

FINAL TECHNICAL REPORT_MAKERERE UNIVERSITY_MCGILL_UKZN

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Final Report for IDRC project number: 108570-001 Trilateral Research Chairs Initiative

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Abstract

The rural poor of tropical countries are being strongly impacted by climate change, as they live in direct contact with the land and depend on their immediate environment for food, water, medicines, and fuel. This close contact results in these communities being severely affected by wildlife that raid their crops, which often causes significant economic hardships. However, our research demonstrates that some wildlife also experience decreased food availability as a result of climate change. Thus, climate change may be increasing human-wildlife conflict. The objective of our project was to establish a team that could build a graduate research and training network between Uganda, Canada, and South Africa to address the critical issue of how climate change affects crop production and crop raiding by wildlife. Despite setbacks due to the pandemic, particularly travel restrictions, we are happy to report that we made significant progress in reaching our objective. We worked together to continue all research activities when it was permitted to do so in Uganda, with the exception of some of the out-park components of our research. The pandemic did challenge the ability of Dr. Patrick Omeja to fully build his international professional profile, as Makerere University was closed a number of times, and there was an internal travel ban for extended periods. However, Dr. Omeja clearly advanced his research/training portfolio as evident in his publications, contributions to mentorship of graduate students, and interactions with researchers both in Africa and more globally. With respect to training of Ugandan Masters students, we were fortunate because all three of the Masters students had completed their data collection prior to the pandemic, thus we were able to focus on analyzing and writing up existing data. These three students have completed their studies, graduated, and all have positions in fields related to their studies, or they are continuing on to do Ph.D.s (independently funded). Our Ugandan Ph.D. student, Wilson Kagoro, is a Community Outreach Warden with the Uganda Wildlife Authority. Because of COVID-19, he was not granted study leave; thus, there have been delays in components of his training program. However, he has completed his field research, and we have found additional funding to help him during his write-up phase. Overall, we view student training to have progressed very well (Uganda - 3 Masters and 1 Ph.D. student, South Africa – 1 M.Sc. completed, 7 Ph.D.s completed, 6 Ph.D.s to complete, 4 Post-docs, Canada 2 Post-docs), and the feedback from the local people and regional and federal governments has been very positive.

To examine how climate change is impacting wildlife and local agricultural communities, we monitored the crop-raiding that local farmers were experiencing,

documenting its extent, the economic loss it entailed, and how it impacted food security. In general, food security in the region is poor, particularly for the most nutritious crops; and crop raiding causes significant hardships, particularly the raiding that elephants conduct. We evaluated what factors could be driving animals out of the park and into people's fields to eat their crops. The climate is getting hotter and wetter, and these changes are contributing to changes in the phenology (timing of leafing and fruiting) of many of the forests tree species, which is leading to a reduction in the food available to some wildlife species. As part of this IDRC project, we repeated censuses conducted since 1996 and documented that the animal populations in Kibale are generally increasing. Again, this could lead to increased crop-raiding. Of particular importance is the increase in the elephant population. Elephant numbers increased exponentially since the 1990 through early 2010. Throughout the granting period we studied the strategies that farmers are using to try to deter crop-raiding animals, and we determined how successful these strategies are. While farmers employed a wide variety of strategies, the most successful at deterring crop-raiding by elephants was the construction of trenches dug 2 m deep and 4 m wide, as elephants do not cross these trenches. We have assessed people's attitudes to the park and how crop-raiding affects their behaviour. We tested the hypothesis that the negative attitude that some people have towards parks reflects crop raiding, which was supported by our studies. We also tested the hypothesis that crop-raiding by park animals will lead to an increase in poaching as people must replace the food lost to crop-raiding animals; however, we found no change in the number of snares set by poachers.

In June 2022, we had our final workshop, and while our South African colleagues were not able to attend due to Covid-related travel restrictions placed on them by their university, the event was very successful. The event was held at the Makerere University Biological Field Station, and we targeted the orientation of our presentations to relaying our results to policy/management people (primarily the Uganda Wildlife Authority - UWA) and the local community. The workshop was well attended by UWA staff, faculty from Makerere University, and the local community. In addition, a dozen foreign researchers (travel independently funded) joined us for the event. We believe that targeting the meeting to policy makers in Uganda will increase the impact of our work and see it be put to use in future years.

Overall, we view our productivity in terms of the continued long term data collection, publication and policy recommendations to the Ugandan government as very high. Over the last 5-years the IDRC grant helped fund 54 papers that are published or submitted, and several policy recommendations presented to the Ugandan government, primarily the Uganda Wildlife Authority. The success of our project reflects the hard work of many researchers and graduate students, the local communities that were very helpful with their participation in interviews, the field station personnel at Kibale, and the field assistants, whose deep knowledge of Kibale National Park and the local communities was integral to our project.

Keywords: Park-People Relations, Climate Change, Crop-raiding, Elephants, Forest Ecology, Food Security

ii) The Research Problem

The rationale behind our IDRC project was as follows: As climate continues to change, as human populations continue to increase, and as animals become increasingly isolated in the few remaining protected areas --human-wildlife conflicts will also increase, in many cases dramatically. Effective strategies must be in place to handle this situation. For example, between 2000 and 2020 the population living within 1 km of Kibale National Park's boundary almost doubled from 123 to 229 people / km². Local people are typically smallholder farmers, cultivating less than 5 ha to grow staple foods, such as bananas, maize, beans, and cassava. As a result, crop raiding by wildlife can cause significant hardships.

Clearly, understanding how to mitigate human-wildlife conflict will be one of the major challenges facing agricultural advisors and conservation biologists in the future. Without clear and effective strategies, the situation will only get worse, leading to decreased resources for the human population and increased social tension. The broader societal relevance is clear – we have two sectors of society at odds, agriculturalists clearly do not want to lose their crops and livelihood, and people in high-income countries and national conservation agencies within Africa advocate for the protection of tropical megafauna, such as elephants, which are often the animals damaging farmer's crops.

Our understanding of the research problem was very clear at the beginning of our project as it was based on 20-30 (Omeja – Chapman) years of experience of the situation in and around Kibale National Park, Uganda. However, with the Covid-19 pandemic, there were growing calls to decrease bushmeat hunting to lessen the chances of zoonotic disease transmission to prevent the next pandemic. This added a new dimension to our project and a new component to our outreach. Developing effective solutions to decrease bushmeat hunting will not be easy but represent a new opportunity to develop novel conservation strategies.

iii) Objectives

Briefly stated, **our first and most general objective was to establish a team that could build a graduate research and training network between Uganda, Canada, and South Africa** to address the critical issue of how climate change affects crop production and crop raiding by wildlife. Dr. Patrick Omeja is the head of this network, and through the groups' activities, he has elevated his standing within the research community in Uganda and globally. We successfully developed our team, training 3 Ugandan Masters (two Females and one male -all completed) and 1 Ugandan Ph.D. student (almost completed); in South Africa we totally or partially funded – 2 M.Sc. students, 13 Ph.D.s, 4 Post-docs, and we trained 2 Post-docs in Canada. Most importantly, Dr. Patrick Omeja was awarded a position as a Senior Research Fellow in the College of Agriculture and Environmental Science at Makerere University. This position allows him to focus on research, graduate training /mentorship, and promoting the Makerere University Biological Field Station, both nationally and internationally. By obtaining this position it places Dr. Omeja in an excellent position to be considered for the next directorship of the field station and cultivate the station so that it meets its full potential as one of the most important tropical field stations in the world,

specializing on park-people interactions. The only component of our program that we were unable to engage in was attending national, regional, and international meetings. This was due to Covid-related travel restrictions. However, we pivoted quickly after the lockdowns in Uganda and restrictions on international travel associated with the pandemic and communicated effectively virtually. Thus, we are confident that our team will continue in its efforts to address the critical issue of how climate change affects crop production and crop raiding by wildlife. Our graduated students are already continuing this work and expanding the network.

With respect to our **second objective - monitor the level of crop raiding and drivers of the animals' behaviour** – we were able to meet our goals and experienced only very limited pandemic related interruptions. **The third objective is related to the second and involved examining possible drivers of animal crop-raiding and human-wildlife conflict, using the long-term ecological data** that Dr. Chapman had collected over the last 33+ years. These data include climate monitoring, forest food availability for animals, crop planting strategies, animal population size, and forest structural changes.

Activities addressing these latter two objectives followed our original design with a couple of exceptions. Following 2019, we increased the spatial scale over which we monitor crop-raiding as the raids did not occur at the frequency, we envisioned based on farmers statements. Except for a period (March – July) in 2020, the pandemic did not stop us from interviewing informants, but we have not hosted community meetings or focus groups post-pandemic. We closely followed Ugandan Covid regulations/restrictions that prevented such gatherings.

Except for the brief period between March and July 2020 we continued to monitor the phenology of major fruiting plants on a monthly basis in Kibale. These are the major foods of the animals that raid people's farms. We now have a 33+ year record of tree phenology, one of the longest in tropical Africa, if not globally. We have also monitored forest plots to examine changes in forest composition that might have affected the need for the wild animals to leave the park. We resampled our extensive plot system in Kibale, and we now have a 31-year record of forest change. We conducted a new sampling component of forest change that was not in the original plans but clearly enhanced our ability to characterize change. We sampled plots set up in 1978 by Dr. Tom Struhsaker. This sampling demonstrated some interesting changes over the last 40+ years. For example, the abundance of light-demanding species that are often preferred food species for crop-raiding animals, including baboons and elephants, have declined in abundance over time; more rapidly than shade-tolerant species (Figure 1). This suggests that crop-raiding animals have an increased need to leave the park to obtain food. We are currently trying to understand why these light-demanding species have declined in abundance and are addressing the competing hypothesis that it is related to forest aging or climate change. If the forest aging hypothesis proves correct, this aging will continue, thus the pressure for wildlife to raid people's crops will increase. The changes in forest structure may also have been driven by changes in the climate, which we have carefully documented but will need further analyses (Table 1, Figure 2).

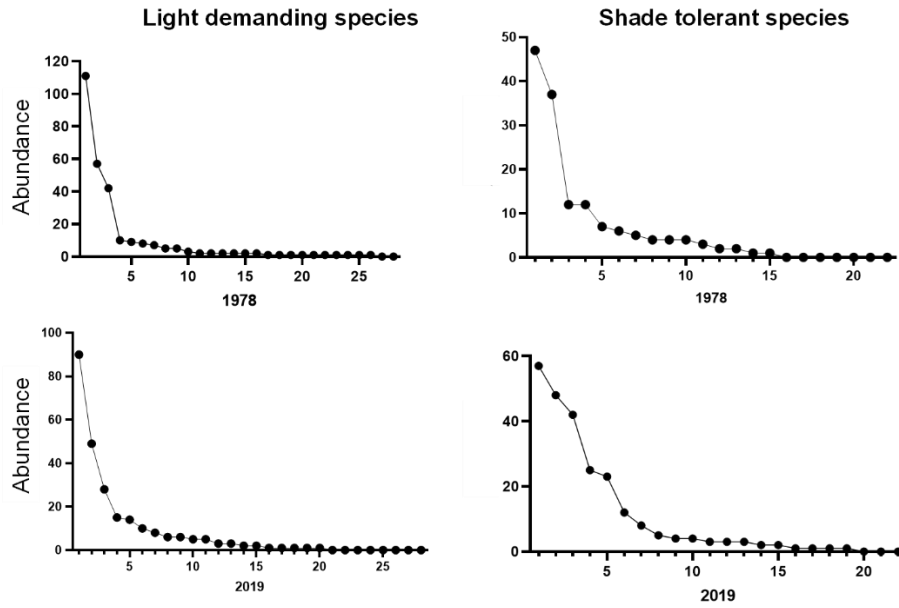


Figure 1:

The shade-tolerant and light-demanding species enumerated in plots ranked in order of abundance. Sampling was conducted approximately 40 years apart (1978 and 2019) in an old-growth area of Kibale National Park, Uganda.

Table 1: Changes in annual rainfall and maximum and minimum temperature over time in the Kibale region of western Uganda

Variable	Start (year)	End (year)	Mean	Max	Max (year)	Min	Min (year)
Annual rain	1903	2020	1553 mm	2214 mm	1996	1047 mm	1925
Tmin – annual mean	1970	2019	13.83 °C	15.33 °C	2009	12.70 °C	1971
Tmax – annual mean	1970	2019	26.10 °C	27.55 °C	2019	24.85 °C	1975

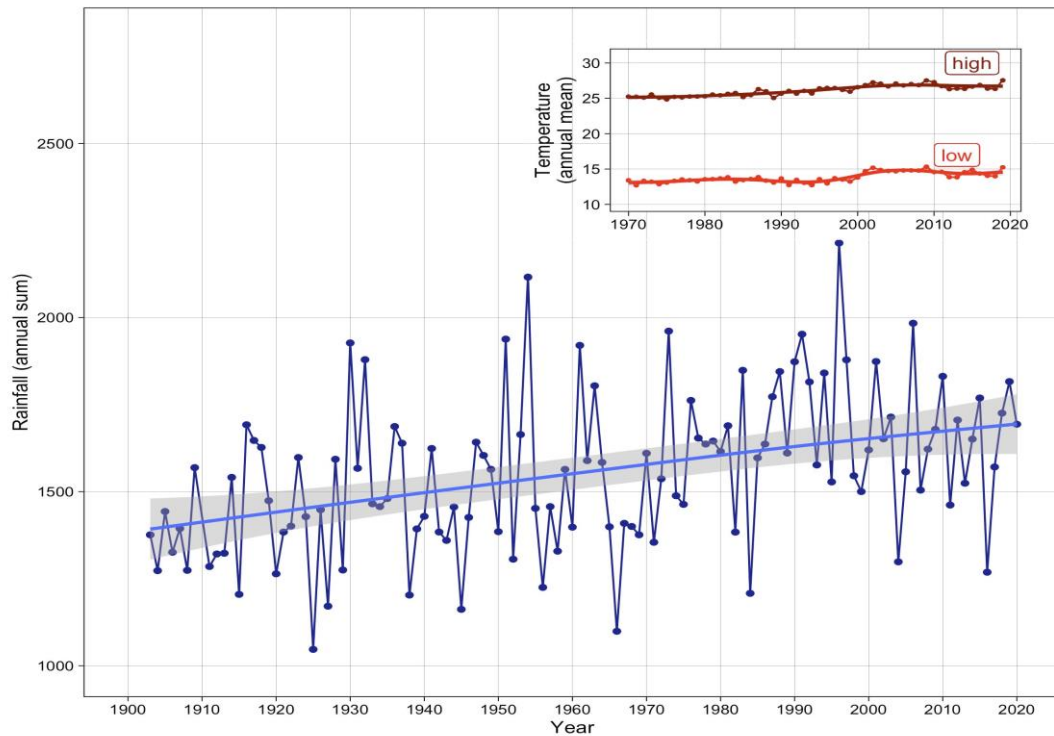


Figure. 2: Annual patterns in rainfall from 1903 until 2020 and temperature from 1970 until 2019 (inlay).

Climate change is affecting the ability of farmers to grow crops. What this climate change means to the local farmers has been assessed by our M.Sc. Student - Emmanuel Opito, and the farmers' statements about the trends in climate echo the quantitative data that we scientists collected. The big issue for farmers is that the climate is getting more variable, thus it has become very difficult for the farmers to predict what should be planted in the next season. They are adopting a strategy of planting a greater diversity of crops each season – i.e., they are hedging their bets (i.e., hoping that if one crop fails, the other will not and they can survive on the remaining crop). We are hoping to extend this work in collaboration with Dr. Dipto Sarkar, Carleton University, to use sensors that can remotely monitor soil moisture, Nitrogen, Phosphorus, temperature, etc., to provide farmers better advice as what plants will do well in the next season – we hope funding will be granted and have a grant submitted.

We have also worked on synthesis of a 30+ year data set on the temperature and dissolved oxygen of a swamp-stream system in Kibale. There is a strong correlation between minimum air temperature and water temperature in the park's largest papyrus swamp.

Finally, to evaluate how change in the abundance of animal populations may be affecting crop raiding behaviour, we evaluated long-term data on the ungulates, pigs, elephants, and primates in Kibale. Changes in abundance (363 surveys totally 1,450 km) were considered in light of the site's management strategy, regional economic indicators, community wealth change, and estimates of illegal hunting. Bushbuck abundance appeared to increase in old-growth and logged forests from 1996 to 2009 and then oscillated around

this level or declined (Figure 3). Duiker abundance showed similar patterns, but their abundance in old-growth forests showed a general increase from 1996 to the present. Duiker abundance in the logged forests exhibited an early increase, but subsequently oscillated (Figure 3). Poaching signs per patrol conducted by the Uganda Wildlife Authority, our close government collaborator, remained stable over the last decade, despite large increases in the size of the surrounding population, the increased cost of living, and the high cost of schooling. This seemingly reflects successful efforts in conservation education and enforcement. Our study indicates a positive impact of park establishment, patrolling, and conservation efforts on ungulate populations and shows the adaptability of forest mammal populations to different management schemes.

Our most significant finding was that the size of the elephant population in Kibale National Park has increased exponentially over the last decades, but the number of elephants now seems to have stabilized (Figure 4). One of our Master students from Makerere University, Ms. Anna Muchwampaka, documented that crop raiding was mostly done (95%) by baboons and elephants. Baboons took small amounts per raid, but elephants often destroyed a significant part of a farmer's whole season's crops. She found that guarding and trenches were perceived as the most effective deterrent strategies for baboons and elephants, respectively. Distance from the park boundary and household income were significantly associated with a greater likelihood of crop raiding. Distance from the park, household head age, and the species that raided crops, influenced whether a household applied one or more deterrent strategies. Households headed by women or older adults were most vulnerable, experiencing greater losses to raiding. We are working with the local government to derive strategies to help households headed by women. We are currently nearing the end of yet another assessment of the population numbers of these species – the assessment will be completed in January 2023.

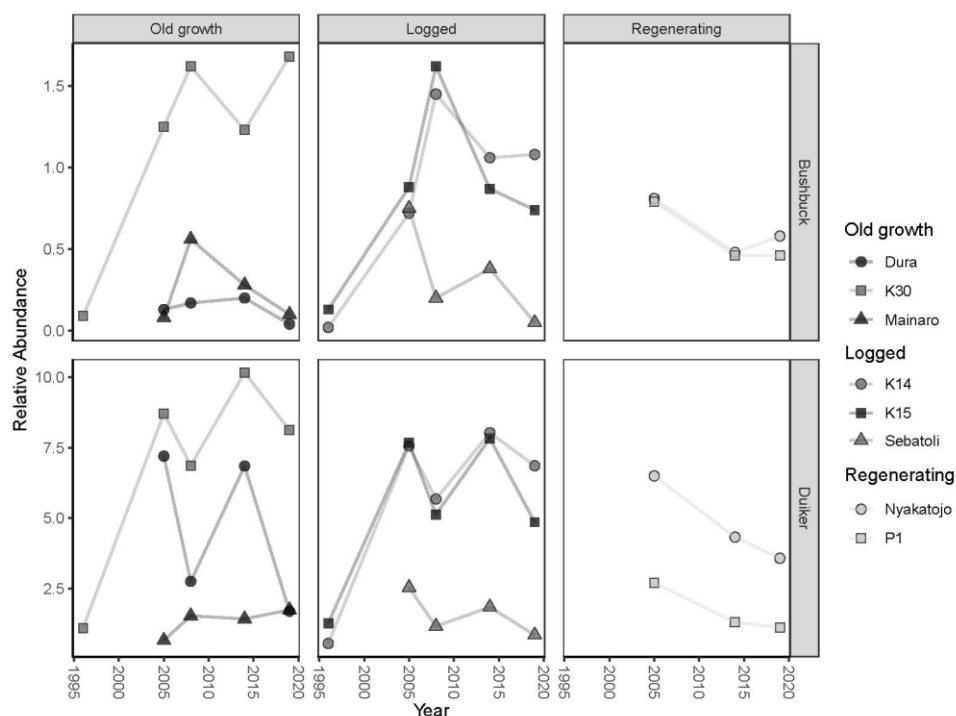


Figure 3. Index of abundance of bushbuck and duiker in old growth, logged, and regenerating forest in Kibale National Park between 1995 and 2019.

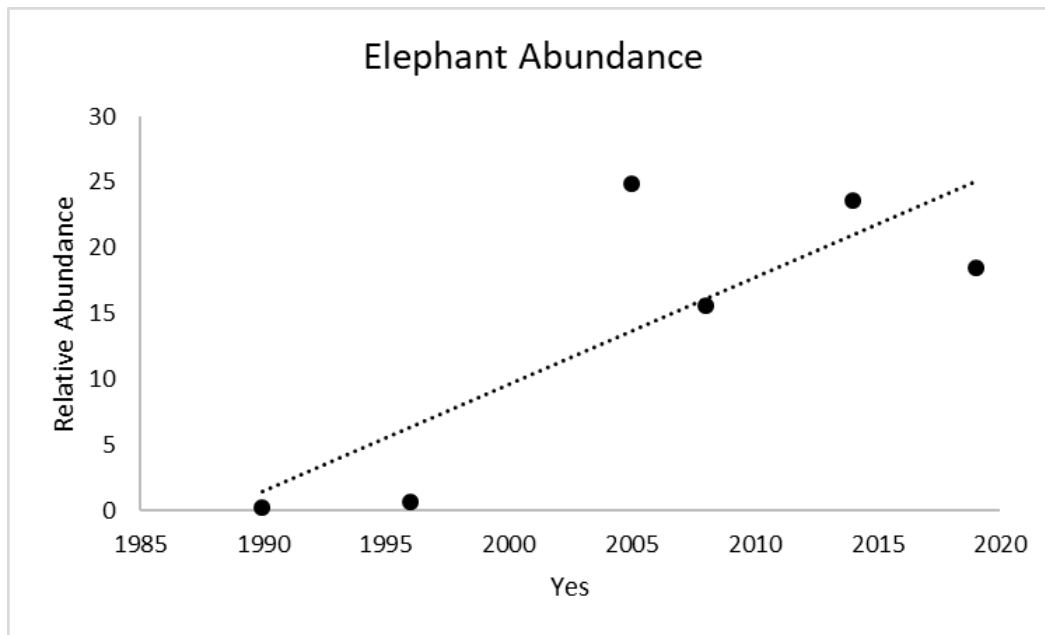


Figure 4: Changes in the relative abundance of elephants between 1990 and 2019 based on track and dung counts in the area neighboring Makerere University Biological Field Station, Uganda. A new census is being conducted this year and will end in January 2023.

iv) Methodology

With the exception of the Covid-related issues already presented, there were no major changes in the research methods and analytical techniques from what was proposed in the original document. As mentioned, following 2019, we increased the spatial scale over which we monitor crop-raiding as it did not occur at the frequency we envisioned. This was primarily due to the fact that elephants raided in a very sporadic fashion and travelled large distances. Thus, we began monitoring a section of park boundary that was approximately 10 km long and had field assistants assess every episode of elephant crop raiding that occurred over this area. This meant a slight shift in effort and funding a person to collect additional data, but this clearly increased the rigour of our assessment, and was critical to our ability to characterize elephant crop-raiding damage.

In brief, our methods involved

- (i) characterizing the ecological reasons that could drive crop raiding, including forest change, changes in animal populations, and climate change;
- (ii) quantifying the extent of crop-raiding by setting up a community based monitoring and assessment system and through community focus groups and interviews;
- (iii) assessing changes in planting strategies and food security issues using mixed method data collection and analyses, combining quantitative social, spatial, demographic, and agricultural survey data with qualitative in-depth interviews and participant-driven methods;

- (iv) quantifying changing attitudes towards the park from encroachment data that are regularly collected by the Uganda Wildlife Authority; and
- (v) finally, exploring methods to reduce crop raiding damage.

To grapple with what the local farmers called “the park’s elephant problem”, we did try a few things that failed. IDRC states that we should discuss failures so others can learn from these attempts; thus, let us provide some details.

Our first effort involved trying to attract elephants away from the forest edge and people’s crops by making one of their most favoured forest foods more readily locally available in the deep interior of the park. Elephants are well known to prefer the fruits of *Balanites wilsoniana* (Babweteera et al., 2007; Chapman et al., 1992; Cochrane, 2003). These fruits are also very odiferous and even people can smell the rotting fruit from hundreds of meters away. Elephants with their renowned sense of smell could likely detect these fruits from kilometers away; however, the detection distance is not known (Plotnik et al., 2014; Santiapillai & Read, 2010). Thus, we collected hundreds of ripe *Balanites* fruits (each fruit is an approximately 10 cm in diameter) and deposited them in a pile at a single location in the middle of the national park. We left the fruits there for over a month, but while elephants were visiting *Balanites* trees we were monitoring elsewhere in the park, they did not go to our artificial *Balanites* provisioning spot. This suggests to us, that we could not bait/entice elephants away from crops on the forest edge. It is possible that elephants detected human smell associated with the baiting site, but this seems unlikely as elephants enter farmer’s fields that must smell of humans. We do not know why this experiment failed.

A second attempt to tackle what the local farmers called “the park’s elephant problem”, was to manufacture a smell that farmers stated elephants’ dislike. When farmers know elephants are approaching and they have time, they light a fire and throw dry chili peppers on the fire, and if the smoke is blowing in the right direction, they believe that it deters the elephants from entering their fields. This strategy has two problems. First, the wind has to be blowing in the direction of the elephants; and second, the farmer has to have time to light a fire and burn the dry chili peppers before the elephants reach the farm and cause the damage. Working with a chemist from Germany (Omer Nevo) we manufactured the capsin smell of the peppers (the capsin is what causes the spicy/burning taste of peppers). Working with engineering students from McGill University in Canada, we manufactured a spray/mister gun made from locally available materials (mostly PVC tubes) that cost approximately 5 Canadian dollars to manufacture locally. We tried the manufactured pepper smell spray a number of times as elephants approaching farmer’s fields, and it seemed to have no effect. It is possible that the capsin is not the chemical that the elephant avoid. We suspect this because when one burns peppers and breaths the smoke or let it gets into one’s eyes, there is no burning sensation and no stinging that is the sensation of a hot pepper. We do not understand why farmers think this method works or even if it is effective. One of the Canadian post-docs is in the process of trying other non-harmful chemicals in a captive setting in South Africa.

The questionnaires used in our studies have all been published as part of the supplementary material associated with the papers and also in the theses of the students – see the publications listed below. Wilson Kagoro’s questionnaire will be published soon.

v) Project Activities

In general, we have already described the activities supported under the IDRC project in the previous sections; however, briefly we were engaged in the following. First, we established a network of scholars, primarily in Uganda, Canada, and South Africa that carried out a number of studies on the impact of climate change on the rural poor of tropical countries, as these people live in direct contact with the land and depend on their immediate environment for food, water, medicines, and fuel. We focused on communities who live adjacent to protected areas. We hypothesized that changes in climate, animal populations, and the food on which they eat would affect crop-raiding of farms adjacent to the park. In doing this we were very actively engaged in graduate student and post-doc training. Overall, we view student training to have progressed well (Uganda - 3 Masters and 1 Ph.D. student, South Africa – 2 M.Sc. completed, 7 Ph.D.s completed, 6 Ph.D.s to complete, 4 Post-docs, Canada 2 Post-docs).

Secondly, we monitored the crop-raiding that local farmers were experiencing, documenting its extent, the economic loss it entailed, and how it impacted food security. In general, food security in the region is poor particularly for the most nutritious crops, and crop raiding causes significant hardships, particularly the raiding that elephants conduct.

Third, we evaluated what factors could be driving animals out of the park and into people's fields to eat their crops. We quantified climate change and documented that the region is getting hotter and wetter. Climate change is one of the factors that is altering the phenology (e.g., fruiting) of many of the forests tree species and leading to a reduction in the food available to some species, particularly the arboreal frugivores and folivores. We also determined how the structure of the forest was changing by monitoring plots with marked individual trees established in 1989 and a second set of plots established by Tom Struhsaker in 1978. We discovered that light demanding species, which are those that are generally more nutritious and less toxic (Chapman et al., 2006; Coley, 1983; Omeja et al., 2016) are declining in abundance. This will result in less food being available to primates, ungulates, and pigs than has been in the past. It is logical to assume that this would encourage animals to leave the forest to try to find nutritious foods in farmer's fields (Rode et al., 2006). Finally, we repeated censuses conducted since 1996 and documented that the animal populations in Kibale are generally increasing. Again, this could lead to increased crop-raiding. Of particular importance is the increase in the elephant population. Elephant numbers increased exponentially since the 1990 through early 2010, but now are stabilizing. It is believed that the initial increase can be attributed to immigration of forest elephants from the Democratic Republic of Congo in the mid-1990s. The elephant population in Kibale is now a mixture of savanna and forest elephants, and their hybrids. Farmers consider elephants the most significant crop-raiding species. We are currently repeating this census and the data collection will be completed in January 2023 providing us a 27-year record of changes in animal populations – one of the longest for tropical forests.

Throughout the granting period we studied the strategies that farmers were using to try to deter crop-raiding animals and determined how successful each strategy was. While farmers employed a wide variety of strategies, the most successful at deterring crop-raiding by elephants were trenches dug 2 m deep, as elephants do not cross these trenches. However, this strategy cannot be used where there are rocky out-croppings or swampy areas, which are many in the region. Also, they have not been used adjacent to tea plantations. The next most effective strategy is to use loud noises to scare the animals back into the park. The people who are most affected by crop-raiding are households led by women or the elderly. This group of people cannot effectively use the scare strategy to deter crop-raiding.

Finally, we assessed people's attitudes to the park and how crop-raiding affects their behaviour (Sarkar et al., 2021). We tested the hypothesis that the negative attitude people could derive as a result of "the park's animals" crop raiding and people need to secure food after their crops were destroyed, could lead to an increase in poaching. Interestingly, we found no change in the number of snares set by poachers that were found by Uganda Wildlife Authority rangers over time. This suggests that the park is people effectively managed with respect to protecting biodiversity.

Most of these activities have been effectively reported on in the 54 papers that are published or submitted for publication – see below in the Project Outputs section.

vi) Project Outputs

Outputs – Publications submitted or published

Colin Chapman and Patrick Omeja have 54 papers submitted or published since the start of the IDRC grant until July 2022 that are directly related to this grant. * Indicates policy-oriented paper using information from the study. Students and Post-Docs funded by this grant are underlined. Additional papers use data collected under the auspices of the grant (e.g., climate data), but were not related to the objectives of the grant; and, as suggested previously by IDRC staff these are not listed.

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Planned Publications Not Yet Drafted

Assessing the implication of rural livelihood diversification on food security around Kibale National Park, Uganda – led by Emmanuel Opito to be submitted in the fall of 2022.

Climate change in region of Kibale National Park, Uganda, and its ecological and social consequence – led by Urs Kalbitzer (Canadian IDRC post-doc) to be submitted early 2023.

Knowledge to action in conservation science: The will to act to scale – led by Colin Chapman to be submitted summer 2022.

A 47-year assessment of primate population size at Ngogo, Kibale National Park, Uganda – led by Colin Chapman to be submitted late 2022.

Capacity:

We successfully developed our team, training 3 Ugandan Masters (all completed) and 1 Ugandan Ph.D. student (almost completed), in South Africa we totally or partially funded – 2 M.Sc. students completed, 13 Ph.D.s, 4 Post-docs, and we trained 2 Post-docs in Canada.

Ugandan Trainees:

Student	Degree	Status	Supervision
Wilson Kagoro	Ph.D.	Write-up Stage	Omeja/Chapman/Tumusiime
Anke Barahukwa	MSc.	Completed	Omeja/Namaganda/Chapman
Anna Muchwa	MSc.	Completed	Omeja/Banana/Chapman
Emmanuel Opito	MSc	Completed	Omeja/Wasswa/Hannington

We believe that the network of experts that we have established will be sustainable and will help Uganda deal with climate change and people's park issues in Uganda and globally in the future. Barahukwa and Muchwa have positions associated with Makerere University dealing with biodiversity and restoration of degraded protected areas using removal of invasive species. Opito is continuing his studies with funding from the Rufford Foundation, Vancouver Island University and Carleton University and is registered as a Ph.D. student at Makerere University. He will do his research under the supervision of Dr. Dipto Sarkar, Carleton University. Kagoro is working with the Uganda Wildlife Authority – the body that handles policy related to the issues that we developed. With a Ph.D. Wilson Kagoro would be considered for a Chief Warden (Conservation Area Manager) position with the Uganda Wildlife Authority – a position of great policy and management importance. Colin and Lauren Chapman's previous student, Arthur Mugisha, became the Executive Director of the Uganda Wildlife Authority – equivalent to the head of National Parks Canada. Wilson Kagoro may also achieve this prominent position. All Ugandan trainees are still in communication and working with the 2 Canadian post-docs.

We currently have three grants awarded (Rufford, Porter, and van Teinhoven Foundations) and six grants submitted to continue this work, particularly the network and training component of the project. We are also in the process of writing a number of other foundations, national government (i.e., USAID), and international grants, which would help us continue the work to understand and mitigate the impacts of climate change. As a result, we are confident that the project will be sustainable. All these grants are being written as a team effort, typically spearheaded by Drs. Omeja and Chapman, but involving junior members as well. This is illustrated by the fact the Emma Opito was awarded a Rufford training grant where he is the Principal Investigator and then Dr. Omeja and Mr. Opito have approached the Aga Khan Foundation to continue the training efforts we are engaged in.

We are committed to capacity building of women or marginalized social groups and 50% of our trainees are women, and each of our Ugandan trainees belong to a different cultural group. The tribal and cultural situation in Uganda is complex, and we hope to provide the appropriate balance in our training efforts.

Members of our team, primarily Dr. Patrick Omeja, met with staff of the Uganda Wildlife Authority on many occasions to discuss our results and aid them in setting Ugandan policy with respect to park-people conflict and climate change. Dr. Omeja met with UWA staff within Kibale countless times. During Dr. Chapman's trip to Uganda in June, the team met with Charles Tumwesigye, the second in command of the Uganda Wildlife Authority and the whole research office to review the finding of the IDRC grant and to discuss the next steps. Finally, our final IDRC workshop was well attended by staff of the Uganda Wildlife Authority from around the country. The workshop was followed by fruitful discussions that dealt with both the implications of our findings and associated management options, and what are the next needed steps for research and management.

A major finding of our project relates to changes in the abundance and activity of crop raiding animals. Because of the effectiveness of the Uganda Wildlife Authority at protecting

Kibale, wildlife populations are increasing. In addition, climate change and possible forest aging is leading to less food in the forest for some species, which is encouraging wildlife crop raiding activities. The most successful method to limit crop raiding is through the digging of trenches (2 m deep and 4 meter wide) that elephants will not cross. More trenches should be dug using funds from the revenue sharing moneys of the Uganda Wildlife Authority. Particular emphasis should be made to come to an agreement with the tea companies who have opposed the digging of trenches on the edge of their plantations. While elephants do not raid tea, they pass through these plantations to access people's food crops in the neighborhood. Our social interviews point to the need to provide particular assistance to family farms led by women or elderly. These farms have difficulty deterring raiding animals and are particularly hard hit – they are also often some of the poorest farms in the region.

Since it is unlikely that management strategies can lead to a significant decline in crop raiding, given the growing animal populations, we suggest that more emphasis should be placed in other means of improving parks-people relationships. One such method would be providing employment. We derived a promising strategy that would both provide substantial employment, help restore sections of Kibale's damaged forest, and fight climate change. We suggest and are seeking funding to protect and restore the forests of Kibale. We will work with the local community to promote forest regeneration by removing the invasive plant species *Lantana camera* and *Acanthus pubscens*. These plants are taking over large sections of forest that were either logged in Kibale in the 1960s or were encroached by agriculturalists in the 1970 – these lands are not protected in the park. We would turn this biomass into clean-burning fuelwood briquettes. This will decrease the community's need to collect fuelwood from the park, as well as remove the vegetation that is stalling regeneration, and provide significant employment for local farmers – a win-win solution that will promote positive people-park relationships and facilitate forest regrowth. Preliminary data and a draft operating model suggest that the sales of the briquettes would be sufficient to employ a group of local community members to continuously make briquettes. We are exploring this idea with our Ugandan partners, particularly the Uganda Wildlife Authority. While burning briquettes does put carbon into the atmosphere, charcoal is the only fuel source available to millions of Ugandans, and in this situation the released CO₂ should be regained by tree growth. This will be studied.

It is worth noting that, this problem of the invasive weed species is not only in Kibale National park, but in all protected areas managed by UWA and NFA. Concerted efforts are necessary for management of invasive species to minimize and where possible eradicate their negative impacts and facilitate the realization of relevant conservation goals. We are already working with UWA to see how effective our piloting in Kibale turns out to be, and a possibility of having it rolled out to other protected areas. This will be done under the wider government's initiative entitled Investing in Forests and Protected Areas for Climate Smart Development (IFPA-CD). The project aims to improve sustainable management of forests and protected areas and increase benefits from forests in target landscapes.

The IFPA-CD project is jointly developed and implemented by Ministry of Water and Environment (MWE) as the Lead Agency and Ministry of Tourism, Wildlife and Antiquities, National Forestry Authority (NFA), and Uganda Wildlife Authority (UWA). The problem being addressed by this project is increased vulnerability of economic productivity, biodiversity and livelihoods to climate change effects due to declining forestry ecosystems goods and services. Among the activities ear-marked for support by the project is control of invasive plant species within key Central Forest Reserves and national parks. This initiative seeks to build on ongoing invasive species control/management activities by NFA and UWA, learn lessons and scale up these operations. As an initial step, the NFA and UWA are desirous of assessing the magnitude and extent of invasive plant species infestation and developing management plans for eradicating invasive plant species in targeted CFRs and Wildlife Pas.

vii) Project Outcomes

Much of this has already been outlined above, so we will not repeat what has been stated. However, all evidence suggests that with climate change crop-raiding will increase in the region, and food security will decline. This will likely lead to a deterioration in park-people relations. We have worked with the Uganda Wildlife Authority to derive strategies for the future, particularly the increase in the extent of elephant trenches and the helping of households close to the park headed by women or the elderly.

As crop-raiding will likely intensify, other means of promoting a positive park-people relationship should be explored. We have come up with one means, the production of briquettes from invasive plant species, and are currently looking for funding to study this option and to bring the idea up to scale.

With the collaboration of Dipto Sarkar from Carleton University, we are working to use sensors that can remotely monitor soil moisture, Nitrogen, Phosphorus, temperature, etc., to provide farmers better advice as what plants will do well in the next season – we hope funding will be granted and have a grant submitted. The use of “smart” technology in agriculture is a promising field that we will explore.

viii) Overall Assessment and Recommendations

Addressing each component that was outlined in the guidelines for the final report includes the following:

1) Comment on the usefulness in achieving the project’s objectives through any partnerships with Canadian or other researchers, with Canadian or other capacity or policy-oriented organizations, and with other donors.

Achieving our project’s objectives was greatly assisted through our two main Ugandan partners – Makerere University and the Uganda Wildlife Authority. Makerere University provided us accommodation and logistical support, connections with the local

community, and a very collaborative research environment. The Uganda Wildlife Authority provided us important guidance in how our results could be put to use in policy that they set. Some recommendations that we could envision were simply impractical for the Ugandan government to implement (e.g., electric fencing to keep elephants inside the park). Thus, through their collaboration we were able derive feasible recommendations that could work within the logistics and culture and in fact some recommendations are currently being followed within the field course units components that run at the field station every third semester break for the undergraduate students from Makerere University.

New Canadian collaborations with Carleton University and Professor Dipto Sarkar are allowing us to ensure that our project moves more in the direction of agricultural improvement. This also helps ensure sustainability. Colin Chapman becoming a Board Member of the African Wildlife Foundation, Canada, is allowing our results to be broadly known by the conservation community in Canada and internationally. Two grants were obtained (the Porter Foundation and the van Teinhoven Foundation) that will allow us to continue our efforts and implement some of the recommendations coming out of the IDRC project. Finally, we envision that our findings will become part of the education package of students from McGill University and Vancouver Island University – McGill University will likely run a field course in Uganda in winter 2023.

2) What contributions to development did the project make?

We have clearly demonstrated that both agriculturalists and wildlife are being negatively affected by climate change. The impact on wildlife will drive them out of protected areas, like Kibale National Park, and into people farms to obtain food. This crop-raiding will lead to a decrease in people-park relationships in the community where food security is already poor, and this must be dealt with in future management plans. This leads to a series of recommendations that we outline in the next point.

3) What would you do differently as a result of this experience, and what general and useful lessons can be derived for improving future projects?

With respect to what needs to be done differently and lessons learned, it is clear crop-raiding, particularly that of elephants, will increase. This will lead to a deterioration of parks-people relations. As a result, efforts should be made to decrease crop raiding; however, it is clear that these efforts will not be totally successful. These efforts need to be made in conjunction with the community to ensure they are involved and that the park and community are working together to solve a joint problem. With respect to elephants, we recommend an increase in the extent of the trenches. The Uganda Wildlife Authority will play a key role here as they can negotiate with the tea plantations management that the trenches can be dug on their property. Furthermore, funds to pay for the trenches to be dug will come from revenue sharing program that UWA has with the local communities. This program involves 20 percent of the park entrance fees going to programs to help the local communities. However, as trenches cannot be dug where there are rocks or swamps, other

solutions need to be sought, for example using the bee hives. Particular assistance is needed for farms led by women and the elderly as they cannot effectively scare animals back into the park and thus suffer greater crop losses.

Even if such measures were put into place, our results suggest that crop-raiding will continue and likely increase as food for wildlife in the park decreases. As a result, ways to improve park-people relationships, such as providing employment from the park, should be explored. We are currently exploring one particular way to employ a large number of people and benefit biodiversity – the removal of invasive plants from the park, turning this biomass into charcoal briquettes for sales, with the sales paying the salaries of the participating community members.

4) Briefly provide your own views on the value and importance of the project relative to the investment of time, effort, and funding.

It is our view that we have provided clear and convincing evidence that climate change will negatively impact food security of local agriculturalists and decrease food availability for wildlife. This will lead to increased crop-raiding by wildlife and deteriorating parks-people relationships. As a result, appropriate management actions will be needed, and we have made a series of recommendations that will function in Kibale and more broadly in other UWA managed protected areas where crop raiding occurs. Given these findings, the extent of training we achieved, the outputs generated (particularly the quality and quantity of publications), and the likelihood that the project will continue and be sustainable, we view the project as a valuable contribution. Due to the extraordinary dedication of Drs. Omeja, Chapman and Downs, the field assistants, and the graduate students, we have achieved our goals while negotiating a pandemic and adapting to findings and feedback.

5) Include any recommendations that you would like to make to IDRC. Candid observations about the overall experience with the project are encouraged.

Our project ran very smoothly, despite the pandemic. The operations were greatly facilitated through good working relations with IDRC Staff, despite changes in the program officer and financial officer, and also the overall Finance Officer at Makerere University. We view that this Tri-lateral Chair approach was very successful as it facilitated networking and effective training.

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