

- **Hard velt region**: The climate and fertile soils in the semi-arid south results in the concentration of agricultural activity in Botswana. In this zone, global warming of 1.5°C is anticipated to result in a drop of 24% for maize yields and a drop of 5% for sorghum yields (Chipanshi *et al*., 2003). Yields will drop further at 2°C and 3°C with maize yields expected to fall by 34% and 58% respectively, and sorghum yields dropping by 8% and 13% respectively.

- **Sand velt region**: Poor climate and soil conditions result in the majority of Botswana having low cereal yields, which are expected to decrease further as the global climate warms. At 1.5°C of global warming yields in this region are expected to drop by 22% for maize and 16% for sorghum. Yield losses will increase as the temperature continues to warm with decreases of 35% and 59% for maize, and 26% and 43% for sorghum, at 2°C and 3°C respectively (Chipanshi *et al*., 2003).

Molapo farming occurs mainly in the Okavango Delta within the semi-arid north zone of Botswana. The farming is highly dependent on flood plain dynamics which are sensitive to the impacts of 1.5°C global warming and higher. As noted under water resources, flood plains in the Okavango delta are expected to shrink in size progressively with each interval of global warming (Murray-Hudson *et al*., 2006). This means areas which do not flood in the delta will grow and molapo farming will suffer due to the loss of fertile flood plains.

HUMAN HEALTH: Increased risk of disease heat stress

Climate change is expected to impact the prevalence of diseases in Botswana. Variations in rainfall can affect areas prone to malaria risks. During high rainfall years, there is the added risk of waterborne diseases such as cholera and bilharzia. Hotter temperatures also drive up the risk of heat stress.

Malaria Exposure: Currently, about 30% of Botswana's population is exposed to risk of malaria infection (Masisi *et al*., 2012). While the exact implications of climate change on malaria are difficult to predict, cases of malaria are closely associated with hot and wet conditions. The semi-arid north zone is particularly prone to malaria towards the end of the rainy season.

Global temperature rise of 1.5°C and higher will likely result in faster breeding of mosquitoes. However, the development of the malaria parasite and vector is slow and requires wet conditions. In hot climates a rainfall season of three months is sufficient to support a malaria season, while in milder climates at least five months of rainfall are needed (Craig *et al*., 1999).

While increasing temperatures could exacerbate malaria transmission, the drying of the climate is likely to reduce the prevalence of malaria in the country. At 1.5°C of global warming the persons exposed to malaria months could decrease by 12%. This will decrease further by 16% and 19% at 2°C and 3°C respectively (Tanser *et al*., 2003). However, it is possible that heavy rainfall and flooding events will result in outbreaks of malaria in new areas of the country (Nkemelang *et al*., 2018).

Table 5: Changes to Botswana's health risks

	Malaria exposure (months of risk)	Deaths (per 100,000) due to heat stress for people aged 65+
1.5°C	- 12%	30
2°C	- 16%	50
2.5°C	- 19%	70
3°C	- 19%	90

Exposure to Heat Stress: High temperatures will expose the population to dangerously high temperatures which will make people vulnerable to heat stroke and heat exhaustion. People living with pre-existing conditions, and rural populations without access to health services will be adversely affected.

- At 1.5°C of global warming all zones in Botswana are expected to receive an additional 11-30 days of exposure to caution days (see Table 6). This exposure increases gradually at each interval with almost year-round exposure (242-365 days) to caution days at 3°C (Garland *et al*., 2015).

- At 3°C there will also be large increases in the exposure to extreme caution days with 82-138 additional extreme caution days. Exposure to danger days will vary with increases of 165-223 days in the semi-arid north zone, and increases of 43-103 days in the semi-arid and arid south zones (Garland *et al*., 2015).

- Increasing exposure to heat stress will lead to an increase in heat-related deaths, particularly for the elderly. At 1.5°C global warming, 30 deaths per 100 000 in persons over 65 will be attributed to heat stress. This will increase to 50 and 90 deaths per 100 000 at 2°C and 3°C respectively (WHO, 2015).

Table 6: 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

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

Unless "rapid and far-reaching" changes occur in global energy, land, urban, infrastructure, and industrial systems over the next 12 years, the world is on track to warm by 1.5°C and more (IPCC, 2018). The impacts of this global temperature rise will be felt particularly hard in Botswana. Even marginal increases in global average temperature will result in significant changes to Botswana's local climate, with an increase in the frequency and intensity of climatic extremes. With the 1.5°C global warming threshold likely to be crossed in the 2020s, the urgency for Botswana to implement effective adaptation strategies is at an all-time high.

At each increment of global temperature, Botswana's vulnerable sectors will be increasingly affected. While temperatures rapidly increase, annual rainfall is expected to decrease, but with heavy rainfall events becoming more frequent and intense. Water resources are likely to decline, further straining the country's water security. Droughts will become more frequent and last longer.

Botswana's government has taken seriously the need to plan for the multi-faceted impacts of drought, and the underlying issues that cause vulnerability to drought. This involved incorporating ASSAR's research-driven recommendations into updating its National Drought Management Strategy. The updated strategy marks a shift away from a reactive, crisis-response approach to one that is more proactive and integrated.

As a largely semi-arid country, Botswana's climate and landscape is extremely marginal for agriculture. Further heat and water stress is likely to result in significant declines in crop and livestock production. Planning for and addressing these impacts requires an examination of the systemic issues that coalesce to make disenfranchised groups, like the poor and most marginalised, particularly vulnerable to climate change impacts.

ASSAR's research found, for example, that mopane caterpillar harvesters in the Bobirwa sub-district are highly vulnerable to drought. Communities in Bobirwa depend on mopane caterpillars for their livelihoods, the caterpillars feed on mopane tree leaves, and the tree is highly sensitive to drought (i.e., it will produce fewer leaves when there is less rain; Ephias *et al.*, 2018). This will result in declining populations of mopane caterpillars, which will have significant impacts on the livelihoods of communities in Bobirwa.

Already, government has been motivated to take action and should be commended for engaging in, and promoting, genuine bottom-up participatory adaptation planning through the Bobonong Vulnerability Risk Assessment (VRA) in 2015. This led to a national VRA training of district development officers and economic planners in 2018. These officials now have the skills to perform VRAs, and do development planning that is participatory, representative and inclusive (ASSAR, 2015). Such planning has a gender focus, and incorporates vulnerable groups into finding solutions to challenges relevant to them.

Government's willingness to integrate vulnerability and risk assessment with a gender focus into its national development planning is encouraging. These steps should be built upon so that adaptation planning is able to reduce vulnerabilities while improving capacities across all levels in order to promote a development pathway which will be resilient to the changes associated with global temperature increases of 1.5°C and above.

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Salma Hegga

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 detail description of this methodology can be viewed on the ASSAR Website.

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