# Human-Elephant Conflict and Climate Change

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**Human-elephant conflict refers to negative interactions between humans and elephants - commonplace across Africa and Asia - where people and elephants share space and resources. Climate change is expected to alter the distribution and frequency of human-elephant conflict. This review outlines the current state of understanding regarding the impacts of climate change on human-elephant conflict across eastern and southern Africa.**

## Overview

- Human-elephant conflict (HEC) is expected to transform as climate change alters the distribution of vegetation and water availability.
- People and elephants will struggle to adapt to climate change due to habitat fragmentation and human land-use.
- Immobile human populations will face resource limitation, increased competition, more elephant crop-raiding and reduced tolerance to elephants, generating more HEC.
- Migrating elephants will encounter human settlements and infrastructure, elevating HEC.
- Long term urbanisation of the human population and declines in elephant numbers may ease HEC.
- HEC reduction will require international cooperation to develop alternative economies and ensure sufficient space for elephants.

## Background

Across Africa, growing human and livestock populations, and the associated conversion of natural habitats into human-dominated landscapes, increasingly squeezes wildlife into smaller and more fragmented pockets of land. This landscape-scale conversion has created a large interface between human and wildlife populations. Interactions at this interface become conflicts when animal behaviours and human activities are incompatible. One species for which this evident is the African elephant. People sharing space with elephants largely rely on agriculture for their livelihoods. Elephant behaviours - such as crop-raiding, causing damage to infrastructure, injuring or killing livestock and even humans[1] - reduce tolerance for elephants within local communities, who retaliate by injuring or killing elephants. Human-elephant conflict (HEC) is thus detrimental to both elephant and human populations, and has large implications for conservation, human well-being and the economy.

The political, social and environmental determinants of HEC have been well studied and a range of preventative and mitigation measures are widely employed across Africa and Asia with varying levels of success. However, whilst the current state of HEC is relatively well understood, climate change is expected to alter the distribution and frequency of HEC across Africa and Asia. This presents the need to better understand how climate change will impact HEC in the future, so that mitigation measures may be developed. This report examines current predictions for HEC under future climate change predictions in southern and eastern Africa.

## Projected changes in climate

When considering how HEC is expected to respond to climate change in southern and eastern Africa, it is first important to understand how the climate here is projected to change.

Various climate change models exist and there are a range of scenarios under which these models make predictions about the future climate. Models differ in the assumptions they make regarding physical interactions of the earth's components (the atmosphere, oceans, land surfaces etc.) and human activities (e.g. technological development and economics), whilst scenarios differ in the predicted timing of peak $CO_2$ emissions, with the best-case scenario being that today marks the peak in $CO_2$ emissions and the worst case predicting a continued rise in emissions throughout the 21st century. Based on the combination of these models and scenarios, exact predictions for future climatic conditions across Africa vary, but there are some general themes which form the basis for many studies investigating the impacts of climate change here.

Overall, climate models predict a decline in rainfall across southern Africa, but present a large degree of uncertainty with regards to rainfall in eastern Africa. When considered in more detail however, it is generally agreed that both regions will experience more erratic rainfall[2], with the timing, location and intensity of rainfall becoming less reliable. This will cause an increase in the occurrence and severity of extreme climatic events such as flooding and drought in both southern and eastern Africa[3–5], despite overall trends.

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### Ecosystem impacts of climate change

Most ecosystems in eastern and southern Africa are limited by water. Because of this, changes in rainfall patterns are expected to quickly cause shifts in the growth of vegetation; where rainfall declines, soil moisture content will drop, causing a reduction in vegetation productivity[6], whilst in areas of increased rainfall, release from water limitation may cause improved plant growth. However, both droughts and flooding reduce productivity of vegetation: drought through water limitation and flooding via water logging and erosion of soil.

Rainfall is also important in supplying surface water for drinking. Changes in rainfall frequency and distribution will alter the occurrence of water sources; in some areas, water will become sparse or completely dry up[3], whilst in others, the supply of water will increase as existing sources fill and new sources become available.

As humans and elephants across Africa rely heavily on natural provision of food and water, climate induced changes to vegetation and water availability will be important for both people and elephants, and it is these effects that will underlie changes to HEC.

### Implications for elephants

The distribution and abundance of elephants is largely governed by the availability of vegetation and water. Elephants range over huge distances in search of these resources, often beyond the extent of protected areas and across international borders[7,8]. As is predicted for many species[9,10], suitable habitats for elephants are expected to shift under future climate change. Adaptation to the shifting distribution of their habitat would require elephants to migrate in line with suitable conditions. However, given the fragmented nature of Africa's landscapes, large-scale range shifts may be limited by anthropogenic barriers including fences, transport links and human settlements, or due to unsuitable habitats (those with insufficient water or food to sustain elephants) interspersing migration routes[3,10,11].

#### Box 2. Species Distribution Models

There has been vast scientific interest in the use of species distribution models (SDMs) to predict how the geographical range of a species will shift under future climate change. SDMs work by first defining the range of conditions under which a species currently exists, then predicts where these suitable conditions and thus this species of interest will occur under future climate change. Some SDMs assume that a species can move freely through the landscape whilst others assume restricted mobility. Projections for a wide variety of species, including African elephants can be found here: https://wallaceinitiative.org/. SDMs have the potential to aid in the identification of areas at high risk of HEC.

#### Box 1. Another Implication of Elevated $CO_2$

Whilst increased $CO_2$ concentrations alter climate conditions globally, elevated $CO_2$ may also impact vegetation more directly. Where water does not limit tree growth rates, $CO_2$ levels usually do. In these situations, $CO_2$ elevation will facilitate improved tree growth and resilience to elephant and fire damage[18,19]. Ultimately, this will aid woody encroachment and may shift wetter savannah towards a shrub- or tree-dominated state[18,20]. Tree-dominated systems support less grazing livestock and more browsing elephants, so may ultimately decrease HEC.

In situations where movement is restricted, elephants may face resource limitation as climate change reduces the availability of food and water. In these instances, elephant body condition, reproduction and ultimately survival will be compromised[4,12].

### Implications for humans

Climate change will not only impact the wildlife of southern and eastern Africa but will also affect its people. The heavy reliance on agriculture in these regions means the implications of climate change for people will mirror those faced by elephants.

Agriculture in these regions largely falls into two categories: pastoralism (rearing livestock) and crop farming. In some places, pastoralists live traditional nomadic lifestyles, moving their livestock in search of food and water[1]. Given the changing distributions of these resources, ideally pastoralists too will move in line with changing suitable conditions. But like elephants, movement of livestock is limited by anthropogenic barriers and uninhabitable landscapes. People also face the added difficulty of land ownership (they cannot generally graze their livestock on another person's land), service provision (such as schools for children and medical centres for treatment) and homes, which enforce additional restraints on the ability of people to move. Sedentary livestock ranching is therefore increasingly common, and where movement is limited, pastoralists face the declining condition of their livestock, and ultimate loss of animals and income. Crop farming will also face challenges under climate change. Regular production of crops requires sufficient and timely rainfall[2]. Crops therefore increasingly fail as rainfall becomes less reliable. Again, given movement restraints crop farmers are rarely able to relocate to better climes and without improved irrigation technology, are likely to see crop farming become unsustainable.

Initially, people will struggle-on with agricultural lifestyles, but the increasing challenges are likely to exasperate intolerance to losses of crops or livestock. Ultimately however, as agriculture becomes less reliable under climate change, people are increasingly likely to adopt alternative sources of income. Many believe this will lead to the dramatic urbanisation of the African population and decreasing numbers of people living in rural areas near wildlife.

### Changes to human-elephant conflict

Given the range of possible climate changes across southern and eastern Africa, along with questions regarding the mobility of elephant and human populations and unpredictable behavioural responses of people, the impacts of climate change on HEC will likely vary.

Where humans and elephants experience a loss of resource availability, these populations will follow one of two responses: to relocate to suitable locations or to stay put. Often the option to move is restricted for both elephants and people, and the resulting immobility in resource limited areas will lead to declining health and ultimate reduction in abundance of livestock and elephants. The implication of this for HEC is two-fold. Firstly, elephants in poorer condition are more likely to engage in risky behaviours such as crop-raiding[12], as the potential benefits of food outweigh the possible costs of injury or death. At the same time, people experiencing crop-raiding will be less tolerant as crop losses are increasingly detrimental to wellbeing. In addition, given the scarce resources that remain to wildlife, crops and livestock, competition between humans and elephants will increase around key resources. All these factors will contribute to an increase in HEC.

In the longer term however, declining abundance of elephants and livestock through starvation, or the reduction in the number of people engaging in agriculture, may relieve competition for these resources and reduce HEC.

Where elephants relocate in search of alternative sources of food and water, the fragmented nature of the landscape and increasing presence of people means elephants are likely to encounter people during migrations[11]. This may bring increasing numbers of elephants onto farmland, into settlements or across roads and railways, and will inevitably lead to damage and loss to human property and life, and retaliatory killings of elephants, increasing HEC.

### Geographic regions at risk

Whilst research has yet to identify named locations at risk of increased HEC, there are several key features of a landscape which may lend it to increased HEC under future climate change:

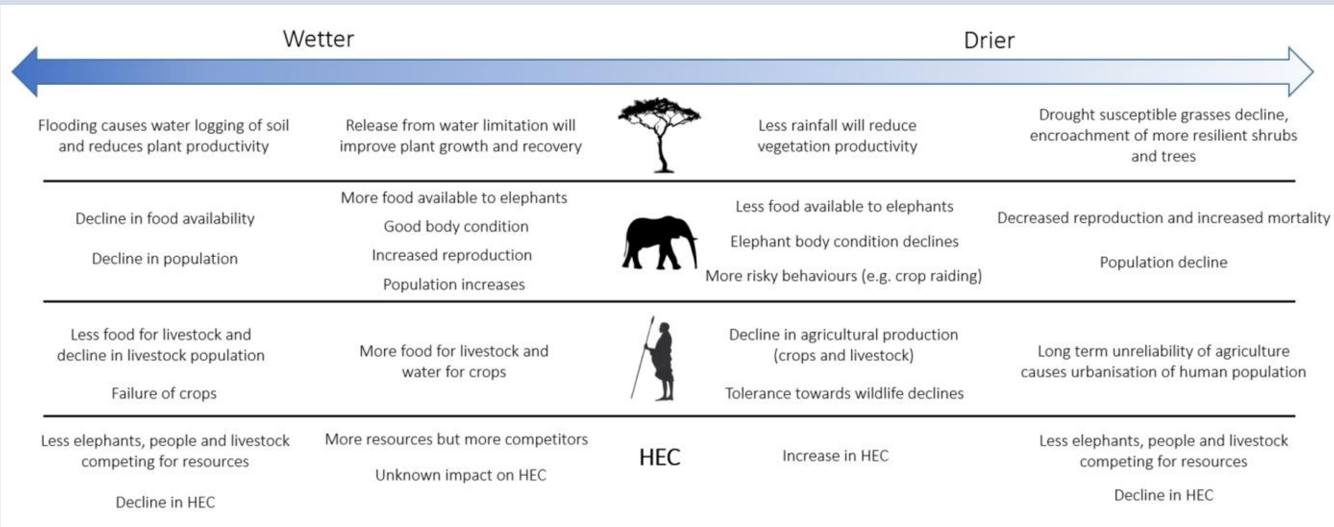
- Locations already suffering HEC will likely experience immediate increased pressures at the human-wildlife interface where resource availability is predicted to decline. This could reduce over time if either humans or elephants move on to greener pastures.
- Locations predicted to see an increase in resource availability with landscape connectivity to areas currently hosting elephant populations.
- Countries with a heavy reliance on agriculture and little alternative economic opportunities.
- Human settlements situated on historic elephant migration pathways.
- Small, fenced protected areas[13,14].

### Gaps in our knowledge

Whilst this review identified a total of 20 articles relevant to the question, none of the research presented explicitly modelled the impacts of projected climate change on HEC[15]. Rather, research examined the implications of climate change for elephants or people or habitats, and then discussed the potential effect of their findings on HEC.

An effort to develop models which incorporate spatially explicit climate change, landscape connectivity and use, human behaviour and lifestyle, and elephant behaviour is therefore required[16]. This will involve an interdisciplinary approach utilising the expertise of both natural and social scientists.

Box 3. Overview of the Impacts of Potential Climate Changes on Elephants, Humans and Human-Elephant Conflict

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### Current HEC prevention and mitigation programs

Given that the ability of humans and elephants to adapt to climate change relies on their ability to find alternative resources or for people to change their lifestyle[17], current prevention and mitigation programs are generally focussed on increasing space for elephants to migrate in line with suitable conditions and providing alternative sustainable sources of income for people.

Ensuring enough space is available for elephants to move in search of sufficient food and water will require a landscape-scale approach[17]. This will mean maintaining and improving current landscape connectivity beyond the boundaries of protected areas and across international borders[7,8,13,14] so that elephants can migrate in line with shifting patterns of rainfall and resources, unhindered by anthropogenic presence.

At the same time, ensuring people have reliable incomes generated via livelihoods that do not lend themselves to conflicts with elephants, is also crucial. This may require the establishment of new economies such as ecotourism and will likely depend on financial and legislative support.

Several organisations are already working on such approaches. In Kenya, Big Life Foundation (https://biglife.org/) has installed fences at the interface between Amboseli National Park and the surrounding farmland. This has effectively reduced current HEC, but there remain concerns about the long-term implications of erecting fencing and the limitations it provides to elephant mobility. To combat this, Big Life have maintained the ability for Amboseli elephants to adapt to future climate change by protecting migration corridors through the fences and farmland to the ecosystems beyond. In southern Africa, Space for Elephants Foundation (http://spaceforelephants.com/) has developed a vision of reconnecting elephant populations via historic migration routes by securing land and dropping fences. Space for Elephants also has a strong belief in community involvement and hopes that, through education and creating jobs for locals, more people will be invested in protecting elephants. Meanwhile, Elephants Without Borders (http://elephantswithoutborders.org/) is working to secure additional corridors and key habitats to allow the elephants inhabiting Angola, Botswana, Namibia, Zambia and Zimbabwe to remain as a single population, so that historic cycles of population contraction and expansion, and source-sink dynamics are maintained to ensure the adaptability of this population. Space for Giants (https://spaceforgiants.org/) is focused on identifying key habitats and corridors for elephants in northern Kenya and working closely with land owners to re-establish these elephant habitats and develop an ecotourism industry for the benefit of local communities.

The preliminary work of these organisations has revealed the need to work with land owners and communities, with local governments and with international partners to identify and secure key elephant habitats, maintain the protection of these spaces from overexploitation or land conversion, and ensure communities living in close proximity to elephants are able to benefit from their conservation. This will require landscape-scale planning, international cooperation between governments and NGOs, and large sources of funding. Given the interconnected nature discussed above on how HEC will be affected by both elephant and human behaviour, sustainable solutions will only be found when working both on elephant conservation and on improving human adaptation to climate change. It is therefore recommended that conservation organisations collaborate with human development and agricultural extension organisations, as well as with policy makers.

### Conclusions

Changes in the frequency and distribution of HEC is expected to occur as a result of climate change in southern and eastern Africa. Locally, some areas will experience a release from HEC whilst others will see an increase and novel sources of conflict occur. Research is yet to identify named locations at risk of increased HEC, presenting an opportunity for an interdisciplinary effort to recognise these areas.

Given the significant threat posed by HEC to the conservation of elephants, human wellbeing and Africa's economy, pre-emptive measures should be developed to allow both humans and elephants to adapt to future climate change. This will require international cooperation to develop landscape-scale initiatives to establish alternative, sustainable sources of income and ensure sufficient space for elephants[17].

### Box 4. Further Reading

Studies demonstrating how interactions between humans and wildlife may be altered by future climate change:

1. Baruch-Mordo, S. *et al.* Stochasticity in Natural Forage Production Affects Use of Urban Areas by Black Bears: Implications to Management of Human-Bear Conflicts. *PLoS One* **9,** e85122 (2014).
2. Mason, T. H. E., Keane, A., Redpath, S. M. & Bunnefeld, N. The changing environment of conservation conflict: Geese and farming in Scotland. *J. Appl. Ecol.* **55,** 651–662 (2018).
3. Carter, N. H. *et al.* Climate change, disease range shifts, and the future of the Africa lion. *Conserv. Biol.* (2018). doi:10.1111/cobi.13102
4. Wilder, J. M. *et al.* Polar bear attacks on humans: Implications of a changing climate. *Wildl. Soc. Bull.* **41,** 537–547 (2017).
5. Porter, J. H. et al.The potential effects of climatic change on agricultural insect pests. *Agricultural and Forest Meteorology* **57,** 221-240 (1991).

## Review Protocol

This review was carried out between January and March 2018 by Vicky Boult, University of Reading for WWF-UK.

*Question definition*

The question of investigating the impacts of climate change on HEC was defined by Vicky Boult and Niki Rust of WWF ensuring the question was feasible given Vicky's technical expertise and timeframe, interesting to WWF and the wider conservation community, novel in its findings, ethical and relevant to current issues and further research.

*Search strategy*

The search strategy for obtaining relevant information was defined prior to the start of the search. Given the timeframe, a single database (Web of Science) was used to obtain published literature and a manual search employed for grey literature sources (via Google). To refine the search, information referring to human-elephant conflict and climate change in eastern and southern Africa only were included. Search terms were defined to obtain all relevant literature (Box 5).

**Box 5. Search terms**

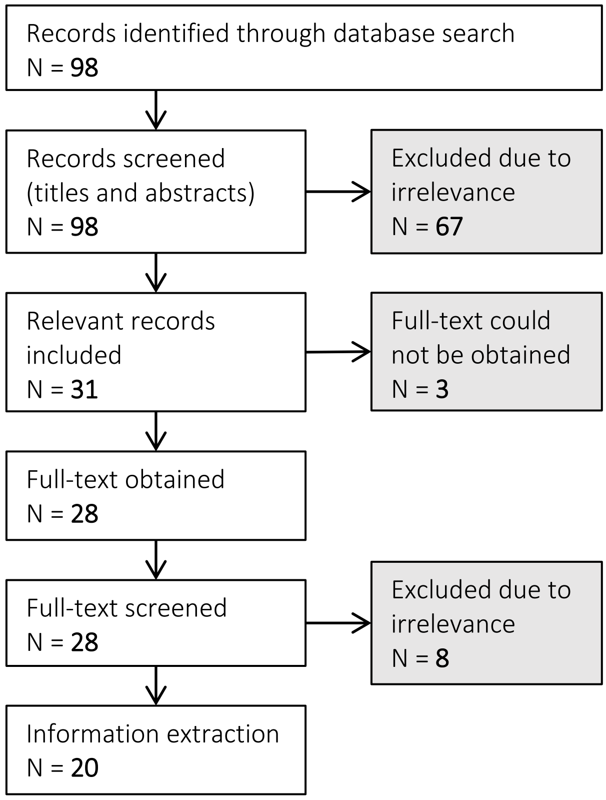
1. elephant* AND ("climate change" OR "global warming" OR "global change") AND conflict
2. elephant* AND ("climate change" OR "global warming" OR "global change") AND Africa
3. ("human-elephant conflict" OR ("human-wildlife conflict" AND elephant*)) AND ("climate change" OR "global warming" OR "global change")
4. elephant* AND ("climate change" OR "global warming" OR "global change") AND human
5. human AND (habitat OR "land use" OR "land cover" OR conversion OR pastoral* OR agriculture OR farming OR sedentar*) AND ("climate change" OR "global warming" OR "global change") AND africa AND (wildlife OR elephant*)

*Search and Screening*

The search strategy returned 98 articles in Web of Science. Articles were initially screened for relevance using just the titles and abstracts, irrelevant articles were excluded from the process. Full-texts were obtained for remaining articles. These were then read in full, articles deemed irrelevant at this phase removed, and the relevant information extracted. The number of articles screened and excluded at each stage are documented in the flowchart. The final list of relevant published material is included in Box 6.

*Key results*

None of the articles identified in the search explicitly modelled the impacts of climate change on the frequency, distribution or intensity of HEC. Rather, articles modelled the impacts of climate change on elephants or humans or habitats and made inferences about how predicted change may impact HEC, which are discussed in the body of this document. This highlights a key area for further research.




**Box 6. Relevant published articles**

1. Bond, J. A holistic approach to natural resource conflict: The case of Laikipia County, Kenya. J. Rural Stud. 34, 117–127 (2014).
2. Boone, R. B. & Lesorogol, C. K. in Building Resilience of Human-Natural Systems of Pastoralism in the Developing World: Interdisciplinary Perspectives (ed. Dong, S.) 251–280 (Springer International Publishing, 2016). doi:10.1007/978-3-319-30732-9
3. Duncan, C., Chauvenet, A. L. M., McRae, L. M. & Pettorelli, N. Predicting the Future Impact of Droughts on Ungulate Populations in Arid and Semi-Arid Environments. PLoS One 7, (2012).
4. Wato, Y. A. et al. Prolonged drought results in starvation of African elephant (Loxodonta africana). Biol. Conserv. 203, 89–96 (2016).
5. Kusangaya, S., Warburton, M. L., Archer van Garderen, E. & Jewitt, G. P. W. Impacts of climate change on water resources in southern Africa: A review. Phys. Chem. Earth 67–69, 47–54 (2014).
6. Bunting, E. L., Fullman, T., Kiker, G. & Southworth, J. Utilization of the SAVANNA model to analyze future patterns of vegetation cover in Kruger National Park under changing climate. Ecol. Modell. 342, 147–160 (2016).
7. Durant, S. M. et al. Developing fencing policies for dryland ecosystems. J. Appl. Ecol. 52, 544–551 (2015).
8. Foley, C., Pettorelli, N. & Foley, L. Severe drought and calf survival in elephants. Biol. Lett. 4, 541–544 (2008).
9. Fullman, T. J., Bunting, E. L., Kiker, G. A. & Southworth, J. Predicting shifts in large herbivore distributions under climate change and management using a spatially-explicit ecosystem model. Ecol. Modell. 352, 1–18 (2017).
10. Thuiller, W. et al. Vulnerability of African mammals to anthropogenic climate change under conservative land transformation assumptions. Glob. Chang. Biol. 12, 424–440 (2006).
11. Hobbs, N. T. et al. Fragmentation of rangelands: Implications for humans, animals, and landscapes. Glob. Environ. Chang. 18, 776–785 (2008).
12. Shrader, A. M., Pimm, S. L. & van Aarde, R. J. Elephant survival, rainfall and the confounding effects of water provision and fences. Biodivers. Conserv. (2010).
13. Georgiadis, N. J., Olwero, J. G. N., Ojwang', G. & Romañach, S. S. Savanna herbivore dynamics in a livestock-dominated landscape: I. Dependence on land use, rainfall, density, and time. Biol. Conserv. 137, 461–472 (2007).
14. Trimble, M. J. & van Aarde, R. J. Supporting conservation with biodiversity research in sub-Saharan Africa's human-modified landscapes. Biodivers. Conserv. 23, 2345–2369 (2014).
15. Nyhus, P. J. Human–Wildlife Conflict and Coexistence. Annual Review of Environment and Resources 41, (2016).
16. Martínez-Freiría, F., Tarroso, P., Rebelo, H. & Brito, J. C. Contemporary niche contraction affects climate change predictions for elephants and giraffes. Divers. Distrib. 22, 432–444 (2016).
17. Lindsay, K., Chase, M., Landen, K., Conservation, K. N.-B. & 2017, undefined. The shared nature of Africa's elephants. Elsevier
18. Stevens, N., Erasmus, B. F. N., Archibald, S. & Bond, W. J. Woody encroachment over 70 years in South African savannahs: overgrazing, global change or extinction aftershock? Philos. Trans. R. Soc. B Biol. Sci. 371, 20150437 (2016).
19. Fox, J., Vandewalle, M. & Alexander, K. Land Cover Change in Northern Botswana: The Influence of Climate, Fire, and Elephants on Semi-Arid Savanna Woodlands. Land 6, 73 (2017).
20. Scheiter, S. & Higgins, S. I. How many elephants can you fit into a conservation area. Conserv. Lett. 5, 176–185 (2012).