WHEN GOOD CONSERVATION BECOMES GOOD ECONOMICS

KENYA'S VANISHING HERDS

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List of Acronyms

CGE	Computable General Equilibrium
DRSRS	Department of Resource Surveys and Remote Sensing
ESAM	Environmentally-extended SAM
Ksh	Kenya shilling
KWCA	Kenya Wildlife Conservancies Association
KWS	Kenya Wildlife Service
RAI	Rural Access Index
SAM	Social Accounting Matrix
SDGs	Sustainable Development Goals
TLU	Tropical Livestock Unit

Executive Summary

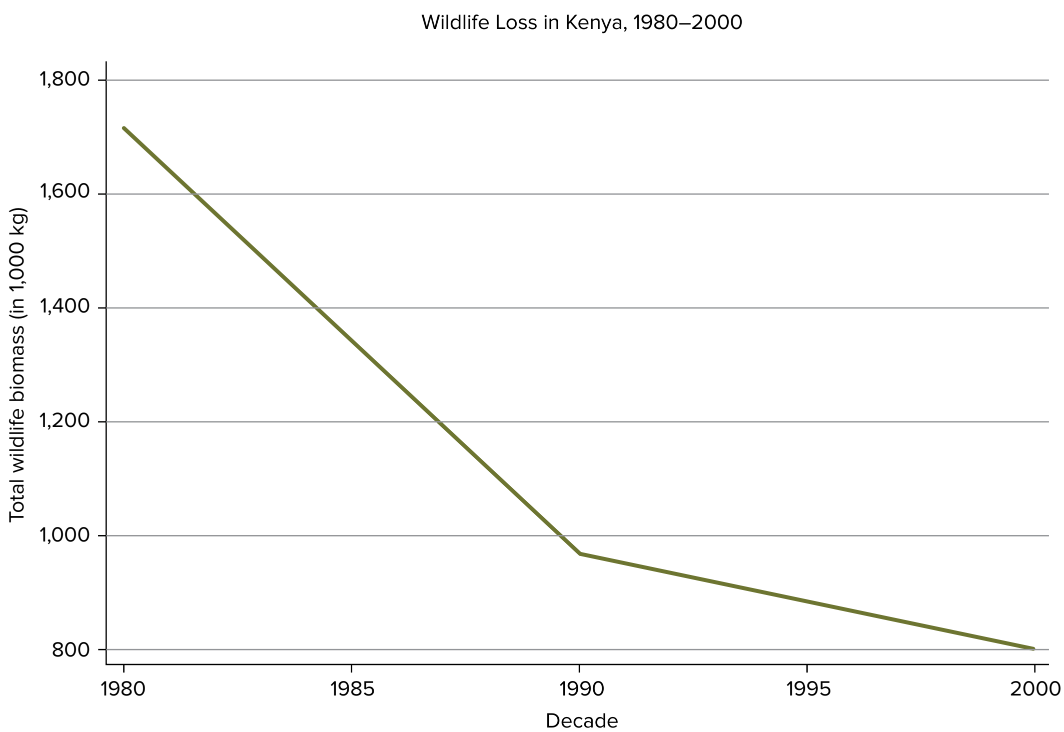
At a crossroads: Safari tourism under threat in Kenya

It is no exaggeration to state that Kenya's wildlife has done much to shape the image and development fortunes of the country. At independence, the country was reliant on agricultural exports for its foreign exchange revenue and was exposed to the vagaries of commodity price cycles. The vast and varied endowment of wildlife catalyzed a new industry—nature-based tourism—that provided an opportunity to diversify and boost export revenues while playing to the country's natural comparative advantage.

Today tourism is among Kenya's top sources of foreign exchange, dominates the service sector, and contributes significantly to employment, especially in rural areas where economic opportunities are limited. The typical international tourist arrives on a package tour that may include a safari, a visit to the beach, or both. It is safari tourism, however, that generates the most employment and economic activity across the country. A recent study by Sanghi et al. (2017) found that despite a diversifying economy, wildlife-based safari tourism is deeply integrated into Kenya's economic fabric in complex ways that stimulate much employment in rural areas. Official statistics of the sector's contribution to the economy tend to neglect the full panoply of backward and forward linkages and their dynamic effects on poverty and rural growth.

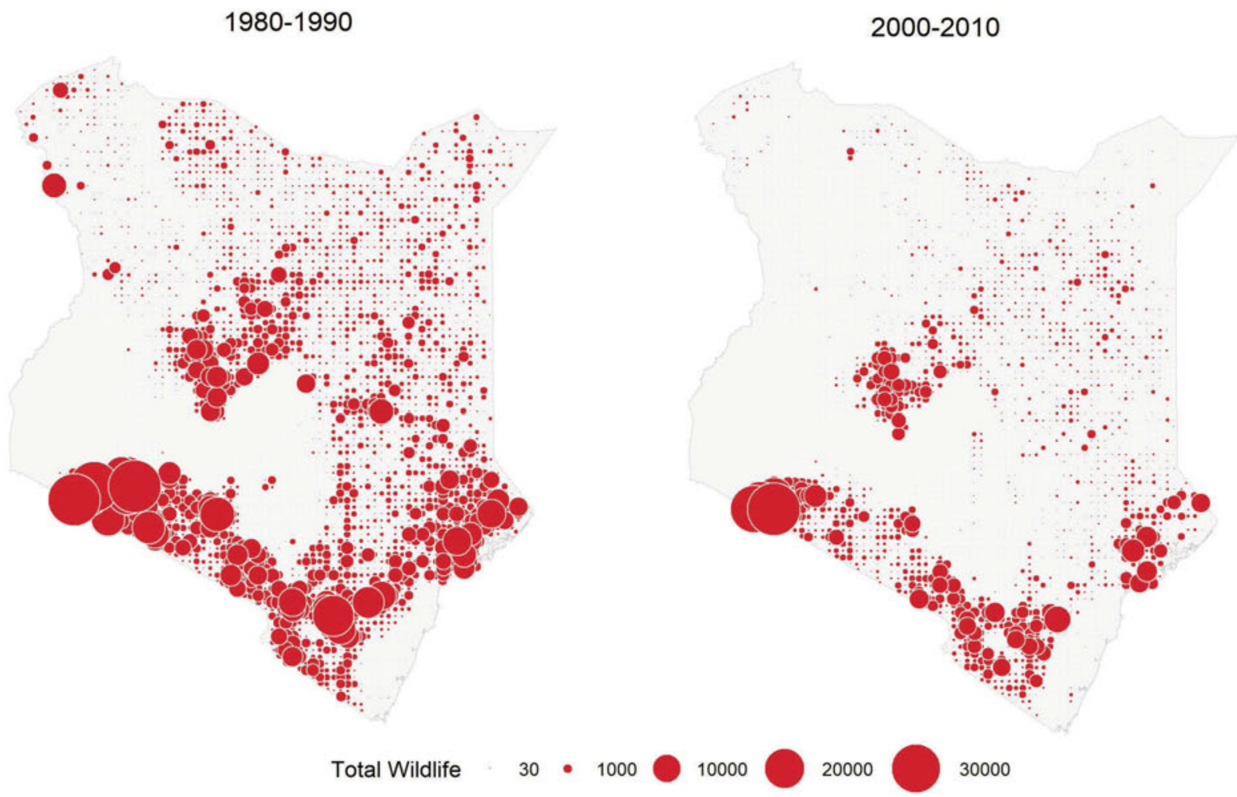
But the wildlife that has lured travelers to Kenya by the planeload is in dramatic decline (Figure ES.1). In the past three decades, the country has lost more than half of its wildlife (ungulate) biomass according to data from the Directorate of Resources, Surveys and Remote Sensing (DRSRS).

FIGURE ES.1: Kenya has witnessed a dramatic collapse in wildlife since the 1980s



Source: Authors based on DRSRS data.

FIGURE ES.2: Wildlife is now found in fragmented habitats and has vanished across vast areas in the North



Source: Authors. Data from DRSRS and Ogutu et al. (2016).

Wild herds that once roamed freely across the borders of Kenya and Tanzania have shrunk dramatically in numbers and vanished completely from much of the North (Figure ES.2). Once connected habitats have been severed, with herds trapped into shrinking areas, jeopardizing the long-term sustainability of many isolated and unconnected populations.

Perhaps most troubling is that recent monitoring of wildlife populations suggests that long-term declines of many of the charismatic species that attract tourists—lions, elephants, giraffes, impalas, and others—are occurring at the same rates *within* the country's national parks as *outside* of these protected areas (Ogutu et al. 2016). Parks in Kenya were established in areas in which large aggregations of animals were observed typically during the dry seasons, but in their haste to establish these protected areas, policy makers neglected the migratory needs of wildlife, especially of the ungulate herds. Dispersal is a fundamental biological process that influences the distribution of biodiversity in every ecosystem and determines whether a species will survive.[1] The process of dispersing from a natal territory is essential to avoid inbreeding and it strongly influences individual fitness.

As a result, wildlife depends as much on adjacent land for continued viability as it does on the protected areas. Pressures around the parks are affecting wildlife within the parks. The way in which land outside of protected areas is utilized and managed will become a crucial determinant of the industry's future. Expanding tourism to these areas remains among the most successful approaches that have been piloted. However, the feasibility of this approach depends upon economic incentives and the opportunity costs of land.

1 Dispersal is a fundamental behavioral and ecological process. The distance that individual animals disperse, and the number of dispersers, can be primary determinants of where and whether species persist. Dispersal fundamentally influences spatial population dynamics, including meta-population and meta-community processes.

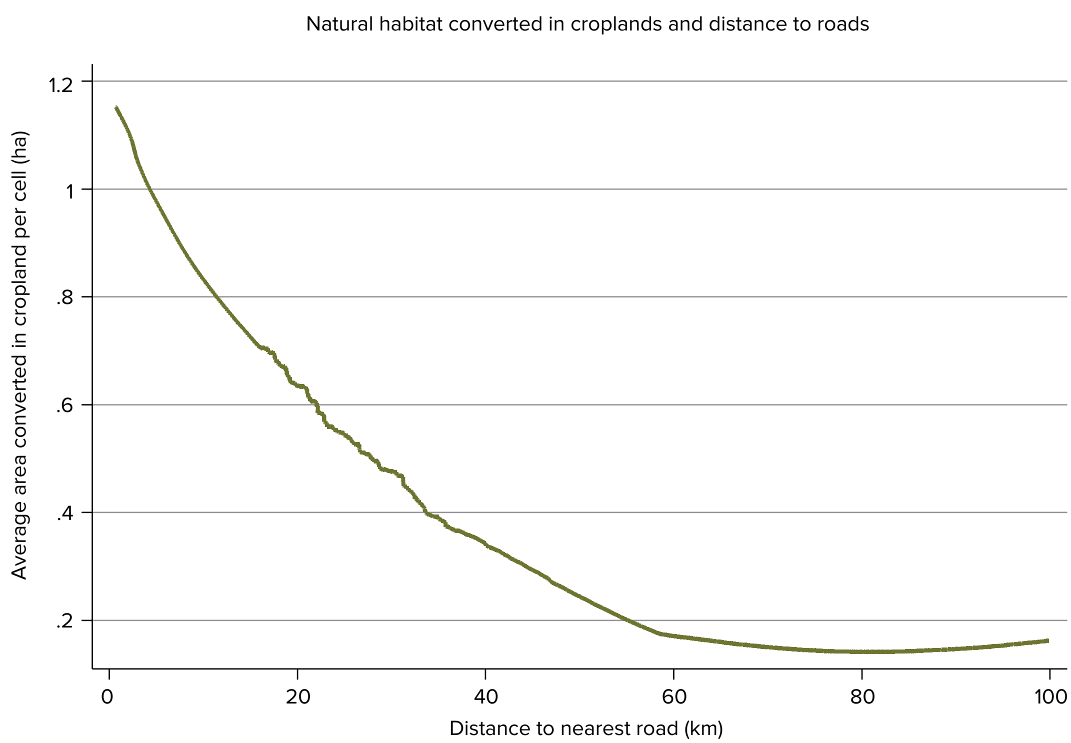
This report uses a variety of approaches to investigate the economic consequences of this decline. State-of-the-art spatial econometric methods are used to identify the causal drivers of the loss and quantify the impacts on wildlife. A Computable General Equilibrium (CGE) model is used to estimate the economic consequences of wildlife loss and compare these consequences to alternative development pathways. Finally, spatial algorithms are developed to show how losses can be avoided and how to create win-win solutions that maximize economic gains.

Following the tracks

Reasons for the decline in Kenya's wildlife have been widely documented, and they entail an interconnected suite of pressures typically linked to habitat conversion—factors such as population growth, the expansion of arable agriculture, fencing, poaching, and intrusive infrastructure. This report identifies with greater precision the drivers of land conversion from natural habitats to other uses, and examines the extent to which land conversion leads to the extirpation of wildlife and the loss of tourism incomes.

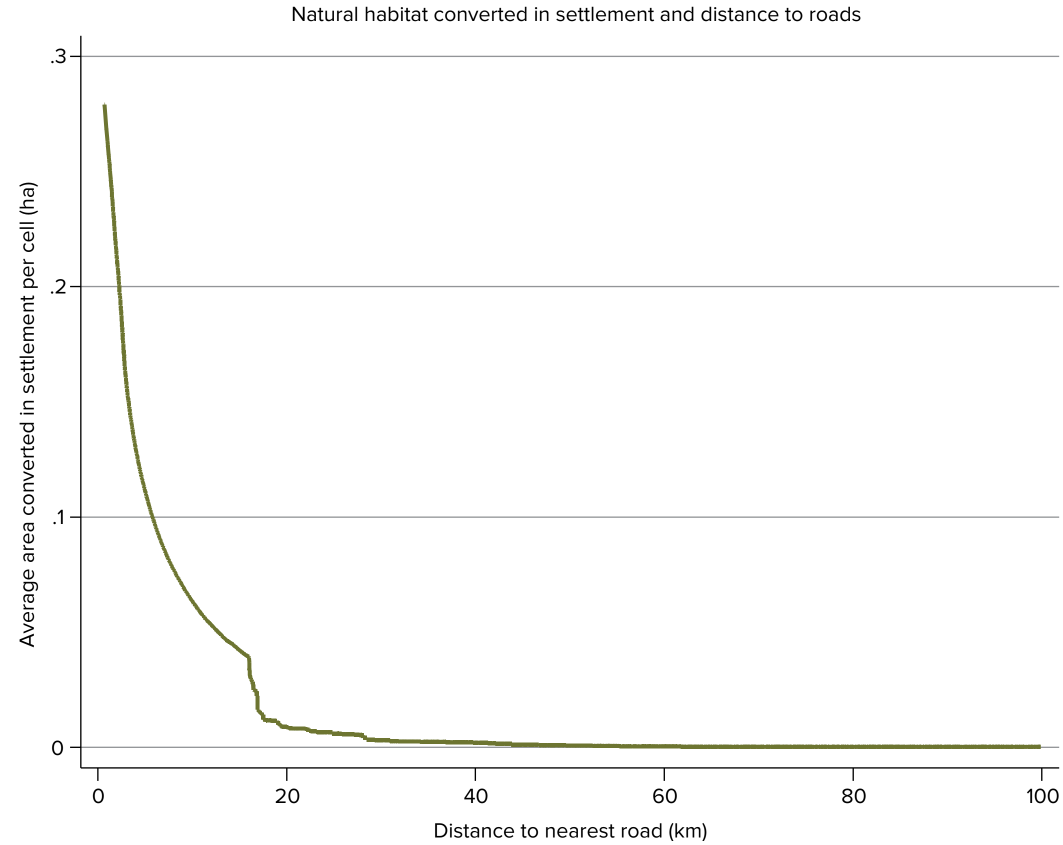
The analysis presented in Chapter 1 finds that roads are typically accompanied by a change in land use pattern from natural habitats to farms and settlements. On average, the extent of conversion is especially stark up within a corridor of about 20 kilometers from the road. Thereafter, the conversion of natural habitats into cropland slowly decreases and is almost negligible for settlements. An obvious consequence of this change in land use is the almost complete collapse of wildlife in areas around the roads (Figure ES.3). The statistical model developed for this report indicates that roads built over the last four decades have caused an 80 percent decrease in wildlife within a 20-kilometer radius. There are also predictable effects on migratory corridors, which have almost all been diminished and degraded to varying degrees (Ojwang et al. 2017).

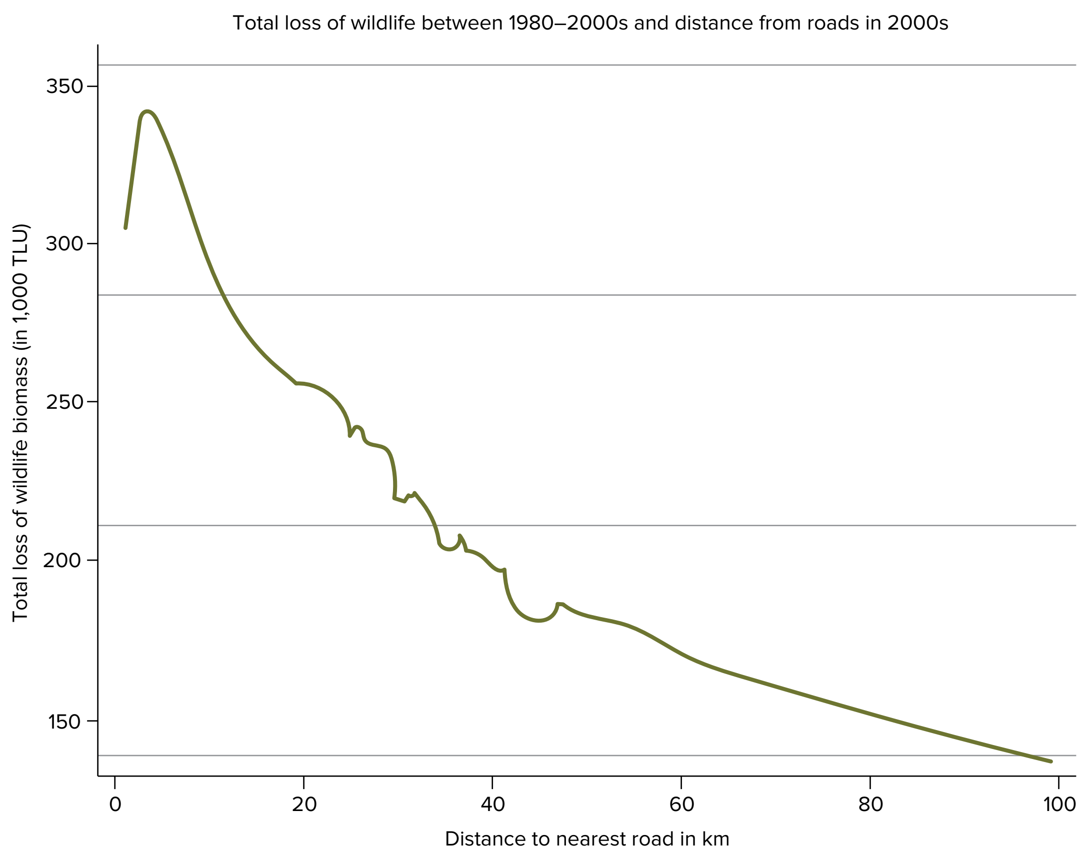
FIGURE ES.3: Roads lead to changes in land use, impacting wildlife most severely within a distance of 20 kilometers



Source: Authors based on ESA land use data and Michelin roads data.
Note: TLU stands for Tropical Livestock Units.

FIGURE ES.3: Continued





Source: Authors based on ESA land use data and Michelin roads data.
Note: TLU stands for Tropical Livestock Units.

The report then provides an assessment of the economic consequences of this loss. Clearly, if the economic benefits brought about by habitat conversion outweigh the losses, it is arguable that the extirpation of wildlife is a necessary, if regrettable, price to pay for development. But if the loss of actual and potential tourism income exceeds the benefits from land conversion, greater care and caution would be warranted in both the placement of intrusive developments and the extent of land conversion.

The trade-off between road construction and wildlife protection

To explore this issue in a rigorous manner, this report employs a computable general equilibrium (CGE) model that divides the economy into two regions—North and South. The model tracks the contribution and linkages between various economic activities and provides an indication of the economic consequences of alternative development strategies (Chapter 2).

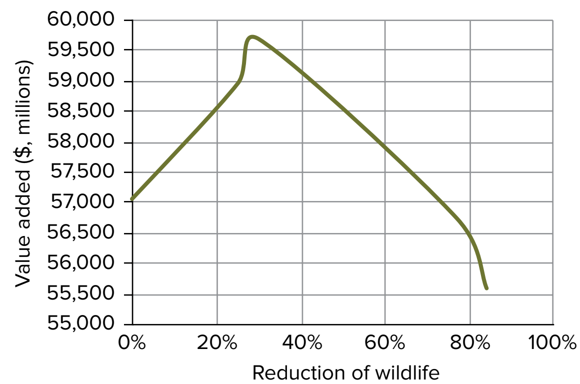
The projections indicate that the two regions have different economic structures. In general, land-based activities, manufacturing, trade, and transport are the sectors that create the largest gains (production multiplier effects) in the economy. Production multipliers, though low in both regions of the country, tend to be comparatively larger in the more developed areas of the South.

Has the loss of wildlife generated economic gains commensurate to the economic loss? A road through rural areas brings multiple benefits through the expansion of agriculture, access to markets, and myriad economic opportunities that such market integration brings. Accordingly, the CGE model finds that if the consequent loss of wildlife is relatively modest and below around 30 percent (or alternatively, if the elasticity of tourism with respect to wildlife is small), there is limited loss of tourism and there is a net gain to the conversion of land.

If, on the other hand, the loss of wildlife is much larger, there is a decline in overall regional GDP. With the 80 percent loss of wildlife experienced in Kenya within 20 kilometers of a road, parts of the country would no doubt fall into the latter category. In general, impacts of wildlife tourism loss are much more severe in the North where there are limited development opportunities.

This relationship is summarized in Figure ES.4, which shows the production possibility frontier of the Kenyan economy. If a road brings losses of wildlife that are below a threshold (around 30 percent), it confers a net economic benefit and an increase in GDP. But losses that are much larger induce a net loss in GDP. Put simply, good conservation has become good economics for Kenya.

FIGURE ES.4: Production frontier for GDP and loss of wildlife



Source: Authors.

One implication of this finding is that the induced conversion of habitats has come at a high cost to much of the country. A second implication is that since the potential and often hidden benefits of habitats are significant, development opportunities exist to harness the dual benefits of both conservation and development. Finally, these results also suggest that if the consequences of construction were managed and controlled better so that habitat conversion was prevented and wildlife losses avoided, it might be possible to simultaneously obtain the benefits of infrastructure development as well as those brought by tourism. This would likely entail significant and different policy interventions. The available data suggest that the declaration of protected area status or conservancy status may slow, though not prevent, the rate of land conversion for agriculture and settlements. The report explores two sets of solutions to maximize the benefits of infrastructure and of tourism: a road network that pays attention to the externalities that it generates, and a policy that expands the role of conservancies.

Building smart infrastructure

The key to avoiding the economic costs identified in this report is to find ways to maximize the benefits from infrastructure and minimize the economic losses. About 30 percent of Kenya's rural population is currently connected to the national all-season road network. Increasing the country's Rural Access Index (RAI) will be key to achieving the goals set in Kenya's Vision 2030 and under the Global Sustainable Development Goals.

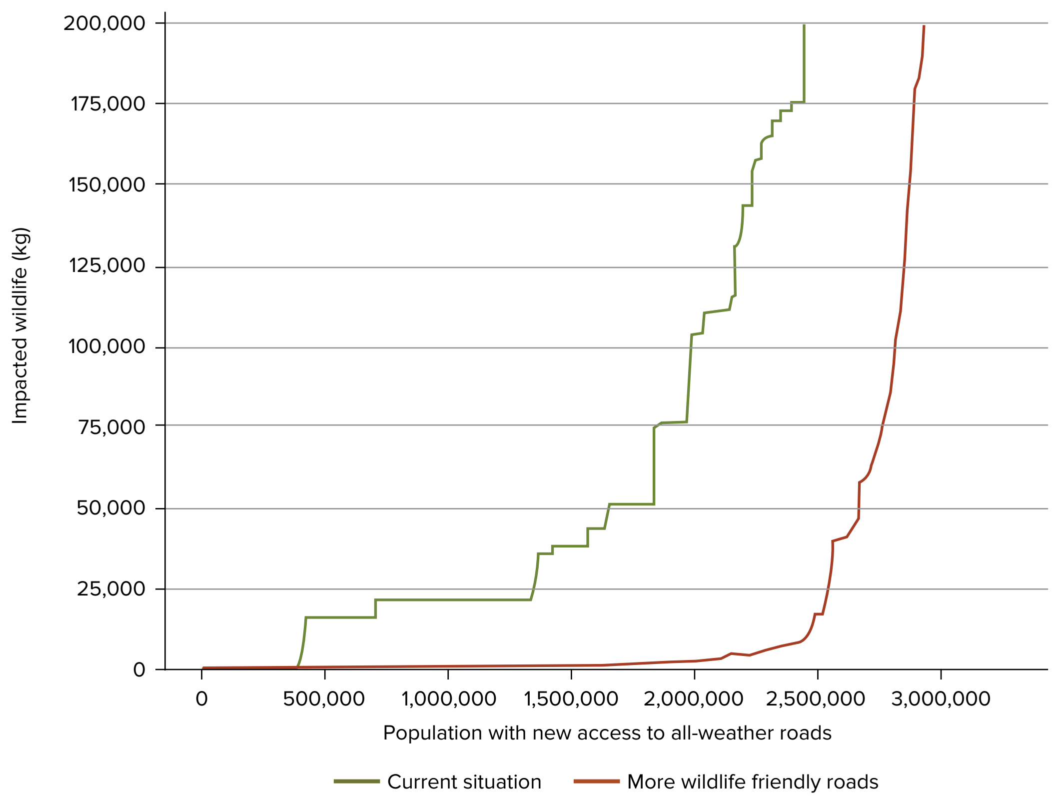
Using state-of-the art algorithms, this report finds that the judicious location of roads can connect much of the country to centers of economic activity while avoiding potential losses of wildlife. This is because much of Kenya's densely populated western counties require rural roads, but they are also areas with low levels of wildlife and tourism potential. Figure ES.5 illustrates one such example and shows that with sophisticated planning approaches, equivalent "connections" can be made with much more limited losses to wildlife (compare the green and orange lines) and at roughly the same cost.

In sum, deploying smarter, greener approaches to infrastructure also makes economic sense. Achieving this equilibrium will call for more sophisticated planning approaches that recognize both the benefits as well as the adverse impacts for both the economy and wildlife.

The promise of conservancies

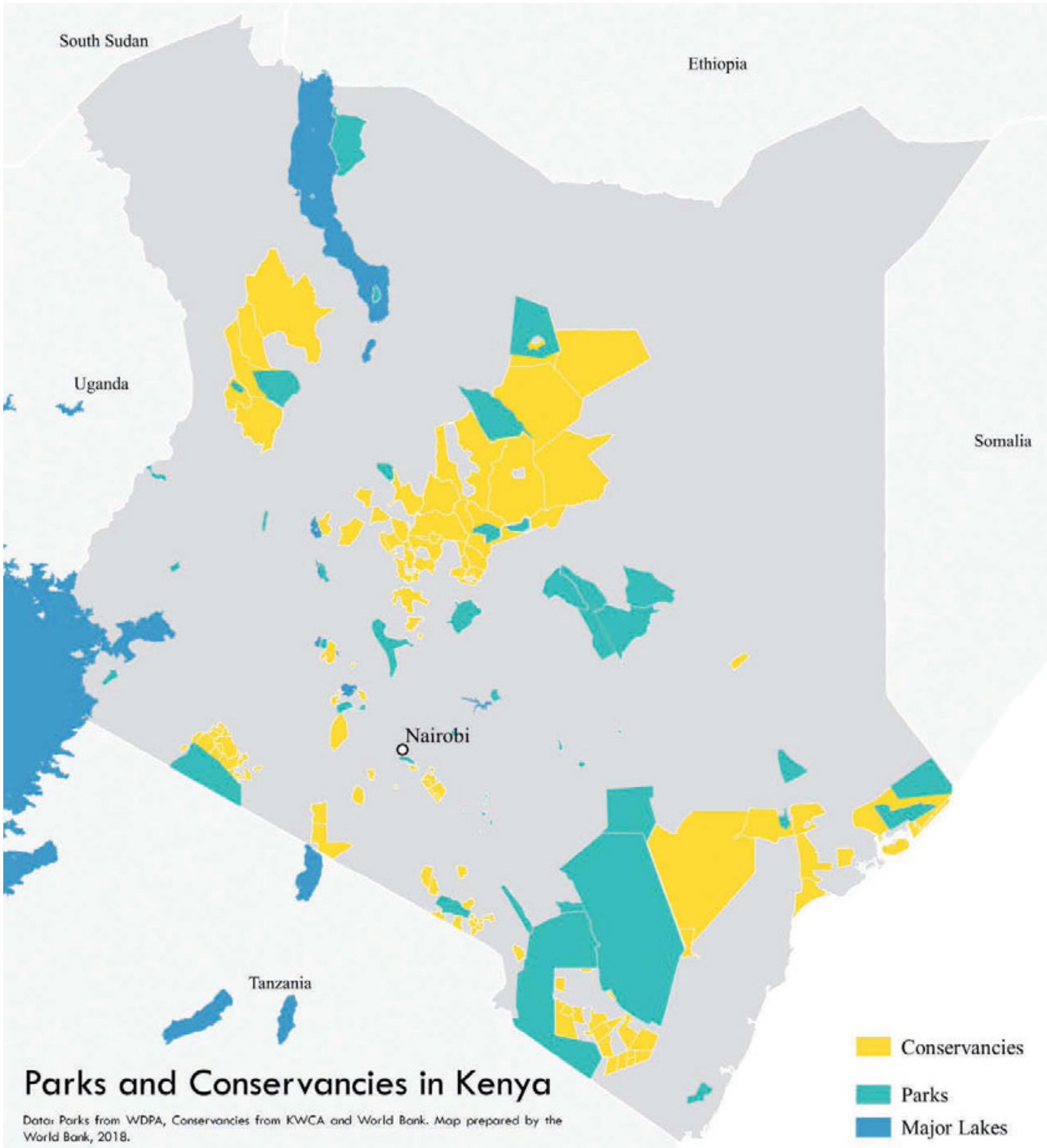
Conservancies can play an important role in diversifying the tourism product and securing critical habitats while generating economic activity. There are currently more than 166 conservancies spread across Kenya's 28 counties (Figure ES.6). They cover an area larger than the country's national parks, are home to more than 22 percent of Kenya's ungulate wildlife biomass, and have some of the highest densities of wildlife in the country. In fact, 18 out of the 20 zones with the highest density of wildlife are in conservancies and not parks. Conservancies create buffers around parks and maintain connectivity between several ecosystems. In essence, conservancies are key to the resilience of wildlife.

FIGURE ES.5: Factoring in wildlife constraints significantly reduces the impact of new roads on wildlife



Source: Authors.

FIGURE ES.6: A map of Kenya's conservancies and parks



Source: Authors.

Tourism remains an important revenue stream for conservancies, accounting for an average of 83 percent of commercial revenue. In many of the conservancies, tourism facilities were established to create an exclusive game viewing experience as an alternative to the mass tourism strategies in neighboring national parks and reserves. The game lodges in the conservancies account for about 16 percent of the total bed-nights spent in Kenyan game lodges, suggesting considerable scope for expansion. In remote areas, conservancies remain among the few ways in which communities can boost and diversify income sources.

The race between conservancies and construction

It is instructive to determine the economic benefits of alternative investment strategies in contexts when there are limited resources available for expansion. Using the CGE model, Table ES.1 provides an indication of the benefits

TABLE ES.1: Regional impacts of investing in conservancies and construction

	Invest in South		Invest in North	
Construction multiplier	1.51	0.88	0.1	1.53
Conservancy multiplier	3.02	0.22	1.75	4.41

Source: Authors.

that accrue from investing in a road in each region of the country, which is compared to investing in conservancies.

The table shows the payoffs from a road-building investment in the South. Each dollar invested in the South generates on average a GDP increase of $1.51 in the South and $0.8 in the North. An equivalent investment in the North has a similar multiplier effect, so that every dollar invested in the North has a payback of $1.53, but this time with a much smaller spillover to the South (.01).[2] The North has historically lagged in economic terms. The investment in tourism offers high payoffs with the promise of igniting economic activity in ways that also contribute to environmental sustainability in an arid area with geographic constraints. Realizing this promise will require enabling policies that provide access to conservancies and share the benefits with the population.

A similar investment in conservancies generates significantly higher multipliers—almost twice as high. This is a consequence of the important role that wildlife plays in the tourism value chain, with multiple direct and indirect connections to employment-generating activities in sectors that themselves have high multipliers, such as transportation and lodging.

Good conservation is good economics

A 70 percent decline in wildlife, within thirty years, is a sobering statistic. As Kenya's population grows, its infrastructure needs expand, and climate change makes rainfall more erratic; the pressures on wildlife and natural habitats will intensify in regions that are already under environmental stress and will spread to other parts of the country. The journey along the current policy path has failed to halt the degradation of natural habitats, and it is unlikely to do so in the future when pressures expand and competition for land, water, and other natural resources intensifies. This suggests an urgent need for a careful reassessment of pressures, policies, and future prospects.

Wildlife in Kenya, especially in the North of the country, represents a lucrative economic asset whose contribution has been underestimated and potential unrealized. Converting habitats and dissecting wildlife migration corridors diminishes populations, tourism appeal, and the earning potential of natural assets in ways that are often irreparable and irreversible. Given the significant and long-term implications of such decisions, a rigorous economic assessment is necessary to guide choices. The CGE assessment indicates that every dollar invested in conservation and wildlife tourism could generate benefits that range from $3 to $20, with returns that increase with the level of investment (Chapter 4). Such increasing returns reflect the ecological importance of connected natural habitats that are more productive in terms of the ecosystem services that they provide and are also more resilient to droughts and other weather extremes. With the right infrastructure and the enabling environment to further develop the conservancy sector, there are significant opportunities to enhance growth through the conservation of wildlife assets.

The evidence presented in this report suggests that there are wide opportunities to stop the dramatic collapse of wildlife populations and that investing in the tourism sector yields significant benefits which are especially pro-poor. The most pressing need is for planners to incorporate the tools developed in this report and elsewhere in order to consider the long-term implications of irreversible decisions and harness the full potential that the country's natural endowment offers.

REFERENCES

Ogutu, Joseph O., et al. (2016). "Extreme wildlife declines and concurrent increase in livestock numbers in Kenya: What are the causes?" PloS one 11.9.

Ojwang, Gordon O., et al. (2017). *Wildlife Migratory Corridors and Dispersal Areas: Kenya Rangelands and Coastal Terrestrial Ecosystems*.

Sanghi, Apurva, Richard Damania, Farah Manji, and Maria Paulina Mogollon. (2017). *Standing out from the herd: An economic assessment of tourism in Kenya (English)*. Washington, D.C., World Bank Group.

2 The magnitude of these multipliers is similar to global estimates.

CHAPTER 1

VANISHING HERDS: WILDLIFE DYNAMICS AND DRIVERS

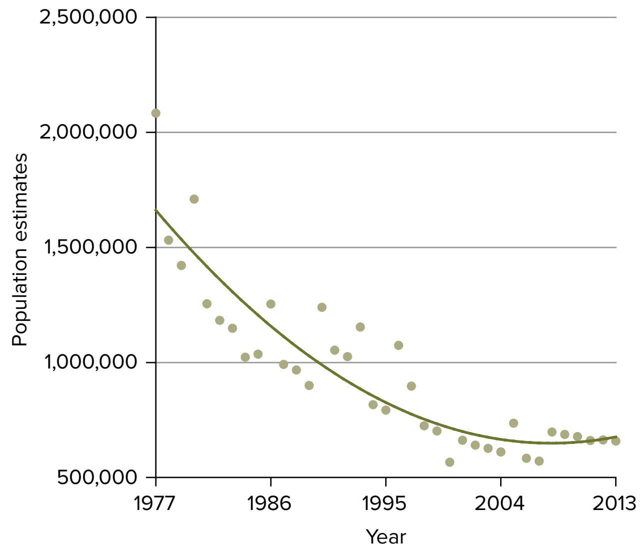
Wildlife, the principal asset of Kenya's tourism industry, is in rapid decline. To some this may be a necessary, if regrettable, price to pay for development and an expanding economy. For others, declining wildlife numbers are associated with costs, including lower tourism revenues, which could have been avoided with a less intrusive development trajectory. The aim of this report is to explore these issues using a suite of rigorous economic modeling approaches. The report combines statistical approaches to determine what has happened, with macroeconomic modeling to answer counterfactual questions regarding what might have happened with alternative policies.

The overall analysis suggests that the economic impacts of natural capital erosion have been significant, and they have received less policy attention than seems warranted since these issues are viewed as environmental problems that drain public funds, rather than an economic loss. The focus of this chapter is on tracking the changes and dynamics of Kenya's key tourism asset—its wildlife. Subsequent chapters explore the economic consequences of this loss and then turn to policy options. At the outset several caveats must be noted. First, due to insufficient data this report is narrowly focused on herds of (charismatic) mammals and thus ignores other species, as well as ecosystem productivity. In addition, the investigation is restricted to the measurable and pecuniary benefits generated by conservation through tourism. Consideration of the wider benefits (such as watersheds) conferred by ecosystems would suggest that the value of Kenya's wildlands are much higher than is suggested in this report.

A declining tourism asset

Globally, there is mounting evidence of catastrophic declines in the number and range of wildlife populations (Ceballos et al. 2017). Rapid human population growth, land use changes, land fragmentation, infrastructure development (Sala et al. 2000; EC 2001), poaching (WWF 2017), climate change (Wiens 2016), and other factors are among the long litany of reasons given for this rapid decline (Dybas 2009; Daskin and Pringle 2018; WWF 2017).

FIGURE 1.1: Kenya has lost 68 percent of its wildlife in recent decades

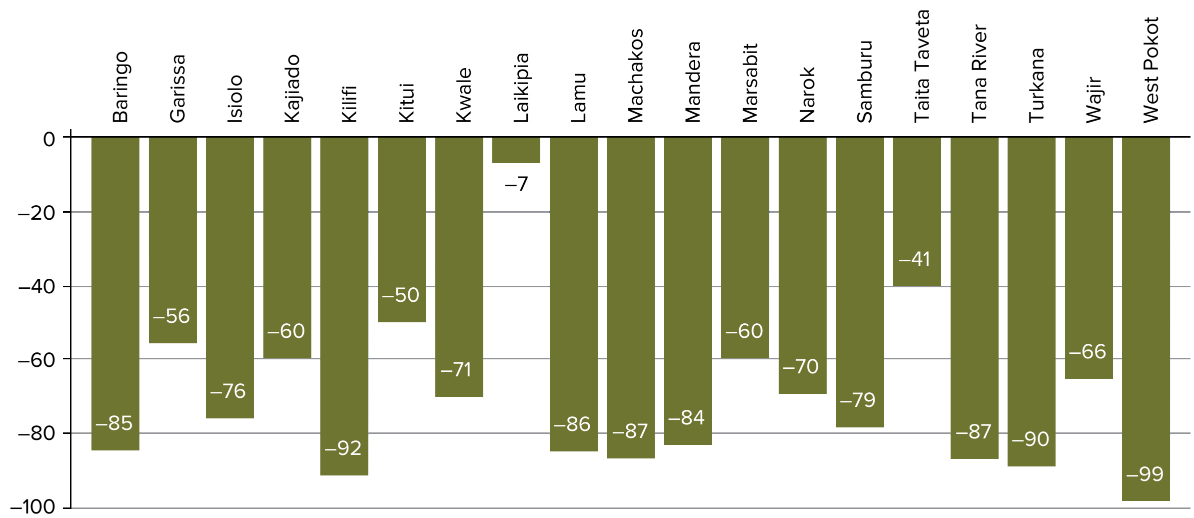


Source: DRSRS, Ogutu et al. (2016).

In Kenya, wildlife has declined precipitously across the country, and for certain species, this decline has been catastrophic. Within three decades, Kenya has lost 68 percent of its wildlife (Figure 1.1). The declines were particularly extreme with a wide cross-section of species that includes ungulates and predators.[3] As a consequence, in 2018,

3 To be precise the declines were: warthog (–87.7 percent), waterbuck (–87.8 percent), Grevy's zebra (86.3 percent), impala (–84.1 percent), Coke hartebeest (84 percent), topi (–82.1 percent), oryx (–78.4 percent), eland (–77.7 percent), Thomson's gazelle (–75 percent), and lesser kudu (–72.4 percent). The declines were also severe for Grant's gazelle (–69.6 percent), gerenuk (68.6 percent), giraffe (–66.8 percent), and wildebeest (–64.2 percent). In comparison ostrich (–43.4 percent), elephant (–42.3 percent) buffalo (–36.9 percent), and Burchell's zebra (29.5 percent) experienced moderate declines. Similar downward trends were exhibited by the big cats and other carnivores as their populations have also declined rapidly (Virani et al. 2011).

FIGURE 1.2: Wildlife trends in the 19 rangeland counties between 1977 and 2016 (percent)



Source: Authors based on Ogutu et al. (2016).

Kenya was ranked 5th in Africa in terms of the number of threatened species within its country (IUCN 2018).

The losses have occurred across the entire country, with some variation over the 19 counties. The highest decline was observed in West Pokot, which has experienced a total collapse, with 99 percent of its wildlife lost. The smallest decline of wildlife was observed in Laikipia, which experienced a 7 percent decrease in wildlife biomass (Figure 1.2). The three other major tourist-dependent counties of Narok, Kajiado, and Taita Taveta showed varying trends: Narok, despite its high dependence on wildlife-based tourism, has lost about 70 percent of its wildlife; in Kajiado, the decline stands at 60 percent; and Taita Taveta registered a moderate decrease of about 40 percent. This suggests that the presence of buoyant wildlife-based tourism in a county may not be sufficient to counter the forces behind the decline in wildlife. This also implies that there is a need for a deeper understanding of the drivers of wildlife loss to counter the problem.

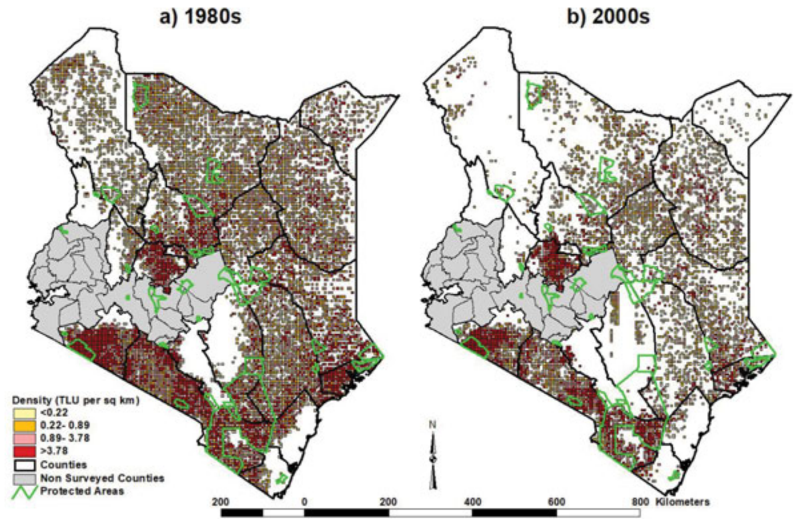
Data from the Department of Resource Surveys and Remote Sensing (DRSRS) provide a more precise indication of trends and drivers of change. DRSRS has conducted aerial surveys of wildlife in the rangelands of Kenya since 1977, offering a uniquely rich database of wildlife population trends at a fine spatial scale. Within each grid, wildlife populations for 18 common species are measured in terms of their biomass (calculated using the Tropical Livestock Unit (TLU) where 250 kilograms is equivalent to 1 TLU).[4]

The changes in the status of wildlife has been striking. In the 1980s, around 53 percent of the (5 × 5 kilometer) grids in the 19 counties were occupied by wildlife. By the 2000s, this had fallen to 31 percent of grid cells. Figure 1.3 provides a summary of these data and shows extirpation over large areas of the country. The distribution map of the 2000s indicates that the wild herds that once roamed freely across the country have shrunk dramatically in numbers and distribution, and have vanished in counties such as West Pokot, Turkana, Baringo, Kilifi, Lamu, Machakos, and Tana River. Once connected habitats have been severed and isolated, with herds trapped into shrinking areas, which affects their long-term sustainability (Said et al. 2016).

Perhaps more troubling is that recent monitoring efforts of key species suggest that the long-term decline of many of the charismatic species that attract tourists—including lions, elephants, giraffes, and impalas—are occurring at

4 Eighteen species were used in the analysis: buffalo (*Syncerus caffer*), Burchell's zebra (*Equus burchelli*), Coke hartebeest (*Alcelaphus buselaphus*), eland (*Taurotragus oryx*), elephant (*Loxodonta africana*), gerenuk (*Litocranius walleri*), giraffe (*Giraffa cemelopardalis*), Grant's gazelle (*Gazella granti*), Grevy's zebra (*Equus grevyi*), impala (*Aepyceros melampus*), lesser kudu (*Tragelaphus imbermbis*), oryx (*Oryx gazelle beisa*), ostrich (*Struthio camelus*), Thomson's gazelle (*Gazella thomsoni*), topi (*Damaliscus lunatus korrigum*), warthog (*Pharcoerus africanus*), waterbuck (*Kobus ellipsiprymnus*), and wildebeest (*Connochaetes taurinus*).

FIGURE 1.3: Kenya's wildlife populations have shrunk dramatically, becoming fragmented, and almost vanishing in some counties



Source: Authors based on DRSRS data.

comparable rates *within* and *outside* protected areas (Scholte 2011). This is consistent with a growing body of evidence in the conservation literature, which finds that the creation of protected areas does not necessarily mean that habitats and species are effectively protected (Andam et al. 2008), and that stricter rules on land use do not necessarily translate into less degradation (Ferraro et al. 2013).

Parks in Kenya were established in areas where large aggregations of animals were observed, typically during the dry seasons. However, in the process of establishing these protected areas, policy makers neglected the migratory needs of wildlife, especially the ungulate herds. Dispersal is a fundamental biological process that influences the distribution of biodiversity in every ecosystem and determines whether a species will survive. Among other things, the process of dispersing from a natal territory is essential to avoid inbreeding and strongly influences individual fitness. As a result, wildlife depends as much on adjacent land as it does on the protected areas for continued viability. Between 60–80 percent of the wildlife in Kenya is found outside protected areas (Grunblatt et al. 1996; Western et al. 2009).

Declining natural assets

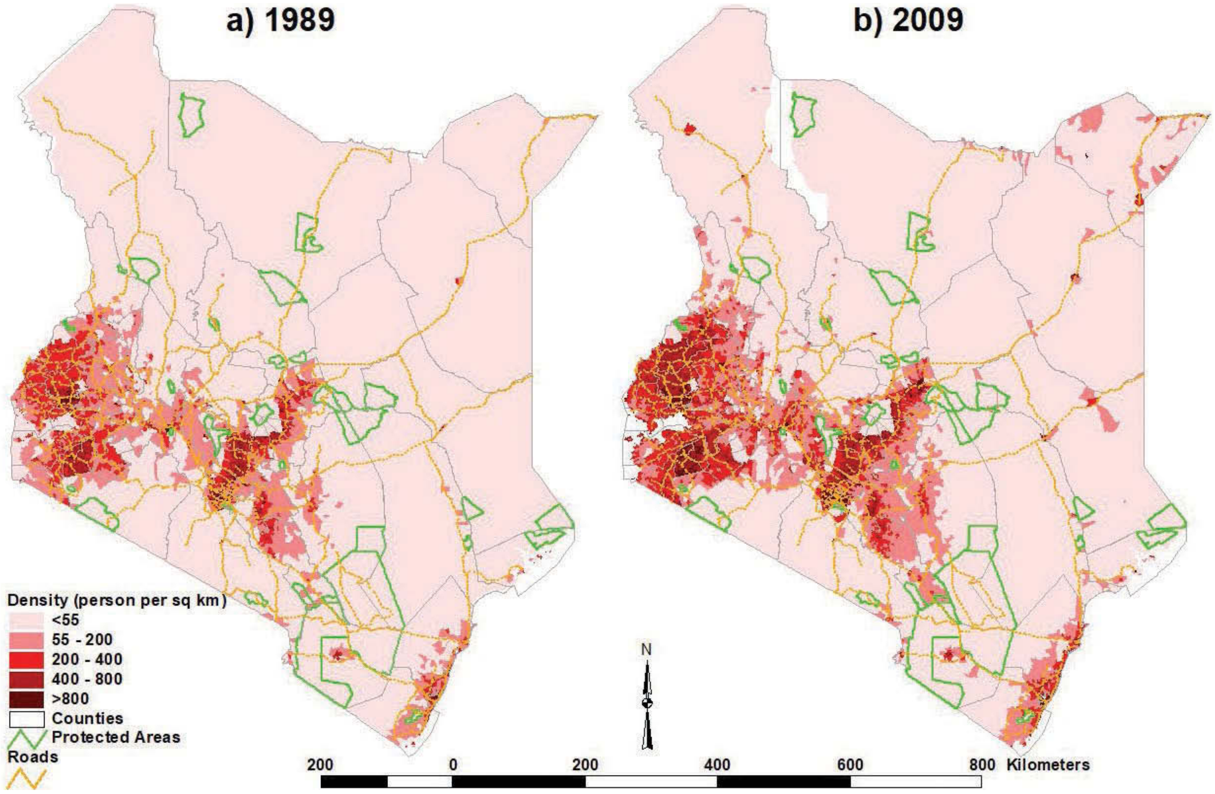
Reasons for the decline of Kenya's wildlife have been widely documented and involve an interconnected suite of pressures typically linked to habitat conversion. These include population growth (Kenya's population has grown more than sixfold since 1961), the expansion of arable agriculture, fencing, poaching, and intrusive infrastructure (Said et al. 2016) (Figure 1.4). This report expands upon this literature by providing quantitative estimates of some of the drivers of the loss of wildlife—something that, to our knowledge, has been done for the first time.

PAVING THE WAY

Roads are a formidable engine for growth and poverty reduction. They connect people to jobs, schools, markets, and hospitals. In rural areas, they improve market access for farmers, allowing them to sell their products at higher prices, thus raising incomes. Roads boost the development of commercial agriculture, aiding in the transition from subsistence to market economies. New roads also connect people to the rest of society, which creates a shared existence and builds a larger identity. For these reasons and more, increasing the rural road network is central to the Sustainable Development Goals (SDGs). Specifically, SDG indicator 9.1.1 encourages policy makers to increase the share of the rural population who live within 2 kilometers of an all-season road that is motorable all year round by the prevailing means of rural transport. In the relatively dry environment of Kenya, paved as well as improved roads can be considered as all-season roads.[5]

5 In countries with more wet conditions, it is often only paved roads that are considered to be all-weather roads.

FIGURE 1.4: Human populations have been expanding in areas with wildlife and around parks



Source: Authors based on Michelin and WorldPop data.

Indeed transport networks such as the railways have played a key part in the development of Kenya.

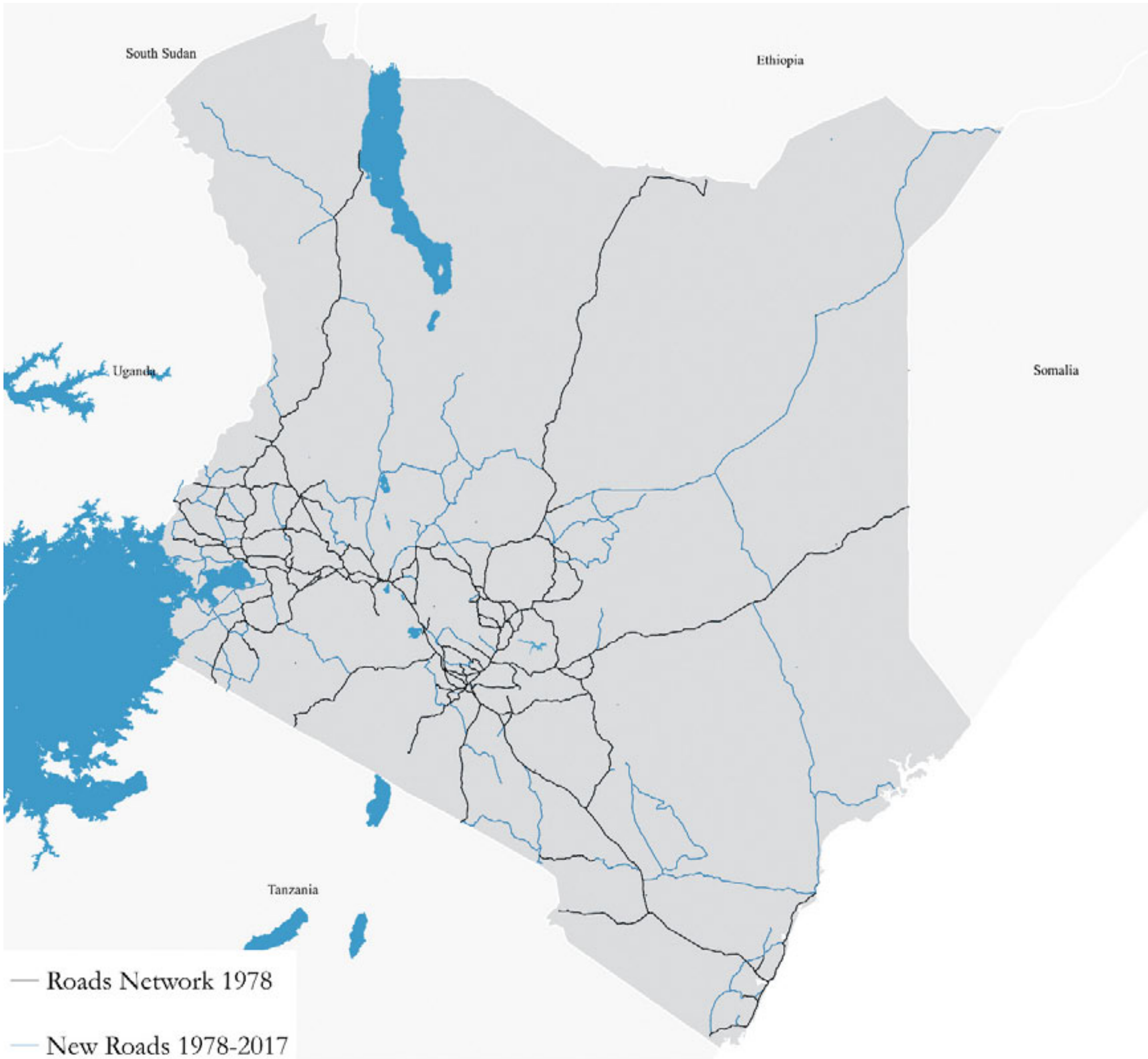
Kenya's road network has grown considerably over the last decades. Michelin maps of East Africa, dating back to 1978, were digitized to investigate the expansion and effects of roads. In 1978, there were around 7,000 kilometers of paved and improved roads (Figure 1.5), and the entire North of the country only featured improved gravel roads at this time. In the subsequent 40 years, Kenya's road network had increased by 50 percent to cover around 11,000 kilometers of improved and paved roads as of 2017. The network of roads has become denser in the South but has also been extended in the North to connect the major urban centers in the region, an example being the recent paving of roads leading to Marsabit and Turkana Counties.

Despite the significant and successful extension of Kenya's road network, the majority of the country's rural population continues to live more than 2 kilometers from an all-season road. Population growth has far outpaced efforts to connect the country's centers of agglomeration. By overlaying data from WorldPop, which provides estimates of population density at a precise spatial scale of about 1 kilometer, with the 2017 road network, an index of accessibility to roads can be derived. This index is termed the Rural Access Index (RAI) (Stevens et al. 2015). The results show that only about 28 percent of the rural population in Kenya lives within 2 kilometers from a road—an RAI that is comparable to most developing countries. Significant opportunities therefore exist to connect Kenya's rural population to the main network, and continued investments in road infrastructure may serve as a key lever to reducie poverty and promote inclusive growth. The challenge for the country is to achieve this in ways that do not diminish the economic value of its natural assets.

CONNECTIONS THAT DISCONNECT

While roads bring important benefits to people, there is a growing body of evidence suggesting that they may also generate significant environmental impacts, especially in areas with rich biodiversity. A large and rapidly expanding literature has documented the impact of roads on forest cover across countries as diverse as Brazil (Laurance

FIGURE 1.5: Kenya's road network has increased by 50 percent in the last 40 years



Data: Michelin Maps, digitized by the authors based on the DeLorme geometry. Roads include all-weather and improved roads.

et al. 2014); the Democratic Republic of Congo (DRC) (Damania et al. 2018); India (Asher et al. 2018); Indonesia, Tanzania (Arcus Foundation 2018); and at a global scale (Arcus Foundation 2018). Studies consistently find that the extension of roads into forested areas catalyzes deforestation or forest degradation, though the magnitude of impact differs considerably across countries.[6] This occurs not only through the direct clearing of vegetation to open up the road, but mainly from the indirect threats brought by people settling around the new roads, who now benefit from easier access to markets, which leads to the conversion of natural habitats into croplands. In the DRC, for example, a significant impact on deforestation is seen up to 2 kilometers from roads, and in Western Tanzania, the impact is seen even farther—deforestation even increased 20 to 30 kilometers away from the newly built Ilagala–Rukoma–Kashagulu Road (Asher et al. 2018). In general, the scale of habitat loss is determined by the incentives unleashed to expand cropland into natural habitats and the capacity to regulate these. There are likely other effects, such as the spread of invasive species, that are ignored in this report.

QUANTIFYING THE CAUSAL IMPACTS

In Kenya too, statistical analyses indicate that roads are a key part of this dynamic and have predictable effects

6 Asher et al. (2018) find no effect of local roads on deforestation in India, but a large impact of national roads on deforestation.

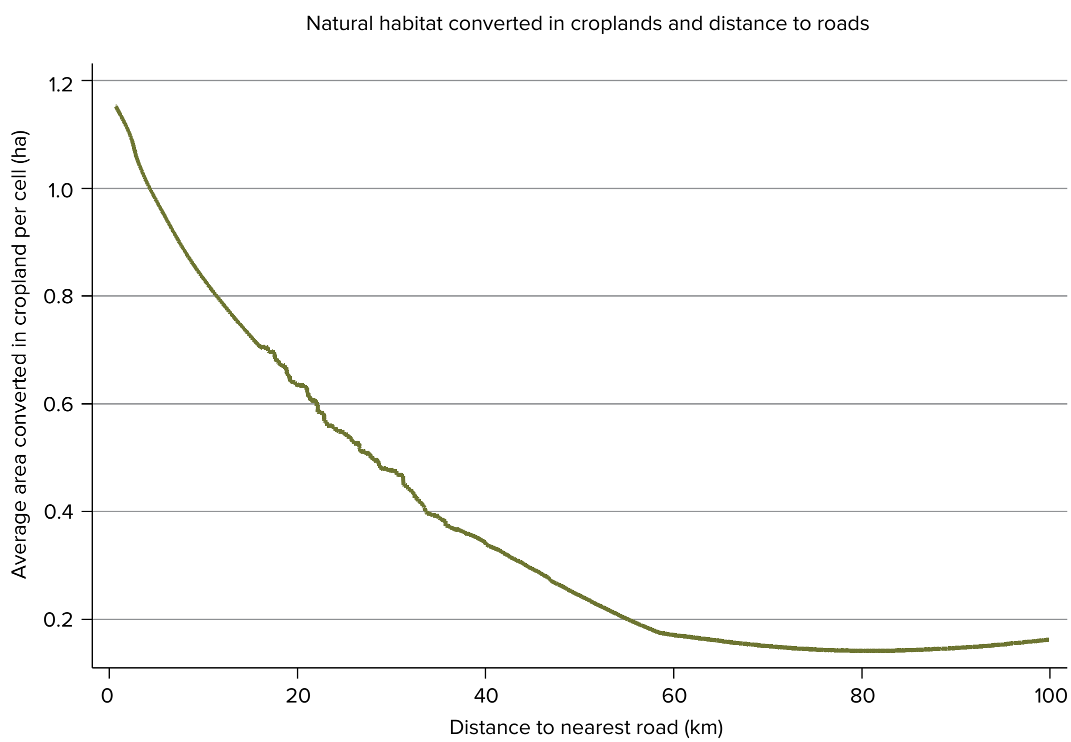
on wildlife and on migratory corridors. Because land use change is the primary driver of biodiversity loss, it is no surprise that the rate of wildlife loss in Kenya between the 1980s and the end of the 2000s was significantly faster in areas in close proximity to roads. Almost all wildlife corridors have been affected by land conversion, though the extent varies (Ojwang et al. 2017).

Nonparametric statistical models known as LOWESS regressions were used to investigate the causal links, if any, between natural habitat loss in Kenya and the distance to roads. The approach uses state-of-the-art statistical models to identify the causal impact of roads and isolate these from the confounding effects (Ali et al. 2015). The Euclidean distance between each grid cell and the nearest paved or improved road was calculated for each decade from the 1980s to the 2000s. These distances were then categorized into different bins depending on whether a cell was less than 5, 10, 15, 20, or 50 kilometers from a road.

Difference-in-differences models were used to estimate the change in wildlife biomass inside cells that, over time, came into closer proximity to a road (treatment) compared to those cells that remained farther away from a road (control). Simultaneity bias may be a significant threat when studying the impact of roads on wildlife since wildlife distribution and road placement are jointly determined. For example, new roads may be targeted for regions with expanding agricultural activity and land use, implying that these roads may be a response to activities that are already causing forest cover reduction. Difference-in-differences models combined with fixed effects are an effective method to overcome this challenge (Asher et al. 2018). The approach presents what may be the first causal estimates for Kenya by exploiting spatial location and timing—comparing rates of biodiversity loss of a cell that remains at a large distance from a road to one that was once a large distance away but has been brought close to the road. Time, cell, and other fixed effects control for other factors to address omitted variable bias and other problems. The full model is presented in Box 1.1.

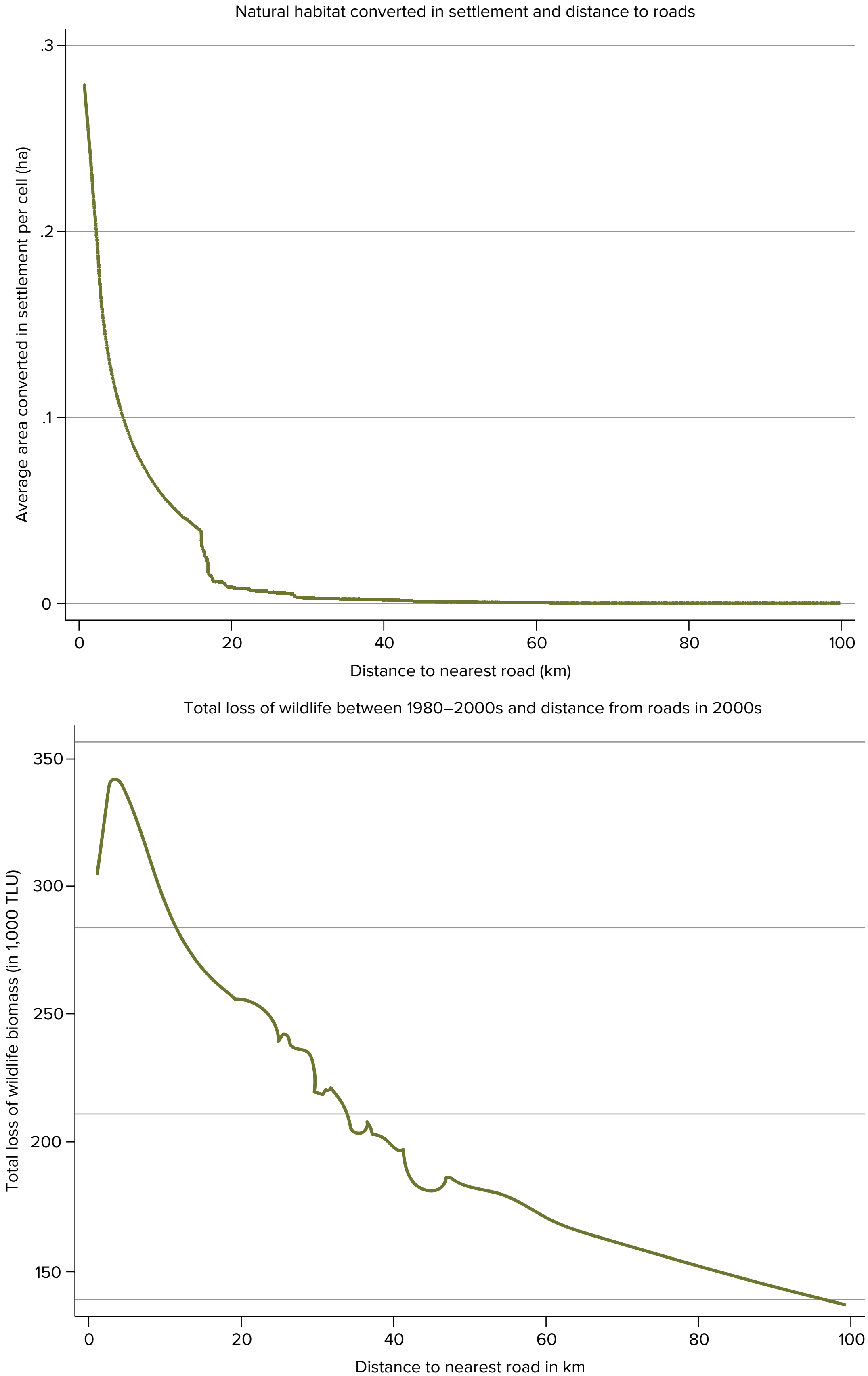
The results, illustrated in Figure 1.6, show that the closer a grid cell is to a road, the faster the conversion of natural habitat to cropland and settlements, which consequently has an impact on wildlife. Results from the statistical model consistently suggest that cells located within a 20-kilometer distance to a road are associated with a

FIGURE 1.6: Roads lead to changes in land use, impacting wildlife most severely within a distance of 20 kilometers



Source: Authors based on DRSRS, ESA, and Michelin data.

FIGURE 1.6: Continued



Source: Authors based on DRSRS, ESA, and Michelin data.

BOX 1.1: Building a Statistical Model to Quantify the Direct Impact of Roads on Wildlife

Data compiled by the Department of Resource Surveys and Remote Sensing (DRSRS) using aerial surveys in the rangelands of Kenya since 1977 cover 19 rangeland counties. The approach used for estimating impacts follows best practices. Kenya was divided into a grid of 10 × 10 kilometers, and for each cell, wildlife in the 1980s were identified in each pixel. Changes in wildlife measured in TLU were then determined for the 1990s and 2000s. In addition, the average distance between each grid cell and the nearest road between 1978 and 2010 was also determined.

A **"difference-in-differences"** specification is used to determine the impact of roads on wildlife loss. The model exploits the expansion of the road network in Kenya in the 1980s–90s. Between 1978 and 1992, the average distance of a cell's centroid from a road went from 55 km to 44 km (10% decrease).

Cells that were originally (1980s) far from a road (50–100 km) are kept in the analysis. Among these cells, the model looks at how the loss of wildlife differed between cells that became closer to a road (treatment groups, 5 km, 10 km, 15 km, 20 km, and 50 km) and cells that remained far from a road (control group, >50 km).

Roads here include both paved and improved roads. Formally, the model is:

$$Wildlife_{i,t} = \beta\ Cell\ Close\ from\ Road_{i,t} + \gamma Post_{i,t} + \omega Cell\ Close\ from\ Road * Post_{i,t} + \eta\ Protected\ Area_{i,t} + {}_i + \mu_t + \in_{i,t}$$

Where:

—$Wildlife_{i,t}$: Total biomass of wildlife in cell *i* during decade *t* (*t* = 1980, 1990, 2000).

—*Cell Close from Road* (Treatment): Whether the cell has become 5, 10, 15, or 20 km closer to a road during the period.

—Post: Dummy variable for post 1980s decade (i.e., once most cells became close to a road).

—Roads of the 1980s = roads observed in 1978; roads in the 1990s = roads observed in 1992; roads in the 2000s = roads observed in 2003.

—Additional controls: Dummy variable for the presence of a protected area in the cell, province × decade fixed effect.

—Clustered standard errors. Weights based on the area of each cell.

The methodology is further detailed in Appendix B.

TABLE 1.1: Quantifying the impact on wildlife of construction of a road (wildlife biomass)

Variables	Less than 5 km	Less than 10 km	Less than 15 km	Less than 20 km	Less than 50 km
Treated × post	–217.369* (121.325)	–185.138** (85.765)	–134.558* (79.109)	–114.494* (65.091)	–65.554 (44.057)
Post	–358.628*** (101.365)	–389.410*** (100.153)	–345.288*** (110.082)	–326.846*** (105.581)	–530.919*** (143.272)
Observations	2,586	2,730	2,868	3,027	4,029
Number of cells	862	910	956	1,009	1,343
Treatment	Road becomes <5 km	Road becomes <10 km	Road becomes <15 km	Road becomes <20 km	Road becomes <50 km
Control	Road 50 to 100 km from cell	Road 50 to 100 km from cell	Road 50 to 100 km from cell	Road 50 to 100 km from cell	Road 50 to 100 km from cell

Note: * = p<0.05, ** = p<0.01, *** = p<0.001.

BOX 1.2: Population Density and Wildlife Loss

The question of how population growth impacts natural habitats and wildlife is at the heart of policy debates, at least since Hardin's (1968) seminal assessment of the *Tragedy of the Commons*. While the *tragedy* can be avoided (Boserup 1965; Ostrom 1990), numerous studies have empirically established a correlation between population growth and environment degradation. Population growth was found to be associated with losses of both natural habitats such as forests and savannahs (Cropper and Griffiths 1994; Jha and Bawa 2006) and wildlife (Du Toit and Cumming 1999). Notably, these correlations were observed in East Africa and Kenya (Du Toit and Cumming 1999; Ogutu et al. 2011; Ogutu et al. 2016; Veldhuis et al. 2019), where demographic growth remains high today (2.4 percent annually in the Seregenti-Mara region (Veldhuis et al. 2019)).

Figures B.1.1 and B.1.2 illustrate the correlations that exist between population density and wildlife in Kenya using the data compiled for this report. Figure B.1.1 shows the correlation between ungulate wildlife biomass between 2000 and 2010, and total human population using 5 km × 5 km gridcells. It shows a negative correlation between ungulate wildlife density in the 2000s and human population. Indeed, in the 5 km × 5 km grid cells where human population is under 500 inhabitants, ungulate wildlife density is estimated at about 40 Tropical Livestock Units (TLU). However, in grid cells where human population reaches 4,000 inhabitants, almost no wildlife is found any more. Figure B.1.2 illustrates a dynamic. It plots the relationship between the rate of ungulate wildlife loss between the 1980s and the 2000s, and human population in the same grid. Once again, it shows that the rate of wildlife loss is positively correlated with human population: the more a grid cell is populated, the larger is the wildlife loss. The results in this section illustrate that for any given population density, the construction of a road will hasten and intensify the decline in wildlife.

A long list of economic literature highlights that the development of infrastructure—particularly roads, is a leading determinant of where population growth happens: people follow infrastructure since it offers economic opportunities. Therefore, the current choices made regarding infrastructure construction will have long-lasting impacts on the demography of the country, and consequently consequences on future wildlife trends. As demonstrated in the rest of this report, large room exists to build infrastructures in key economic areas and protect wildlife at the same time.

FIGURE B.1.1 Declining wildlife

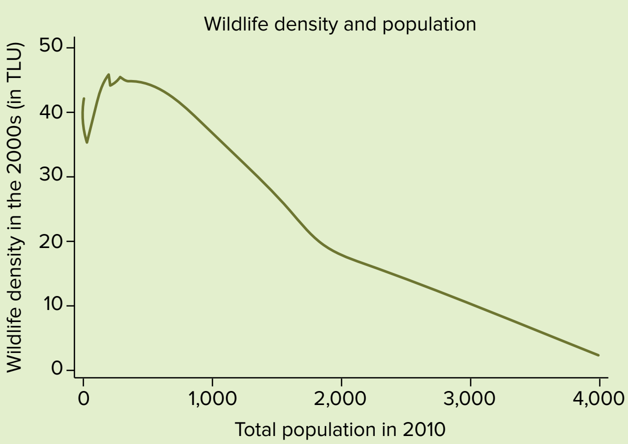
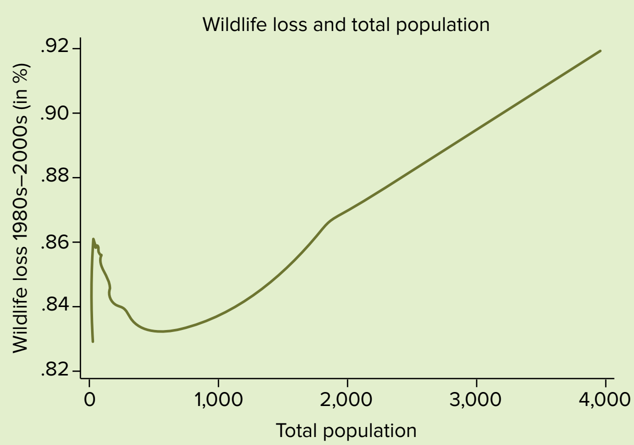


FIGURE B.1.2 Declining wildlife



significant decrease in wildlife following construction of the road, and the closer a cell is to a road, the larger the impact.

To be specific, the results in Table 1.1 suggest that a cell that was once 50 kilometers away from a road and that has been brought to within 5 kilometers of a road will have lost *an additional* 217 Tropical Livestock Units (TLUs) (or 54,250 kilograms of wildlife biomass) over a decade compared to cells that remained 50 kilometers from a road. Given that the average wildlife biomass in a cell between 1980 and 2009 was 266 TLU, the impact of roads has been significant. The estimates suggest that in the first 5 kilometers from a road, wildlife loss is the most severe, at 80 percent (217/266). Wildlife loss falls to 69 percent at a distance of 5 to 10 kilometers, 50 percent at a distance of 10 to 15 kilometers, and 40 percent at a 20-kilometer distance. Hence, even after 20 kilometers from a road, the impact remains ecologically significant though much smaller. Overall, and on average, a road results in a decline of 76 percent of wildlife biomass within a 20-kilometer radius.

Having identified the causal impact of roads on wildlife, it is necessary to determine if the resulting gains have outweighed the forgone losses of tourism revenue. An economic model of Kenya is used to answer this question in the next chapter, followed by a discussion of win-win solutions to these problems.

REFERENCES

Ali, Rubaba, et al. (2015). *Highways to success or byways to waste: Estimating the economic benefits of roads in Africa.* Washington DC: The World Bank.

Andam, Kwaw S., et al. (2008). "Measuring the Effectiveness of Protected Area Networks in Reducing Deforestation." *Proceedings of the National Academy of Sciences* 105.42.

Arcus Foundation. (2018). *State of the Apes: Infrastructure Development and Ape Conservation*, (Cambridge: Cambridge University Press—Chapter 3).

Asher, S., T. Garg, and P. M. Novosad. (2018). *The Ecological Impact of Transportation Infrastructure*. Washington DC: World Bank.

Boserup, Ester. (1965) *The conditions of agricultural growth: The economics of agrarian change under population pressure*.

Ceballos, G., P. R. Ehrlich, and R. Dirzo. (2017). "Biological Annihilation via the Ongoing Sixth Mass Extinction Signaled by Vertebrate Population Losses and Declines." *Proceedings of the National Academy of Sciences*. 114 (30).

Cropper, M., and Griffiths, C. (1994). The interaction of population growth and environmental quality. *The American Economic Review*, *84*(2), 250–254.

Damania, R., et al. (2018). "The Road to Growth: Measuring the Tradeoffs between Economic Growth and Ecological Destruction." *World Development* 101.

Daskin, J. H., and R. M. Pringle. (2018). "Warfare and Wildlife Declines in Africa Protected Areas." *Nature* 553, 328–332.

Du Toit, J. T., and Cumming, D. H. (1999). Functional significance of ungulate diversity in African savannas and the ecological implications of the spread of pastoralism. *Biodiversity & Conservation*, *8*(12), 1643–1661.

Dybas, C. L. (2009). "Infectious Diseases Subdue Serengeti Lions." *BioScience* 59, 8–13.

EC. (2001)."Biodiversity in Development." *Biodiversity Brief 8*.

Ferraro, Paul J., et al. (2013). "More Strictly Protected Areas are not Necessarily More Protective: Evidence from Bolivia, Costa Rica, Indonesia, and Thailand." *Environmental Research Letters* 8:2.

Grunblatt, J., M. Y. Said, and P. Wargute. (1996). *National Rangelands Report: Summary of Population Estimates of Wildlife and Livestock (1977–1994).* DRSRS, Ministry of Planning and National Development, Nairobi, Kenya.

Hardin, G. (1968). The tragedy of the commons. *Science*, *162*(3859), 1243–1248.

IUCN. (2018). "The IUCN Red List of Threatened Species." *Version 2018-2*: http://www.iucnredlist.org. Downloaded on 17 March 2019.

Laurance, W. F., et al. (2014). "A Global Strategy for Road Building." *Nature* 513.

Ogutu, J. O., Hans-P. Piepho, M. Y. Said, G. O. Ojwang, L. W. Njino, S. C. Kifugo, and P. W. Wargute. (2016). "Extreme Wildlife Declines and Concurrent Increase in Livestock Numbers in Kenya: What are the Causes?" *PLoS ONE* 11 (9).

Ogutu, J. O., Owen-Smith, N., Piepho, H. P., and Said, M. Y. (2011). Continuing wildlife population declines and range contraction in the Mara region of Kenya during 1977–2009. *Journal of Zoology*, *285*(2), 99–109.

Ojwang, Gordon O., et al. (2017). *Wildlife Migratory Corridors and Dispersal Areas: Kenya Rangelands and Coastal Terrestrial Ecosystems*.

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge University Press.

Said, M. Y., J. O. Ogutu, S. C. Kifugo, O. Makui, R. S. Reid, and J. de Leeuw. (2016). "Effects of Extreme Land Fragmentation on Wildlife and Livestock Population Abundance and Distribution." *Journal for Nature Conservation* 34: 151–164.

Sala, O. E., et al. (2000). "Global Biodiversity Scenarios for the Year 2100." *Science* 287 (5459), 1770–1774.

Scholte, P. (2011)."Towards Understanding Large Mammal Population Declines in Africa's Protected Areas: A West-Central African Perspective." *Tropical Conservation Science*.

Stevens, Forrest R., et al. (2015). "Disaggregating Census Data for Population Mapping Using Random Forests with Remotely-Sensed and Ancillary Data." *PLoS ONE* 10:2.

Veldhuis et al. (2019). *Science* 363, 1424–1428.

Virani, M., C. Kendall, P. Njoroge, and S. Thomsett. (2011). "Major Declines in the Abundance of Vultures and Other Scavenging Raptors in and around the Masai Mara Ecosystem, Kenya." *Biological Conservation*. 144, 746–752.

Western, D., S. Russell, and I. Cuthill. (2009). "The Status of Wildlife in Protected Areas Compared to Non-Protected Areas of Kenya." *PLoS One* 4.

Wiens, J. J. (2016). "Climate-related local extinctions are already widespread among plant and animal species." *PLoS Biology*, 14, e2001104.

WWF. (2017). *Poaching and Illegal Wildlife Trade*. WWF, Switzerland.

CHAPTER 2

WEIGHING THE IMPACTS: GENERATING SCENARIOS AND SIMULATING TRADE-OFFS

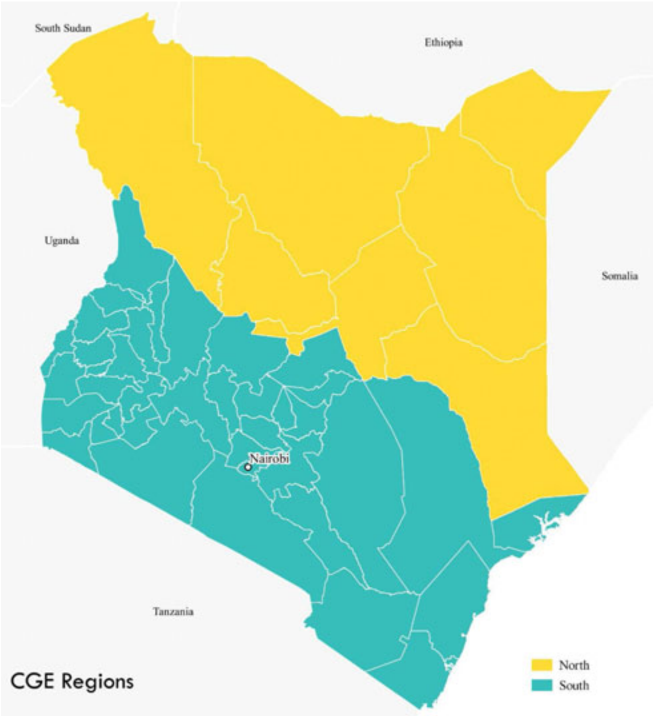
The aim of this chapter is to examine the economic consequences of the trade-offs that confront policy makers. While roads are necessary for development, they bring economic costs through the loss of tourism income. The magnitude of gains and losses involved is unknown, rendering policy choices difficult and questionable. This chapter attempts to provide answers to these far-reaching and difficult issues.

To do so, it relies on two analytical tools: a regional social accounting matrix (SAM) extended to a set of environmental accounts (environmentally-extended SAM or ESAM), and a computable general equilibrium (CGE) model. Consistent with the characteristics of a new generation of applied economic models (Perali and Scandizzo, 2018), SAM and ESAM provide a way of linking Kenya's national accounts to investment scenarios and policy changes in order to estimate impacts on growth, jobs, incomes, exports, and other key economic and social indicators, as well as environmental variables. While the ESAM provides the data for the exercise, the CGE is the engine (the model) that simulates impacts. It remains one of the most rigorous quantitative methods for generating economically consistent scenarios to evaluate the impact of economic and policy shocks. The model used for this report is an extension of an earlier model that was used to assess the economic impacts of tourism in Kenya (see Sanghi et al. 2017).

Developing a regional ESAM

The ESAM estimated for Kenya divides the country into two parts—the South and the North—as shown in Figure 2.1. It comprises 30 sectors for each region, and several environmental sectors and factors, as well as household types and institutional accounts (government, capital formation, and rest of the world). Details of the methodology and the estimates are contained in Appendix B, Scandizzo and Ferrarese (2015), and Sanghi et al. (2017).

FIGURE 2.1: Mapping the CGE regions for Kenya

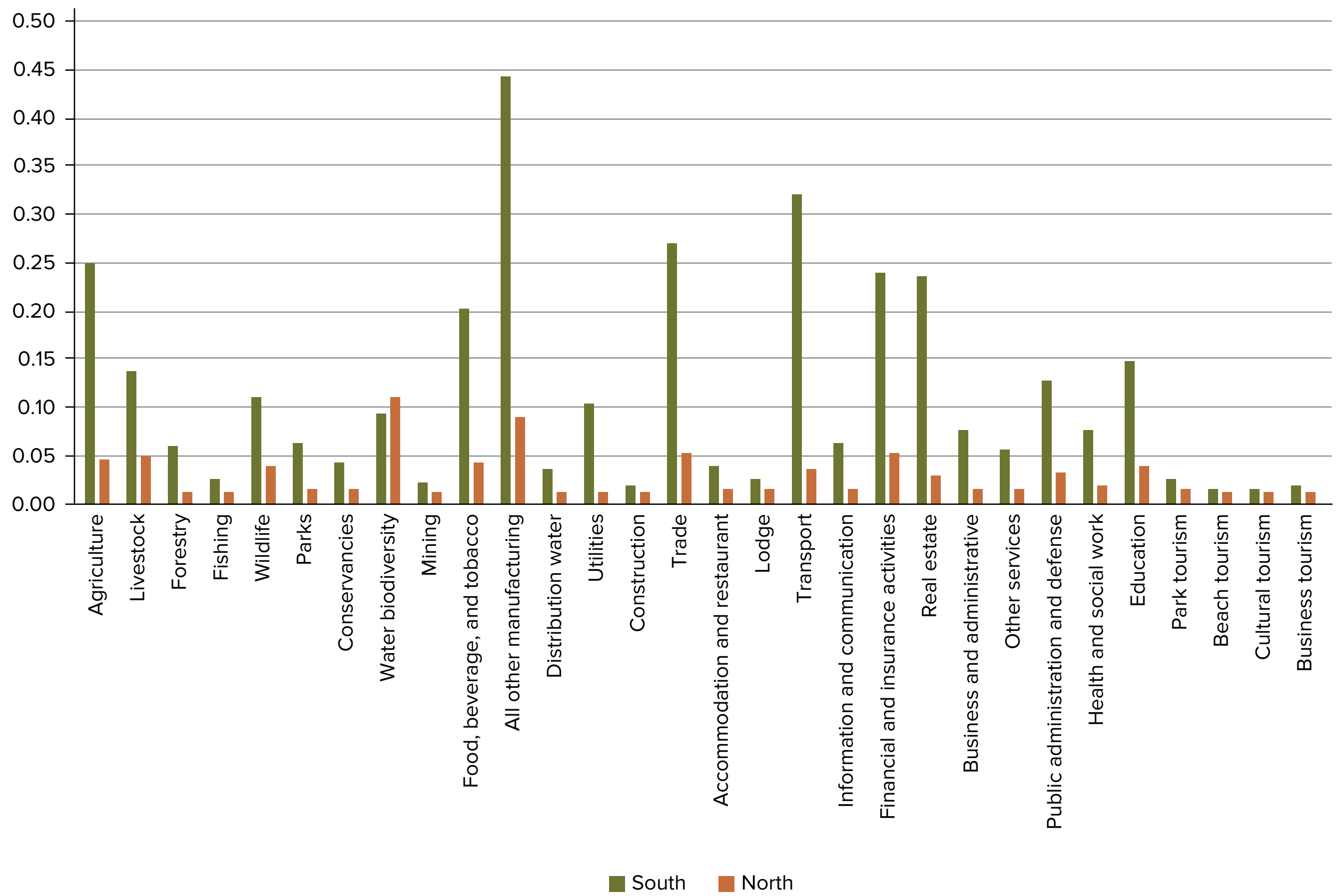


Source: Method developed by the World Bank.

The ESAM describes an economy with strong dualistic features, where the South is vastly more developed than the North, and where inter-sector linkages tend to reinforce a pattern of concentration of economic activities in the more advanced South. While the Southern value chains have depth, especially in agriculture and other land- and food-related activities, the region is still highly dependent on imports in the manufacturing sectors (Figures 2. 2 and 2.3).

To gain a better understanding of the structure of the economy, it is instructive to examine the multipliers in

FIGURE 2.2: Forward multipliers for productive sectors



Source: Elaboration of the Kenya SAM.

the model. In a CGE context, "forward" multipliers measure the degree to which a sector participates in an overall expansion (or contraction) of the economy, i.e., the increase required in the supply of one sector to meet a uniform increase of demand, spread over all sectors. Conversely, "backward" multipliers measure the degree to which a sector is capable of stimulating other sectors through an increase in the demand for inputs. A backward multiplier thus indicates the amount of output generated in an economy due to an exogenous increase in the demand in a given sector.

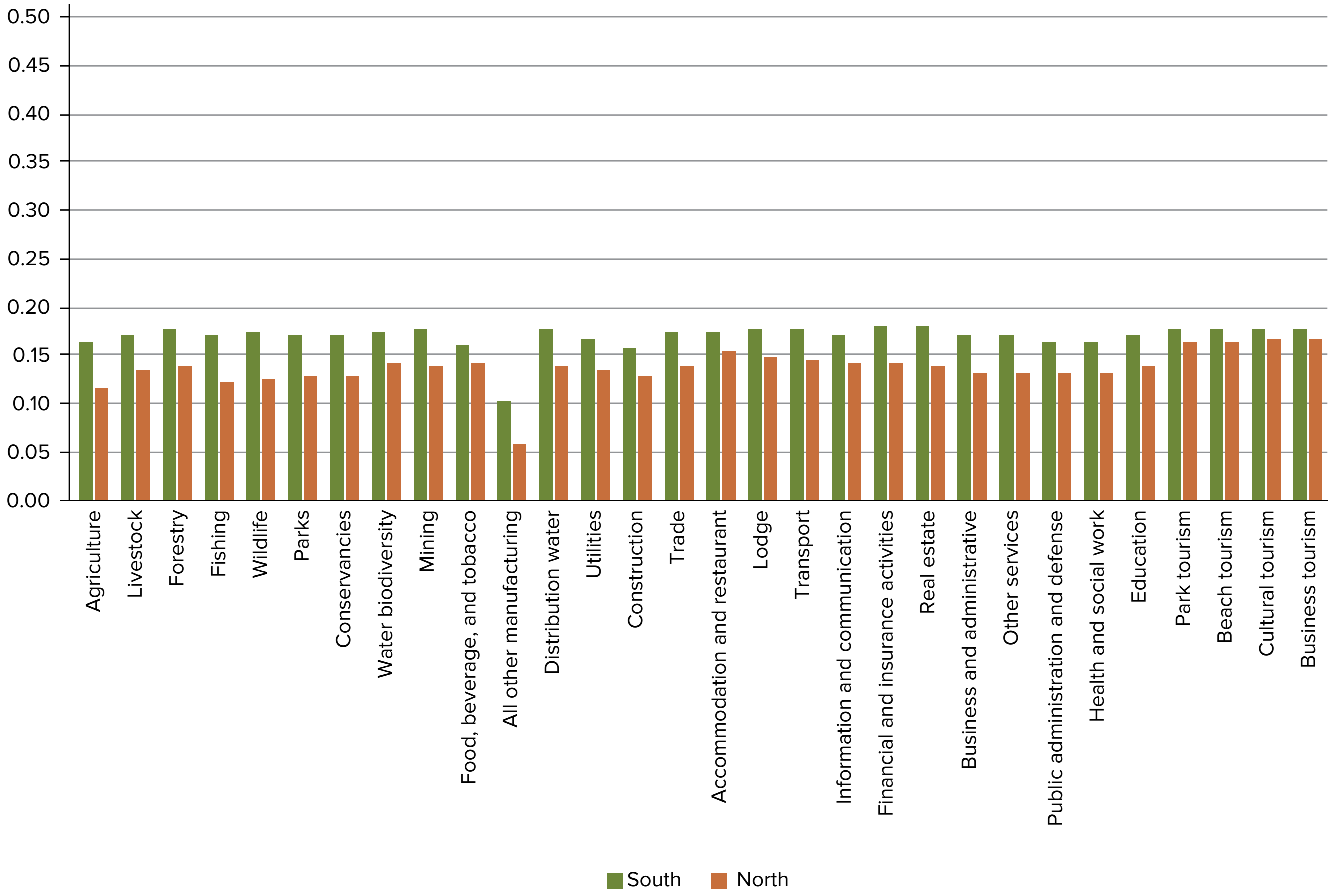
The multipliers tend to be comparatively larger in the more developed areas of the South, where forward multipliers are much larger in sectors such as agriculture, trade, transport, manufacturing, and financial services. Differences are smaller in natural resource–based sectors and ecotourism, reflecting the comparative advantage of the North. Backward multipliers are low in both regions, suggesting that value chains still lack overall depth and interconnectedness. However, backward multipliers in the South are without exception higher than in the North.

The CGE model

While the SAM multipliers may give a first approximation of the indirect effects of investment and other policy changes, they do not take into account the more complex secondary impacts on employment and prices. These effects are likely to be important when exploring economic changes of significance, such as a large investment or a policy shift. Box 2.1 provides an overview of the key assumptions of the CGE model.

Figure 2.4 illustrates the ability of the model to track the Kenyan economy. Model calibration achieves almost a perfect fit, except for the category of "all other manufacturing activities," which is a residual.

FIGURE 2.3: Backward multipliers for productive sectors



Source: Elaboration of the Kenya SAM.

BOX 2.1: Key Assumptions of the CGE Model

The CGE is built on the assumption of a "small economy," in the sense that the country cannot influence international prices of imported and exported goods. Each sector produces a composite commodity that can either be exported or produced for the domestic market. Each producer is assumed to maximize profits by producing one commodity, with labor, capital, land, and ecosystem services as primary inputs, according to a constant elasticity of substitution (CES) production function. The demand for intermediate inputs assumes fixed input-output coefficients, and the demand for primary factors is given by the first order condition for profit maximization using value added prices. Production is either for the domestic market in each region or for trade/exports with the other region or the international market according to a Constant Elasticity of Transformation (CET) function. Producers are assumed to maximize revenue from sales subject to the CET function. Export supply represents the first order condition and is a function of the elasticity of transformation and the relative export price with respect to domestic price. The allocation of imports and domestic production is determined according to the hypothesis that domestic and internationally traded goods are imperfect substitutes that are combined in a composite good according to a constant elasticity technology.

Aggregate domestic demand is divided into four components for both regions: consumption, intermediate demand, government, and investment, referring to both capital formation and natural capital formation. Following the SAM, four types of households are considered for each region according to their income threshold, and who receives income from production factors and enterprises, as well as who receives income in the form of remittances from abroad and transfers from the government. Households also pay taxes to the government and save a proportion of their incomes. Consumer expenditure is a function of prices and incomes according to a Linear Expenditure System (LES) that in its simpler version reduces to fixed expenditure shares and a Cobb-Douglas Utility function (Robinson et al. 1989). Households also spend their incomes to use natural capital, which is added to the expenditure function as an exogenous variable.

Intermediate sector demand, including the exchange between the two regions, is given by fixed input-output coefficients. Aggregate spending for government consumption is exogenously determined and defined in terms of fixed shares of aggregate government spending for goods and services. Part of government spending is also natural capital, which is added to the government expenditure function and exogenously determined. Sector capital investment is assumed to be allocated in fixed proportions among various sectors and is exogenously determined.

The rest of the world includes foreign and out-of-state tourists and is set exogenously. For the balance of trade, we adopt the hypothesis that this is set exogenously and the real exchange rate adjusts to achieve equilibrium. CET, Armington, and export elasticity parameters were taken from literature such as Hinojosa-Ojeda and Robinson (1991), Hanson et al. (1989), and Reinert and Shiells (1991).

Factors are assumed to be mobile across activities, available in fixed supply, and demanded by producers at market-clearing prices. Factor incomes are distributed on the basis of fixed shares (derived from base-year data) and transferred to the households. For the depletion of natural capital, an exogenous variable is added to the intermediate use of commodities in the supply-demand equation of final goods.

POLICY SIMULATIONS

The CGE model can be used to determine the effects of investment in different sectors by examining the multipliers and the overall impact on key economic variables of interest such as value added (GDP). Table 2.1 and Figure 2.5 show how the CGE multipliers vary with the size of the investment involved. The table shows the consequences of different levels of investment in three sectors—construction which proxies investment in roads, conservancies as an indicator of investment in wildlife tourism, and greater wildlife protection (such as anti-poaching patrols and habitat restoration and regeneration).

TABLE 2.1: CGE investment impact multipliers

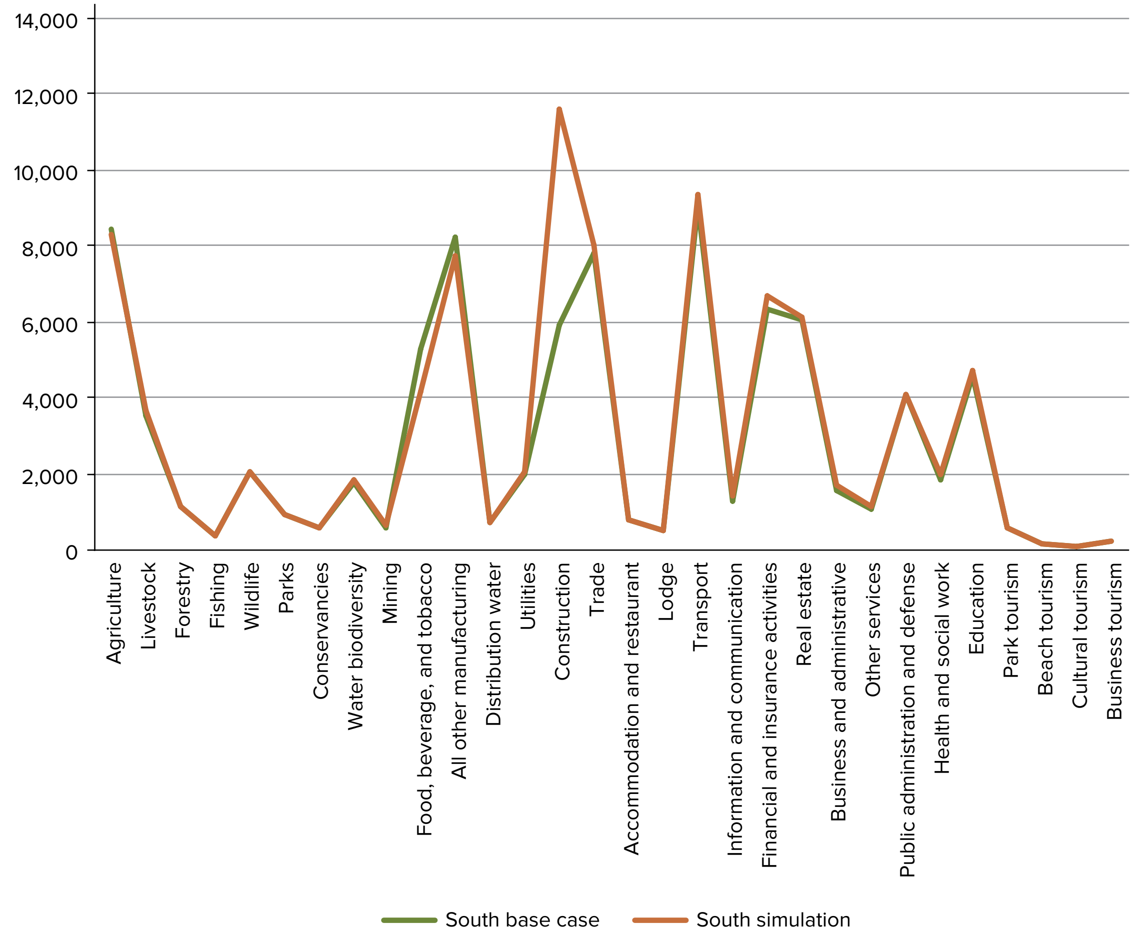
	Investment ($, millions)				
	10	50	100	500	1,000
Sector	Value added multipliers ($, millions)				
Construction	1.96	1.97	1.98	2.06	2.17
Conservancies	4.28	4.41	4.57	6.55	13.61
Wildlife	4.26	4.39	4.57	6.75	16.54

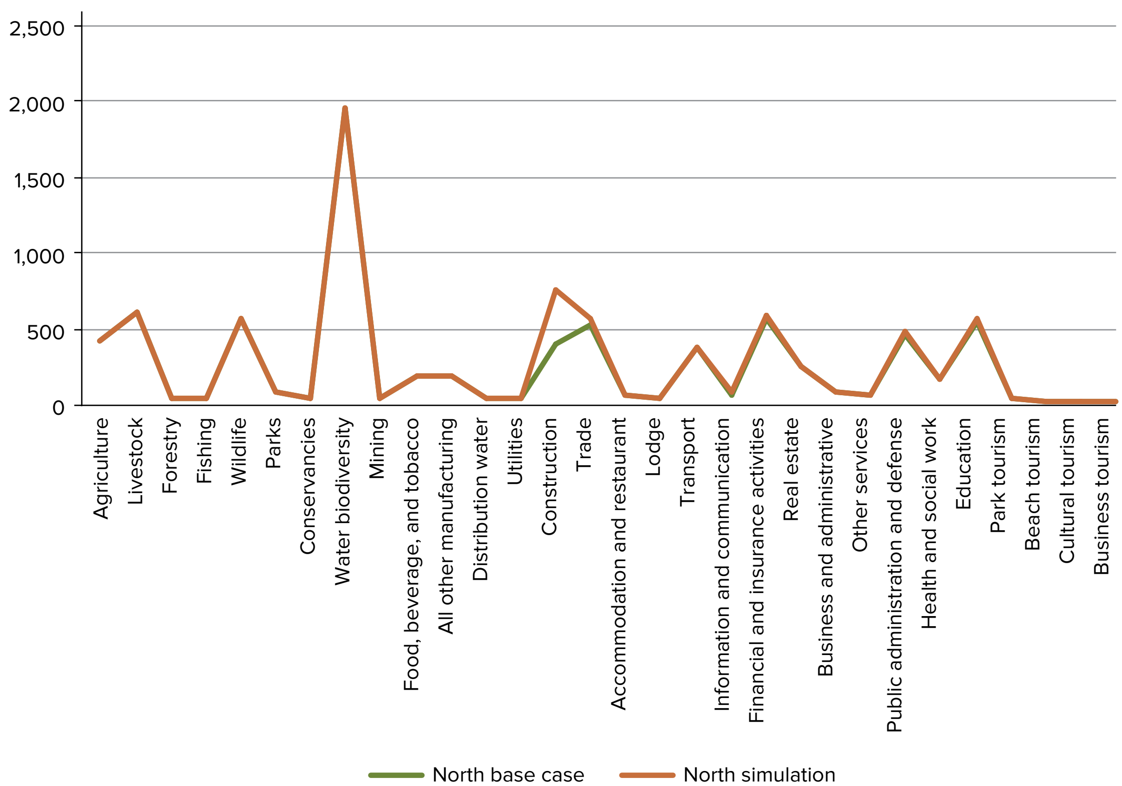
Source: Elaboration of the Kenya CGE model.

Three critical features of the Kenyan economy become evident. First, investment multipliers for construction appear to be linear (i.e., they do not vary with the scale of the investment). Second, the construction multipliers are *lower* than the multipliers associated with conservancies and wildlife conservation activities. This is due to the greater complexity and connectivity of tourism value chains and the complementarity of wildlife tourism with other sectors of the economy. Third, in contrast to the construction sector, conservation investments exhibit scale effects and increase with the amount invested. These effects emerge as a consequence of deeper linkages to other parts of the economy.

Table 2.2 shows the impact on value added of an investment in conservancies of the same magnitude in both regions. Since the regions are so different, with the South commanding most of the export trade compared to the North, an investment in the South has a high own-multiplier effect, but virtually no spillover effects to the North. Investment in the North, on the other hand, spills over into the South. Note too the high investment multiplier (4.41) in the North, which reflects the fact that investments in wildlife tourism in the North entail better utilization of the endowments of land and natural

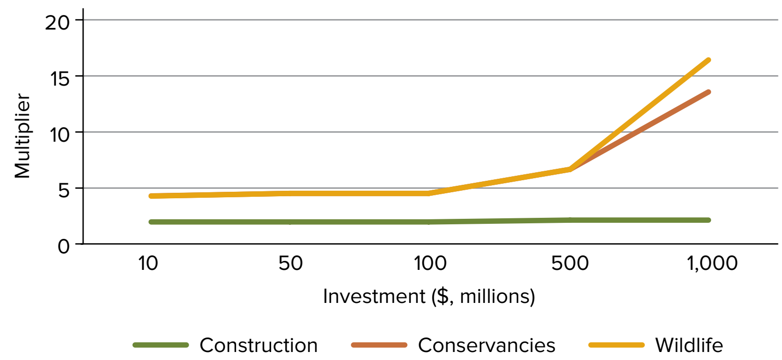
FIGURE 2.4: CGE model simulation for base-year production activities





Source: SAM base year data and CGE simqqlations.

FIGURE 2.5: Multipliers as a function of investment size



Source: Elaboration of the Kenya CGE model.

resources, which are relatively abundant in this part of the country.

Consider next an equivalent investment in roads in both regions. Using the econometric estimates from the previous chapter, it is assumed that this leads to an expansion in agricultural activity and a reduction in wildlife.

The absolute impact of investment in construction is higher when it occurs in the North. In percentage terms, however, unlike the case of conservancies, investment in construction has more balanced results when carried out in the South (Table 2.3). Even though the multipliers are smaller, they are significant in both regions. The size of the multiplier (about 1.5 in both cases) is similar to estimates obtained in other countries.

These results suggest that investment in conservancies and wildlife tourism display important scale effects. Investments in conservation and construction both appear to have higher potential in the North, where natural resources are more abundant and land is cheaper, and where induced tourist activity may spill over to the rest of the country through connections to the better developed southern value chain and infrastructure.

TABLE 2.2: Impacts of investment in conservancies (50% of current value = $142 million)

	Investment in the South (Region A)		Investment in the North (Region B)	
Value added components	**Impact on Region A ($, millions)**	**Impact on Region B ($, millions)**	**Impact on Region A ($, millions)**	**Impact on Region B ($, millions)**
Labor	100.12	8.73	96.49	102.95
Capital	120.26	13.34	114.53	175.50
Land	132.69	4.99	22.95	176.92
Other (eco) services	353.08	27.06	233.96	455.36
Total value added	**706.15**	**54.13**	**467.92**	**910.73**
	Investment in the South (Region A)		**Investment in the North (Region B)**	
Value added components	**Impact on Region A (%)**	**Impact on Region B (%)**	**Impact on Region A (%)**	**Impact on Region B (%)**
Labor	0.52	0.51	0.50	6.00
Capital	0.38	0.53	0.36	6.92
Land	2.62	0.56	0.45	20.00
Other (eco) services	6.69	0.64	1.25	25.30
Total value added	0.75	0.54	0.44	10.78
Investment multiplier	**3.02**	**0.22**	**1.75**	**4.41**

Source: Kenya CGE model.

TABLE 2.3: Impacts of investment in construction ($142 million)

Value added components	Investment in the South (Region A)		Investment in the North (Region B)	
	Impact on Region A ($, millions)	Impact on Region B ($, millions)	Impact on Region A ($, millions)	Impact on Region B ($, millions)
Labor	91.07	4.31	49.67	79.26
Capital	109.48	6.16	61.87	109.91
Land	11.41	2.02	9.82	15.88
Ecoservices	211.96	12.48	121.35	205.05
Total value added	**423.93**	**24.97**	**242.70**	**410.11**
Value added components	**Investment in the South (Region A)**		**Investment in the North (Region B)**	
	Impact on Region A (%)	**Impact on Region B (%)**	**Impact on Region A (%)**	**Impact on Region B (%)**
Labor	0.47	0.25	0.26	4.62
Capital	0.35	0.24	0.20	4.33
Land	0.23	0.23	0.19	1.80
Other (eco)services	0.25	0.22	0.31	1.89
Total value added	0.38	0.24	0.22	3.75
Investment mutiplier	**1.51**	**0.88**	**0.1**	**1.53**

Source: Elaboration of the Kenya CGE model.

Trade-offs between road construction and wildlife toursim

Having described the sector multipliers, this section turns to the central policy question—the trade-offs involved between road construction and investments in wildlife-based tourism. To gain a clearer understanding of likely effects and the sensitivity of results to key parameters, the simulations are based on a wide range of alternative scenarios. A variety of cases are considered regarding the sensitivity of tourism to wildlife loss.

The simulations explore the impact of an increase in investment in road construction on GDP and its components, assuming different demand elasticities and different rates of wildlife loss.[7] Clearly, the greater the sensitivity of tourist demand to wildlife loss, the greater will be the decline in demand resulting from wildlife declines. Likewise, a variety of cases are considered for the loss of wildlife from road construction (15 and 30, to 77 percent), depending on the amount and location of agricultural and livestock expansion. Included are the following three scenarios: (1) a 10 percent increase in investment in road construction and a 15 percent reduction in wildlife in the South; (2) high levels of reduction in wildlife in the South (30 to 77 percent) as a result of higher levels of road construction; and (3) combining conservation and infrastructure policies—capturing the elusive win-wins.

SCENARIO 1: A 10 percent increase in investment in road construction and a 15 percent reduction in wildlife in the South

The combination of a 10 percent increase in road construction and a 15 percent decrease in wildlife in the South has a positive impact on agriculture and livestock production but a generally negative impact on service activities in both the North and the South, but especially in the South. The fall in production is particularly large in the tourism sector.

The impact on value added in the South (Table 2.4) mainly occurs through land, whose demand rises because of the expansion of agriculture and trade. In the North, on the

7 The CGE model is calibrated using elasticities of substitution of CES production functions ranging from 0.6 (agriculture) to 1 (industry). CET functions for Armington hypothesis are also calibrated with a higher elasticity range (0.5 to 2) and elasticity of foreign tourism demand with respect to wildlife ranging from 0.3 to 1.5. The model is run with a Keynesian closure with labor supply perfectly elastic, capital mobile across each region, and wage as the numeraire.

TABLE 2.4: Impact on regional value added of an increase in infrastructure (+ 10%) and reduction in wildlife in the South (percent from baseline)

	South (Region A)		
	Wildlife (15%) Tourism demand elasticity = 1	Wildlife (15%) Tourism demand elasticity = 0.6	Wildlife (15%) Tourism demand elasticity = 0.3
Labor	3.71	3.81	3.90
Capital	3.41	3.49	3.57
Land	12.78	12.99	13.20
Ecoservices	–1.10	–0.80	–0.49
Total value added	**4.21**	**4.31**	**4.41**
	North (Region B)		
Labor	4.60	4.71	4.82
Capital	5.80	5.92	6.03
Land	4.74	4.89	5.03
Ecoservices	–3.36	–3.19	–3.03
Total value added	**4.39**	**4.51**	**4.63**

Source: Elaboration of the Kenya CGE model.

TABLE 2.5: Impact on regional income distribution of an increase in infrastructure and reduction in wildlife in the South (percent from baseline)

	South (Region A)		
	Wildlife (15%) Tourism demand elasticity = 1	Wildlife (15%) Tourism demand elasticity = 0.6	Wildlife (15%) Tourism demand elasticity = 0.3
Enterprises	3.41	3.49	3.57
Rural poor	5.37	5.49	5.61
Rural non-poor	5.30	5.42	5.54
Urban poor	3.46	3.55	3.64
Urban non-poor	3.44	3.53	3.62
	North (Region B)		
Enterprises	5.80	5.92	6.03
Rural poor	3.95	4.06	4.17
Rural non-poor	4.00	4.11	4.22
Urban poor	4.21	4.31	4.42
Urban non-poor	3.84	3.94	4.03

Source: Elaboration of the Kenya CGE model.

other hand, income increases across all factors of production. In both regions, multipliers are high, indicating both direct and indirect effects of the same orders of magnitude and large spillovers from backward linkages. The results suggest an overall improvement across most sectors of the economy, despite the loss of tourism income.

In conclusion, when the decline in wildlife and tourism demand elasticity is moderate, there is an overall increase in value added (GDP), with the decrease in the tourism value chain being compensated by the increase in value added in other parts of the economy. It is also useful to note that the poor in both rural and urban areas benefit equitably in this scenario. In this case, it pays to deplete the natural assets that attract tourists, since the gains from other sources of income outweigh the losses.

SCENARIO 2: High levels of reduction in wildlife in the South (30 to 77 percent) as a result of higher levels of road construction

A second set of simulations investigates the same investment in road construction but with higher impacts on wildlife in the South, involving reductions of wildlife biomass 30 to 77 percent in both regions. Elasticities of tourism demand with respect to wildlife are also assumed to be higher, ranging from 1 to 1.5.

In both regions there is a general boost to the economy in the agricultural and construction sectors. But in all cases considered, this is insufficient to compensate for the fall in production that is catalyzed by the near collapse of the wildlife tourism industry and its value chain. Moreover, since these effects are the result of spillovers from the South, the multiplier effects are similar in both regions, with only a slight tendency for the North to compensate with its larger and cheaper supply of land and labor.

In terms of value added however, differences emerge across regions and scenarios (Table 2.6) where the South benefits and the North contracts. In the first two scenarios where wildlife is assumed to decrease 30 percent, total value added in the South increases. In the North, however, land incomes fall in response to the higher supply of more accessible and fertile lands in the South, and value added is reduced. This is a scenario in which more amenable conditions in the South "crowds out" economic activity from the North.

The third and fourth columns explore scenarios with higher rates of wildlife reduction (assumed to be 70 percent according to recent trends in areas close to roads). In this scenario both regional economies suffer, with negative value added changes being especially large in the North. The losses accruing from the decline in tourism revenue and the associated value chain outweigh any gains that a road might bring. What is especially striking is the magnitude of the loss in the North relative to the South, reflecting the different comparative advantages of the two regions.

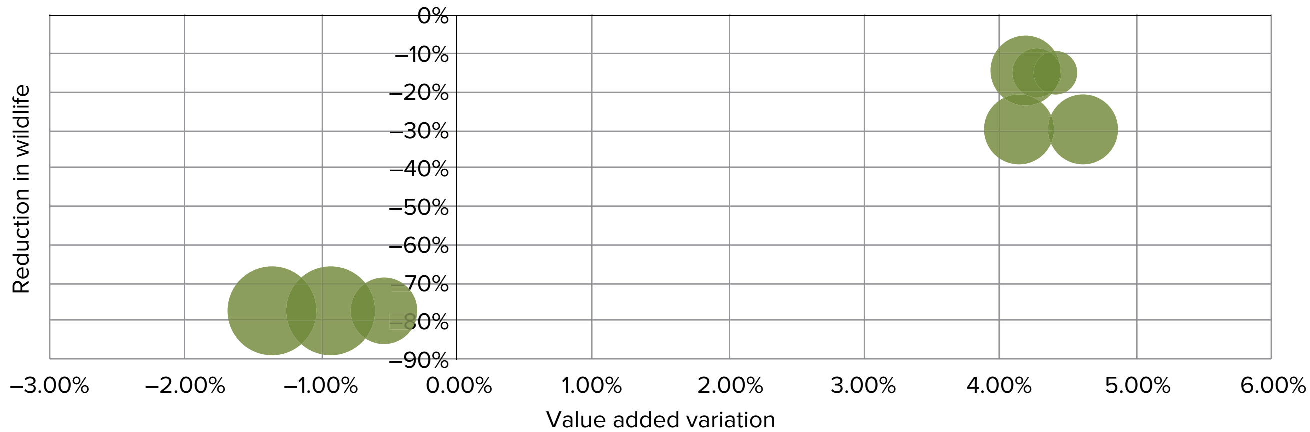
The value added effects bring to light a central discontinuity in the response of the economy, which is illustrated in Figure 2.6. In this diagram, the size of the balls represent the assumed elasticity of tourism demand with respect to wildlife, while the horizontal and vertical axes measure the changes in value added and the reduction

TABLE 2.6: Impact on regional value added of an increase in investment in road construction (+10%) and greater reduction in wildlife in the South (percent from baseline)

	Wildlife (30%) Tourism demand elasticity = 1	Wildlife (30%) Tourism demand elasticity = 1.5	Wildlife (77%) Tourism demand elasticity = 1	Wildlife (77%) Tourism demand elasticity = 1.5
South (Region A)				
Labor	4.13	3.76	–0.05	–0.52
Capital	4.50	4.17	1.21	0.80
Land	10.35	9.63	–5.69	–6.54
Ecoservices	–9.18	–10.07	–34.63	–35.66
Total value added	**4.62**	**4.23**	**–0.54**	**–1.02**
North (Region B)				
Labor	1.52	1.13	–8.83	–9.30
Capital	2.55	2.14	–8.82	–9.29
Land	–5.28	–5.75	–30.15	–30.62
Ecoservices	–15.73	–16.22	–44.78	–45.25
Total value added	**–1.08**	**–1.50**	**–16.26**	**–16.73**

Source: Elaboration of the Kenya CGE model.

FIGURE 2.6: Value added variation in regard to wildlife reduction and tourism elasticity



Source: Kenya CGE model.

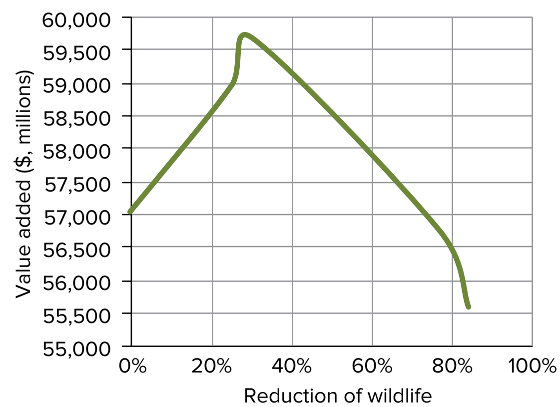
in wildlife, respectively. The diagram shows that outcomes cluster around two key points: (1) a moderate level of reduction of wildlife with low tourism elasticity and an associated increase in value added, and (2) a high level of reduction of wildlife, with an associated fall in value added.

To summarize, the simulations suggest that when the decline in wildlife is modest (less than around 30 percent), then the benefits of construction investments outweigh the losses brought by a decline in tourism and its value chain. The North is more vulnerable to the adverse impacts due to limited alternative forms of economic activity. But when the decline is large (≈ 70%), there is a fundamental shift in the balance of costs and benefits. In this case the loss of income associated with the panoply of wildlife tourism–related value chains, outweighs the benefits from improved access from road investments.

While it may be objected that these are hypothetical simulations, the estimates are based on observed magnitudes, suggesting these results are a cause for policy consideration. Box 2.2 provides a more detailed explanation of these results in the context of a production possibility frontier.

Figure 2.7 shows the relationship between wildlife reduction and GDP emerging from these model solutions, with a general equilibrium frontier exhibiting an inverted "U" shape pattern. The figure represents a production possibility frontier. It shows that when construction induces declines in wildlife that are relatively modest and less than around 30 percent, then there is a net economic

FIGURE 2.7: Relationships between wildlife reduction and value added, and value added growth



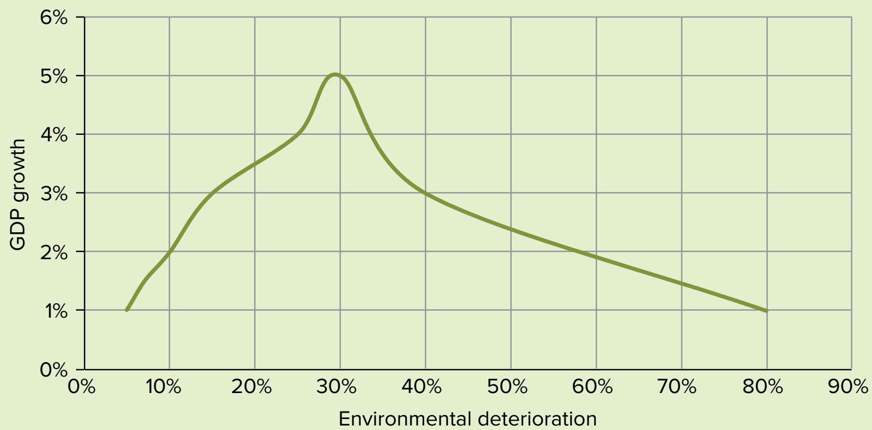
Source: Elaboration of the Kenya CGE model.

gain with value added increasing. Beyond this threshold, further declines in wildlife induce net losses of value added. The current magnitude of wildlife loss across much of the country suggests that Kenya is on the

BOX 2.2: Trade-offs between Economic Growth and Environmental Impact

The CGE model summarizes an economy-wide equilibrium outcome that is termed a "general equilibrium" (GE). The results of the model can be used to define the outcome and trade-offs between economic growth and ecological effects. The curve in Figure B.2.1 summarizes the outcomes of the simulations conducted in this exercise. It shows that at low levels of environmental impact, growth rises with environmental deterioration but it then reaches a turning point and begins to decline after around a 30 percent loss of wildlife.

FIGURE B2.1: Impact on environmental deterioration against GDP growth



This curve in fact represents an efficiency frontier, in the sense that it bounds a feasible set of growth rates and degrees of environmental deterioration (ED). Points below the curve are both feasible and ***inefficient.*** In the first part, for example, a combination of 3 percent GDP growth and 20 percent ED could be improved upon by increasing growth at the same level of ED or by reducing ED and maintaining the same level of growth. In the second part of the curve, this would also be possible by exploiting the two branches of the curve. For example, the combination of 1 percent growth and 60 percent ED could be improved upon by increasing growth up to the declining branch with the same amount of ED, or by decreasing ED with the same amount of growth by moving to the increasing branch of the curve. The latter case, however, would signal a much larger inefficiency than the former one.

More generally, the non-monotonic relationship between economic and ecological outcomes, popularized as the Kutznets curve, suggests that growth-depressing feedback may indefinitely prolong the negative relationship between development, inequality, and a deteriorating environment. For example, the limits theory (Arrow et al. 2013) defines the economy-environment relationship in terms of environmental damage hitting a threshold beyond which production is so badly affected that the economy shrinks. The so-called new toxics view claims that emissions of existing pollutants are decreasing with economic growth, but the new pollutants substituting for them increase with growth. In fact, consistent with the new toxics hypothesis, the U.S. EPA claims that it receives premanufacturing notices to approve over 1,000 new chemicals each year.

declining portion of this frontier. This is a region where good conservation becomes good economics.

The impact on income distribution reflects, to an extent, the changes in value added, and is also highly asymmetric across regions and income groups (Table 2.7). In spite of the surge in agriculture in all scenarios, the rural poor appear to be the population group most disadvantaged by the negative effects on the tourism industry, especially in the North. This is unsurprising as the evidence on conservancies presented in Chapter 5 suggests that wildlife tourism provides employment to sections of the labor market with low levels of human capital and few fungible skills.

TABLE 2.7: Impact on income distribution of an increase in infrastructure and a greater reduction in wildlife in the South (percent from baseline)

	Wildlife (30%) Tourism demand elasticity = 1	Wildlife (30%) Tourism demand elasticity = 1.5	Wildlife (77%) Tourism demand elasticity = 1	Wildlife (77%) Tourism demand elasticity = 1.5
South (Region A)				
Enterprises	4.50	4.17	1.21	0.80
Rural poor	5.24	4.80	–1.79	–2.33
Rural non-poor	5.25	4.81	–1.60	–2.14
Urban poor	4.07	3.71	0.07	–0.38
Urban non-poor	3.97	3.61	–0.22	–0.66
Government	4.51	4.15	–0.92	–1.37
North (Region B)				
Enterprises	2.55	2.14	–8.82	–9.29
Rural poor	–0.15	–0.53	–12.68	–13.11
Rural non-poor	0.00	–0.38	–12.36	–12.80
Urban poor	1.77	1.38	–7.45	–7.88
Urban non-poor	1.78	1.43	–6.58	–6.99

Source: Elaboration of the Kenya CGE model.

TABLE 2.8: Doubling the investment in conservancies: impact on value added

Value added ($, millions)	South (Region A)		North (Region B)		% change	
	Base case	Simulation	Base case	Simulation	Region A	Region B
Labor	19,324.90	19,500.00	1,764.40	1,764.90	0.9	0.0
Capital	31,278.20	31,497.90	2,607.40	2,634.20	0.7	1.0
Land	5,163.20	5,292.00	895.40	911.30	2.5	1.8
Ecoservices	1,214.00	1,289.30	700.30	701.90	6.2	0.2

Source: Elaboration of the Kenya CGE model.

SCENARIO 3: Combining conservation and infrastructure policies—capturing the elusive win-wins

A third set of simulations assesses the possible consequences of win-win policies, i.e., policies aimed at increasing (doubling) investment by targeting both environmental preservation and efficiencies. For this purpose, three components of possible investment policies were analyzed: (i) expanding conservancies, (ii) preserving wildlife, and (iii) increasing productivity through "smart" infrastructure of the kind described in the next chapter.

As Tables 2.8 and 2.9 show, doubling the investment in conservancies has an overall positive effect (investment multiplier = 1.9 in terms of total value added). Its distribution is regionally unbalanced, however, with the investment boosting overall economic activities in the North, but with most benefits spilling over to the South. Natural capital activities (maintenance and conservation) increase in both regions.

When investments in conservancies are also complemented with wildlife preservation,[8] the results in Tables 2.10 and 2.11 suggest a synergic effect, with a high beneficial impact (investment multiplier = 2.42), which would favor a pattern of growth more balanced across regions and income groups. The simulations indicate

8 Wildlife preservation includes all investment aimed at identifying, protecting, and expanding key areas to help wildlife thrive, and in many cases, recover from endangered and threatened status.

TABLE 2.9: Doubling the investment in conservancies: impact on income distribution

Income ($, millions)	South (Region A)		North (Region B)		% Change	
	Base case	Simulation	Base case	Simulation	Region A	Region B
Enterprises	31,278.20	31,497.90	2,607.40	2,634.20	0.7	1.0
Rural poor	7,996.50	8,102.30	1,683.90	1,698.30	1.3	0.9
Rural non-poor	13,069.50	13,238.20	2,607.00	2,629.40	1.3	0.9
Urban poor	1,437.90	1,450.40	214.80	216.10	0.9	0.6
Urban non-poor	36,365.70	36,693.50	6,480.90	6,523.90	0.9	0.7
Investment in conservancies	285.4	570.8	0.1	0.2		

Source: Elaboration of the Kenya CGE model.

TABLE 2.10: Doubling investment in conservancies and wildlife conservation: impact on value added

Value Added ($, millions)	South (Region A)		North (Region B)		% Change	
	Base case	Simulation	Base case	Simulation	Region A	Region B
Labor	19,324.90	20,884.90	1,764.40	2,503.30	8.1	41.9
Capital	31,278.20	33,931.20	2,607.40	4,005.90	8.5	53.6
Land	5,163.20	7,722.90	895.40	2,218.30	49.6	147.7
Ecoservices	1,214.00	2,374.70	700.30	1,964.00	95.6	180.5

Source: Elaboration of the Kenya CGE model.

TABLE 2.11: Doubling investment in conservancies and wildlife conservation: impact on income distribution

	South (Region A)		North (Region B)		% Change	
Income ($, millions)	Base case	Simulation	Base case	Simulation	Region A	Region B
Enterprises	31,278.20	33,931.30	2,607.40	4,005.90	8.5	53.6
Rural poor	7,996.50	9,615.10	1,683.90	2,772.90	20.2	64.7
Rural non-poor	13,069.50	15,642.00	2,607.00	4,261.90	19.7	63.5
Urban poor	1,437.90	1,580.70	214.80	303.30	9.9	41.2
Urban non-poor	36,365.70	40,401.30	6,480.90	8,903.90	11.1	37.4
Investment in conservancies	285.4	570.8	0.1	0.2		
Investment in wildlife	1,598.8	3,197.5	529.7	1059.3		

Source: Elaboration of the Kenya CGE model.

that agriculture and livestock would contract (moderately) in the South and expand in the North, where the economy would grow in terms of both value added and personal incomes.

Tables 2.12 and 2.13 show the results of the simulations of a hypothetical scenario that involves combining "smart" technologies with traditional conservation techniques through productivity increases and resource allocation. The Spatial Monitoring and Reporting Tool (SMART), already in use in some conservancies in Kenya, is one such example of a new technology. It is a protected area management tool designed to measure, evaluate, and improve the overall effectiveness of law enforcement patrols.[9] In this simulation, the model predicts synergistic effects with more than proportional increases of the multipliers. The impact on incomes is large and more balanced across regions and income groups, with the North and the poor reaping the largest benefits. In sum,

9 https://loisaba.com/smart-using-cutting-edge-technology-monitor-loisabas-wildlife-populations/

TABLE 2.12: Doubling investment and capital productivity in conservancies and wildlife conservation: impact on value added

Value Added ($, millions)	South (Region A)		North (Region B)		% Change	
	Base case	Simulation	Base case	Simulation	Region A	Region B
Labor	19,324.90	22,029.30	1,764.40	3,102.80	14.0	75.9
Capital	31,278.20	36,626.40	2,607.40	5,476.40	17.1	110.0
Land	5,163.20	9,358.40	895.40	3,284.50	81.3	266.8
Ecoservices	1,214.00	3,142.90	700.30	2,993.00	158.9	327.4

Source: Elaboration of the Kenya CGE model.

TABLE 2.13: Doubling investment and capital productivity in conservancies and wildlife conservation: impact on income distribution

Income ($, millions)	South (Region A)		North (Region B)		% Change	
	Base case	Simulation	Base case	Simulation	Region A	Region B
Enterprises	31,278.2	36,626.5	2,607.4	5,476.4	17.1	110.0
Rural poor	7,996.5	10,769.4	1,683.9	3,702.5	34.7	119.9
Rural non-poor	13,069.5	17,492.1	2,607	5,676.2	33.8	117.7
Urban poor	1,437.9	1,701.1	214.8	383.8	18.3	78.7
Urban non- poor	36,365.7	43,777	6,480.9	11,055.3	20.4	70.6
Investment in conservancies	285.4	570.8	0.1	0.2		
Investment in wildlife	1,598.8	3,197.5	529.7	1,059.3		

Source: Elaboration of the Kenya CGE model.

"smart" investments in conservation could be a "win-win" policy with huge gains for both regions, a healthy balanced expansion of the economy, and larger benefits for the rural poor.

Rural poverty and tourism

Rural poverty and the conservation of natural capital are linked to each other in several ways. First, a majority of the rural poor directly depend for their livelihoods on agriculture, pastoralism, and other natural resource–dependent livelihoods. Second, this dependence, while supporting their subsistence status, is also risky, as it exposes them to the vagaries of weather and the oscillations of market prices. Third, because the population continues to grow at very high rates, the pressure on land increases and productivity (per person) tends to fall, making the plight of pastoralists and small farmers facing a shrinking resource base ever more dramatic. Because landholdings are subdivided across an increasing population, the expansion of agriculture at the expense of traditional pastoralism and ecological balance has also undermined the productivity of natural capital. The overall effects of these trends has resulted in a negative link between population growth and agricultural expansion on the one hand, and the productivity of renewable natural capital on the other.

On the positive side, a significant reduction of rural poverty has occurred because the pattern of development in Kenya has been sufficiently diversified to offer both alternative and complementary economic opportunities to the rural populations. In the past 20 years, Kenya has developed a diversified industrial and service economy, with a vibrant tourism industry, which is itself diversified across the whole range of the country's considerable supply of alternative products, from beaches to landscapes rich in wildlife. Nature-based tourism thrives on a value chain directly dependent on local agriculture, agroindustry, and specialized services.

The development of tourism in Kenya is thus a part of the transformation from quasi-subsistence into commercial agriculture and brings with it greater integration into the rest of the economy. Increasing reliance on the market has several dimensions, including the share of consumption that is purchased in the market, expenditure for food as a share of total expenditure, old and new sources of off-farm income, debt, and the need for storage facilities. Tourism-related services and employment provide a series of backward linkages that increase the flexibility of the farm household in ordinary times, reduce its direct and exclusive dependence on agricultural markets, and make the poor more resilient to adverse shocks. The backward linkages of tourism to the rural economy may thus improve income prospects and stability for all the rural population, including the rural poor.

The CGE captures the interdependence between the rural economy and nature-based tourism, both through the estimates of transactions across the value chains, and through the regional and economy-wide multipliers arising from backward and forward linkages. General equilibrium price effects are also estimated by the model, which registers a rise in value added through both higher factor employment and higher prices of land.

For example, Figure 2.8 shows how in the CGE base solution, household income elasticities, with respect to park tourism expenditure (i.e., the percentage increases in incomes following a 100% increase in park tourism expenditure), range from 3.4 percent to about 2.3 percent across income groups in the two regions. The elasticities decline smoothly from their highest value for the rural poor in the South to the urban poor in the North, but their basic values are not very different across the various income groups.

If all tourism-related activities (not just expenditures on maintaining parks) are given a boost by increasing investment in parks and conservancies, as shown in Figure 2.8, income elasticities (percentage increases in incomes in response to 100 percent increase in spending) rise significantly (ranging from 25 percent to 16 percent) and the difference in response between rural and urban and poor and non-poor groups is heightened. For completeness Figure 2.8 and Figure 2.9 also show how these elasticities vary between urban and rural areas.

Concluding comments

The CGE model developed for this study presents a picture of the Kenyan economy, with stark differences of factor supply and employment between the more developed South and the less developed North. The two regions are interdependent to an extent, especially because most of the industrial and service value added is produced in the South. These linkages result in investments in the North generating larger spillovers in the South in absolute terms, following a pattern common to many unequal regional economies. At the same time, for activities that depend on open spaces and nature, damage to wildlife and tourism value chains in the South tend to negatively affect both regions. However, absolute

FIGURE 2.8: Income elasticities

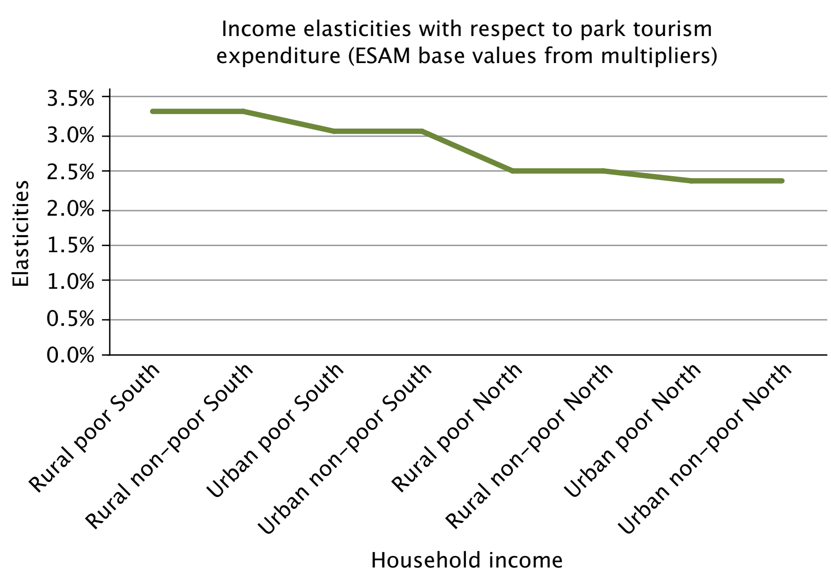
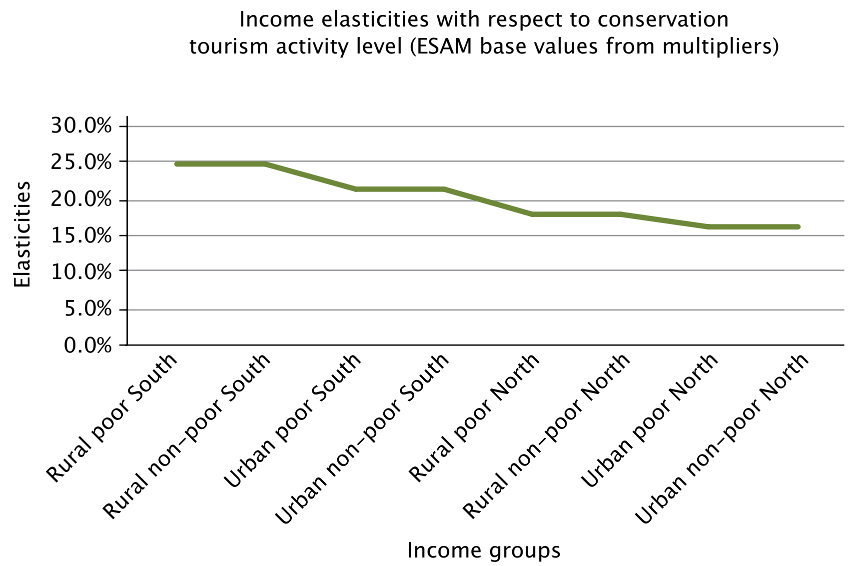


FIGURE 2.9: Income elasticities



effects are larger in the South, while relative damages are proportionally higher for the nascent tourism activities in the North.

The present surge of infrastructure investment in Kenya is thus likely to bring some benefits to the already developed regions, though this will come at a cost of increasing congestion and aggravating inequalities and environmental damage. Where the damage is large, it could outweigh the benefits. The reason is that the decline in wildlife results in a drastic fall of nature-based tourism in both regions, as well as a decline in many service sectors due to the linkages. Perhaps of greater concern is that these impacts are disproportionately felt by the rural poor and in the North. Prospects of development in this region thus appear to be vulnerable to investment choices in the South because of the concentration of economic activities in this more developed region and the widespread negative effects on the environment and tourism in the North.

In sum, if wildlife reduction is large (which it is now), and/or demand elasticities of tourism are high (which is also probably true), higher investment in infrastructure may lead Kenya into a development trap, where major negative effects on wildlife, the environment, and tourism ultimately hamper both its resources and its economic growth. The empirical findings suggest that, at the present, Kenya is moving closer to this trap, which it will likely only escape by appropriately combining investment in both infrastructure and conservation policies.

REFERENCES

Arrow, K. J., P. Dasgupta, L. H. Goulder, K. Mumford, and K. Oleson. (2013). "Sustainability and the Measurement of Wealth: Further Reflections." *Environment and Development Economics* 18 (4).

Hanson, Kenneth, Sherman Robinson, and Stephen Tokarick. (1989). Working paper no. 510 United States Adjustment in the 1990s: A CGE Analysis of Alternative Trade Strategies. California Agriculture Experiment Station, University of California, Berkeley.

Hinojosa-Ojeda, R., and S. Robinson. (1991). "Alternative scenarios of US-Mexico integration: A computable general equilibrium approach.' Working paper series, California Agricultural Experiment Station, Department of Agricultural and Resource Economics.

Perali, F., and Scandizzo, P. L., eds. (2018). *The New Generation of Computable General Equilibrium Models*, Springer.

Reinert, K. A., and C.R. Shiells. (1991). *Trade Substitution Elasticities for Analysis of a North American Free Trade Area*. US International Trade Commission.

Robinson et al. (1989). Multisectoral models. In *Handbook of development economics,* vol. II, ed. H. Chenery and T. N. Srinivasan. Amsterdam: Elsevier Science Publishers.

Sanghi, Apurva, Richard Damania, Farah Manji, and Maria Paulina Mogollon. (2017). *Standing out from the herd: An economic assessment of tourism in Kenya (English)*. Washington, D.C., World Bank Group.

Scandizzo, Pasquale L., and Ferrarese, Cataldo. (2015). "Social Accounting Matrix, a New Estimation Methodology," *Journal of Policy Modeling* 37 (1).

CHAPTER 3

WILDLIFE-FRIENDLY ROADS: FABLE OR FACT?

The development of new roads in Kenya will be crucial to spurring growth and human development, and promoting shared prosperity. At the same time, as established in previous chapters, the expansion of Kenya's road network ranks high in the list of factors contributing to wildlife loss. As the CGE analysis has indicated, where wildlife losses are substantial, the economic benefits that a road brings may not outweigh the benefits forgone, especially in the more remote parts of the country where economic opportunities are limited (and multipliers are small). This problem would be overcome if it were possible to construct a road with limited impact on wildlife in ways that minimize losses and maximize benefits. This chapter presents a new tool that can help identify which roads should be developed based not only on their economic potential, but also factoring in the possible negative impacts on wildlife. The results highlight the existence of important margins to develop an economically inclusive road network that at the same time acknowledges externalities and is respectful to wildlife.

New approaches to enhancing road access

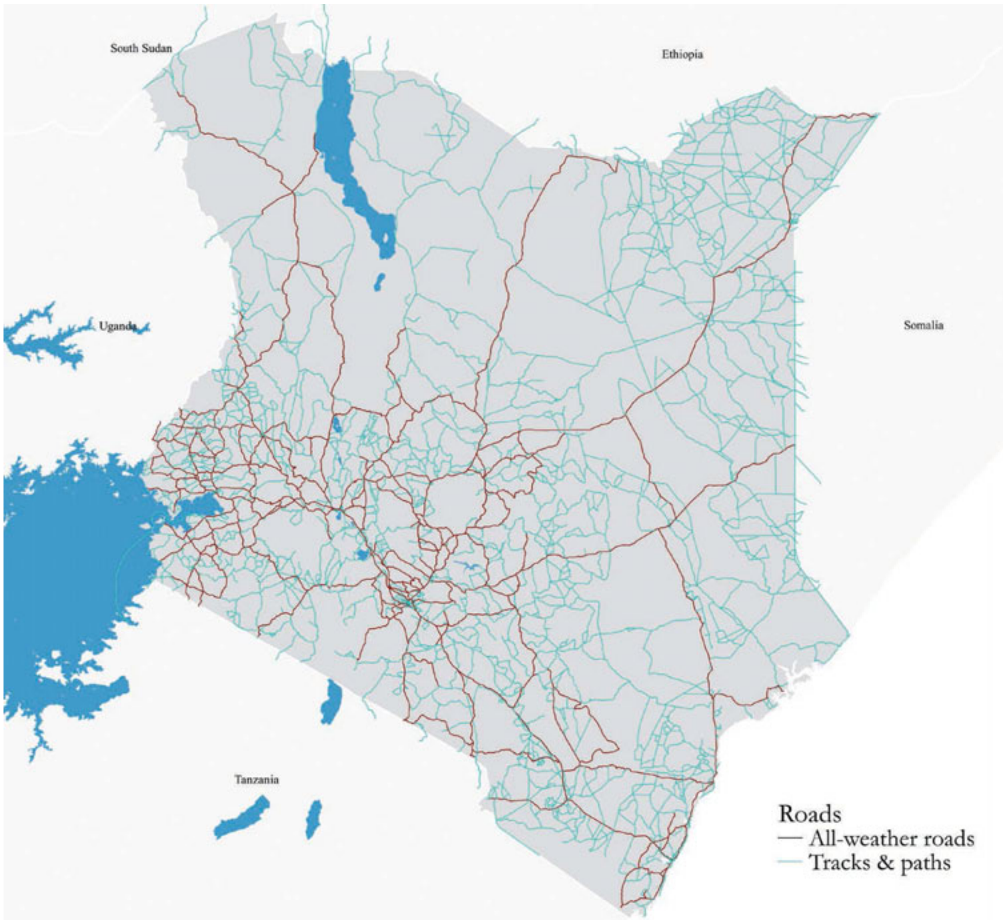
Roads are key for economic development, and as previously highlighted, a staggering 70 percent of Kenya's rural population still lives more than 2 kilometers from an all-season road. The SDGs promote the construction of all-season roads, defined as roads motorable all year round by the prevailing means of rural transport. In the relatively dry context of Kenya, in addition to tarmac roads, paved and improved roads are also considered as all-season roads. Indicator 9.1.1 of the SDGs encourages policy makers to increase the share of the rural population living within a 2-kilometer distance of an all-season road, calculated as the Rural Access Index (RAI). Earlier studies first measured RAI using household survey data (Roberts et al. 2006), but advances in technology and the use of GIS data have significantly expanded the scope of such analyses, notably in data-poor contexts (Iimi et al. 2016). The approach based on GIS data was refined and scaled to 166 countries by Mikou et al. (2019), who also developed a tool to help predict which all-season roads should be built by upgrading existing tracks in order to maximize the RAI. Indeed, an algorithm using information pertaining to where the population lives, where all-season roads exist, and where other roads/tracks are located can lead to prioritizing road improvements that connect the highest number of people to the network at the lowest cost.

This chapter applies the method pioneered by Mikou et al. (2019) to the Kenyan context and goes a step further to take into account the externalities generated by the road network. The method relies on data of human populations, existing roads, and a set of possible new roads. WorldPop data from 2015 provides gridded estimates of population distributions at a 1-kilometer resolution, and similar to the methodology outlined in Chapter 1, data for Kenya's existing major roads are derived from Michelin maps (2017). DeLorme data for Kenya is used to identify paths and tracks that are potential candidates for new roads (Figure 3.1). The DeLorme dataset is considered to be comprehensive and up-to-date regarding transportation infrastructure, including roads, paths, and tracks, but it is limited in terms of information on the quality of surfacing. Michelin data are then used to more precisely classify which segments correspond to existing all-weather roads and which ones correspond to paths or tracks. The latter are then used as candidate segments for possible extensions of the road network.

Conventional approaches of increasing road access

Conceptually, a road network is a mathematical graph. This graph can be extended by converting a track

FIGURE 3.1: Existing all-weather roads and tracks in Kenya

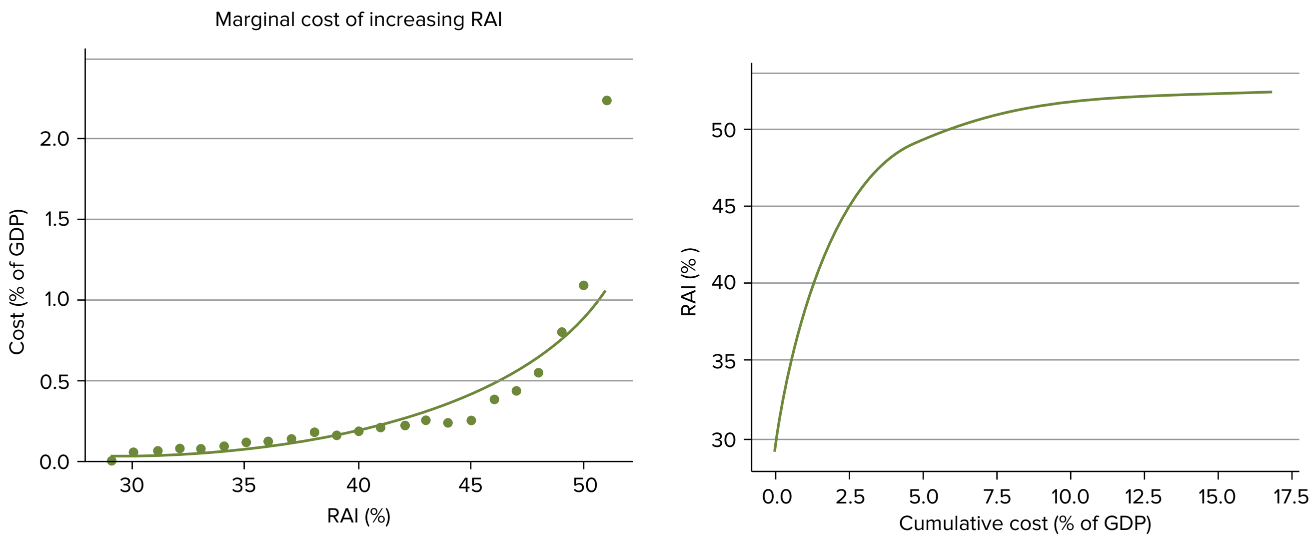


Source: Michelin maps (roads); DeLorme data (tracks).

connected to the current network into a road. An algorithm determines all possible new graphs that would be formed by the connection of one new track to the existing graph. For each graph, the new RAI is calculated. By doing so, the algorithm determines which track leads to the highest increase in the RAI, and based on the length of each segment, it determines the cost of converting this segment into a road. Here, the construction cost of the road is a linear function of the length of the new road (see Mikou et al. 2019 on costs). The track that brings the maximum increase of the RAI at the lowest cost is chosen and added to the road network. A more complete mathematical graph is consequently formed, and the procedure is repeated until no gain in the RAI is possible. This method from Mikou et al. is used to determine a set of priority roads. It adopts what could be termed a "business as usual" scenario in which the negative effects of roads on wildlife are not internalized or considered in the construction process.

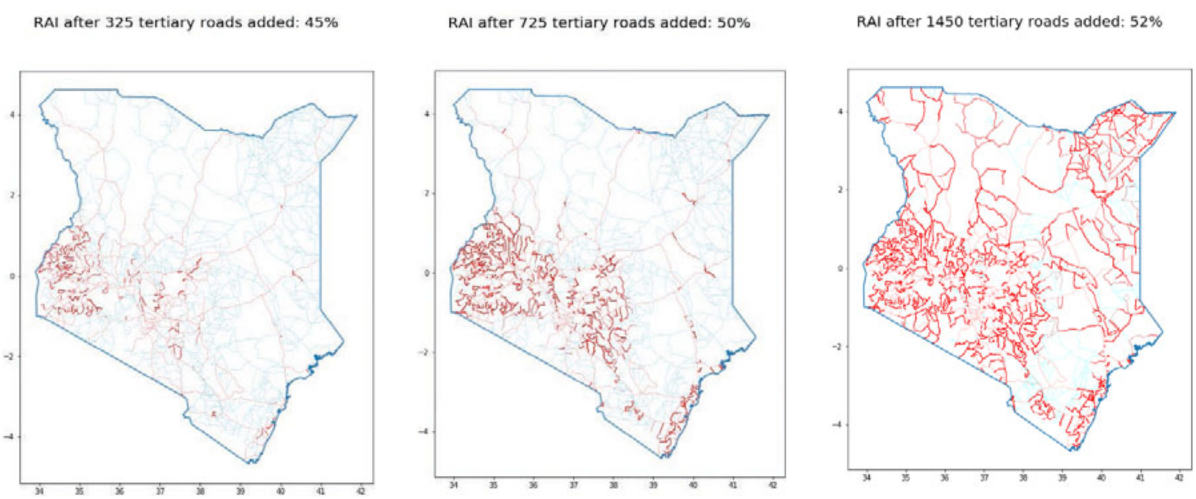
According to available data, the share of Kenya's rural population living within 2 kilometers of an all-season road is currently around 28 to 30 percent. The algorithm developed here suggests that this RAI could be increased to more than 50 percent simply by converting existing tracks to roads. Figure 3.2 displays the marginal and total cost of increasing the RAI, expressed as a percentage of GDP. The cost of increasing the RAI is fairly constant from the current level up to about 45 percent of the population. The figure indicates that for about 2.5 percent of current GDP, an additional 15 percent of the rural population could be connected to the road network. This additional 15 percent roughly represents 6 million new people who primarily live in Kenya's densely populated western counties and around Nairobi (Figure 3.3).

FIGURE 3.2: The costs of increasing Kenya's RAI under the "business as usual" scenario



Source: Michelin and DeLorme data; Method developed by the World Bank.

FIGURE 3.3: Building new roads to increase Kenya's RAI, starting with the densely populated western counties



Source: Michelin and DeLorme data; Method developed by the World Bank.

Progressively, more remote areas start to be connected to the network. However, the cost of connecting each additional household sharply increases; for instance, increasing the RAI from 45 percent to 46 percent would cost an additional 0.5 percent of GDP. Even more so, bringing the RAI to 52 percent (from 51 percent) would cost a further 2.5 percent of GDP—which is the same cost as connecting the first 15 percent of the population to the network. This is consistent with global trends observed by Mikou et al. (2019) across Sub-Saharan Africa. However, thanks to the higher GDP of Kenya compared to most other African countries, the relative cost of increasing its RAI, expressed in GDP, is lower.

Counting the costs of business as usual

What would the environmental cost of the "business as usual" scenario be? Of primary interest, the western part of Kenya,[10] where many roads would be upgraded, falls outside the rangelands and is home to limited wildlife. This suggests that a large part of the rural population could be connected to the road network at a low environmental cost in terms of biodiversity loss.

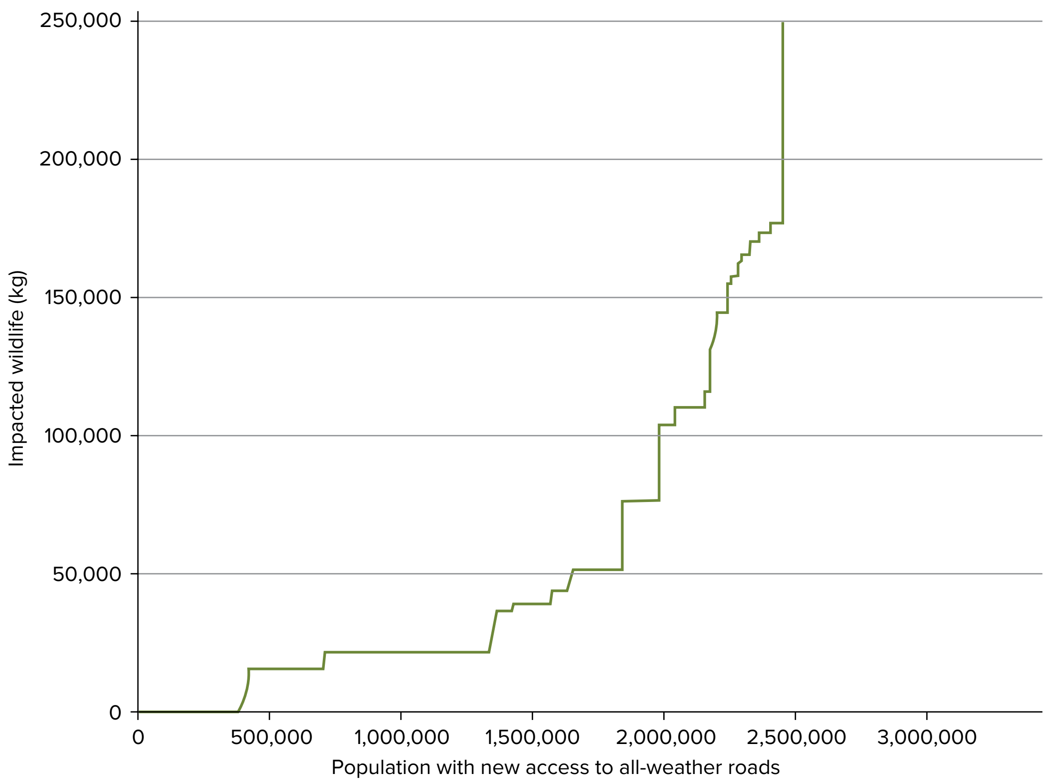
To quantify the impact on wildlife when this conventional "business as usual" approach is used, biomass data of ungulate wildlife, derived from DRSRS, are overlapped with roads. Using the estimates presented in Chapter 1, it is assumed that the conversion of a track into a road would lead to a decline of wildlife in a 20-kilometer buffer around the newly built road. At each step of the algorithm, wildlife loss in each extension is calculated.

Figure 3.4 shows how much wildlife would be lost as the RAI increases. The results suggest that the costs for wildlife associated with extending the road network slowly begin increasing and are followed by losses of wildlife sharply increasing as more people are connected to the network. Even among the first road segments built in the rangelands, important wildlife areas are threatened. Observe that the impact on wildlife is constant for the first 1.5 million people connected to the network, and that it jumps very dramatically thereafter. The CGE analysis in Chapter 2 warns that losses of this scale bring adverse GDP consequences, especially in areas with limited potential for growth and labor-intensive employment.

A greener scenario

However, even if the costs outweigh the benefits of such policies outlined above, it is unlikely that this would prevent the construction of roads in the rangelands. This

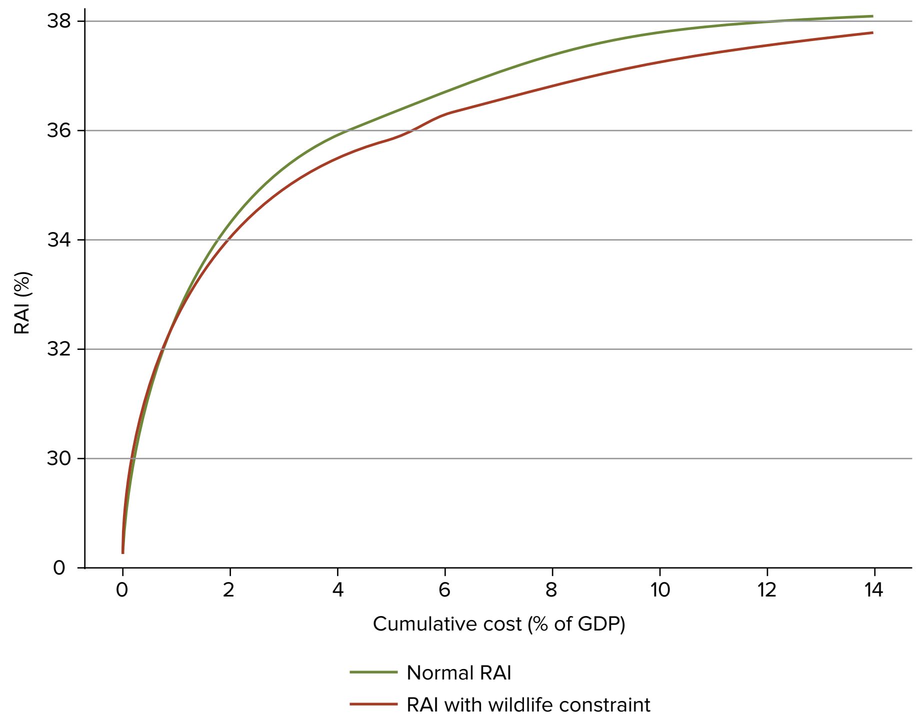
FIGURE 3.4: Wildlife loss is constant for the first 1.5 million people connected to the road network, with losses sharply increasing thereafter



Source: Authors.

10 This would include the following counties: Migori, Homa Bay, Kisii, Nyamira, Bomet, Kericho, Kisumu, Nandi, Vihiga, Siaya, Busia, Bungoma, Trans-Nzoia, Marakwet, Uasin Gishu, Nakuru, Nyandarua, Nyeri, Muranga, and Nairobi.

FIGURE 3.5: The costs of increasing Kenya's RAI under the two scenarios



section demonstrates that a more careful extension of the road network allows for as many people to be connected to the network as in the "business as usual" scenario, at a similar cost, but with moderate consequences for wildlife.

To run the greener scenario, the original algorithm from Mikou et al. (2019) was modified, allowing for the consequences of road construction on wildlife to be considered. Thus far, the objective function of the algorithm was to maximize the number of people connected to the network at the lowest cost. In this section, an extra parameter is added: simultaneously minimizing the impact on wildlife. As is standard in statistical analysis, human population data and wildlife biomass data were normalized and scaled over the same support to ensure that neither one was overweighed in the algorithm.[11] In doing so, the objective of this approach was to find areas where roads could be built to maximize access and minimize impact on wildlife.

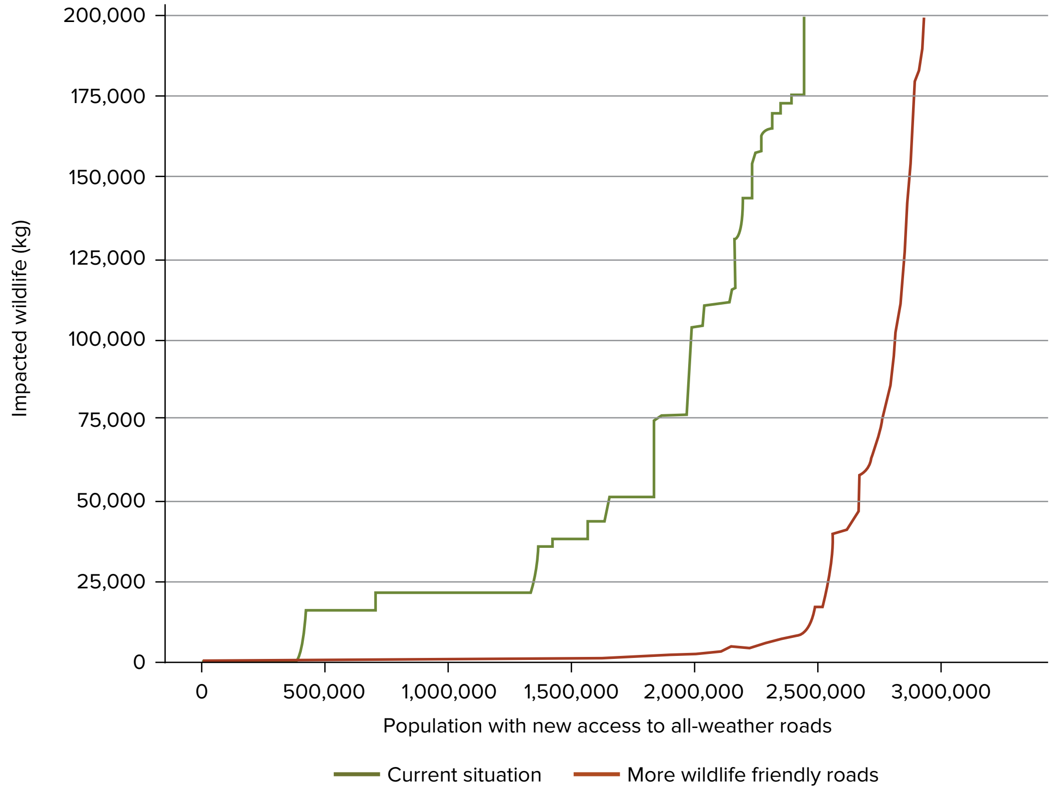
The results are promising. The first striking finding is that both models (the original one as well as the model with the added parameter on wildlife impact) attain the same increase in the RAI at comparable cumulative costs (Figure 3.5). When focusing only on the rangeland counties for which there is biodiversity data, the current RAI of about 28 percent could be increased with both models to approximately 38 percent. This holds for the model that does not include a wildlife constraint (green line) as well as the modified model that factors in a wildlife constraint (orange).

Of crucial importance, the model that includes the wildlife constraint allows for a significant reduction in the loss of wildlife from increased road access. Figure 3.6 compares the environmental effectiveness of both models, highlighting that the modified model (orange line) offers solutions to connecting people to the road network while having limited detrimental effects on wildlife.

Under the original model, wildlife is lost after approximately 500,000 people are connected to the road network (green line), while wildlife loss in the modified model only happens after 2 million people gain access to these improved roads. Further, while wildlife loss in

11 Mathematically, the objective function of the algorithm is: maximizing people/(km*wildlife impacted).

FIGURE 3.6: Factoring in wildlife constraints significantly reduces the impact of new roads on wildlife



the first model skyrockets after 1.5 million people are connected, under the modified model, this happens after 2.5 million people gain access to the road network. Hence, most people could be connected to the network while avoiding negative impacts on wildlife.

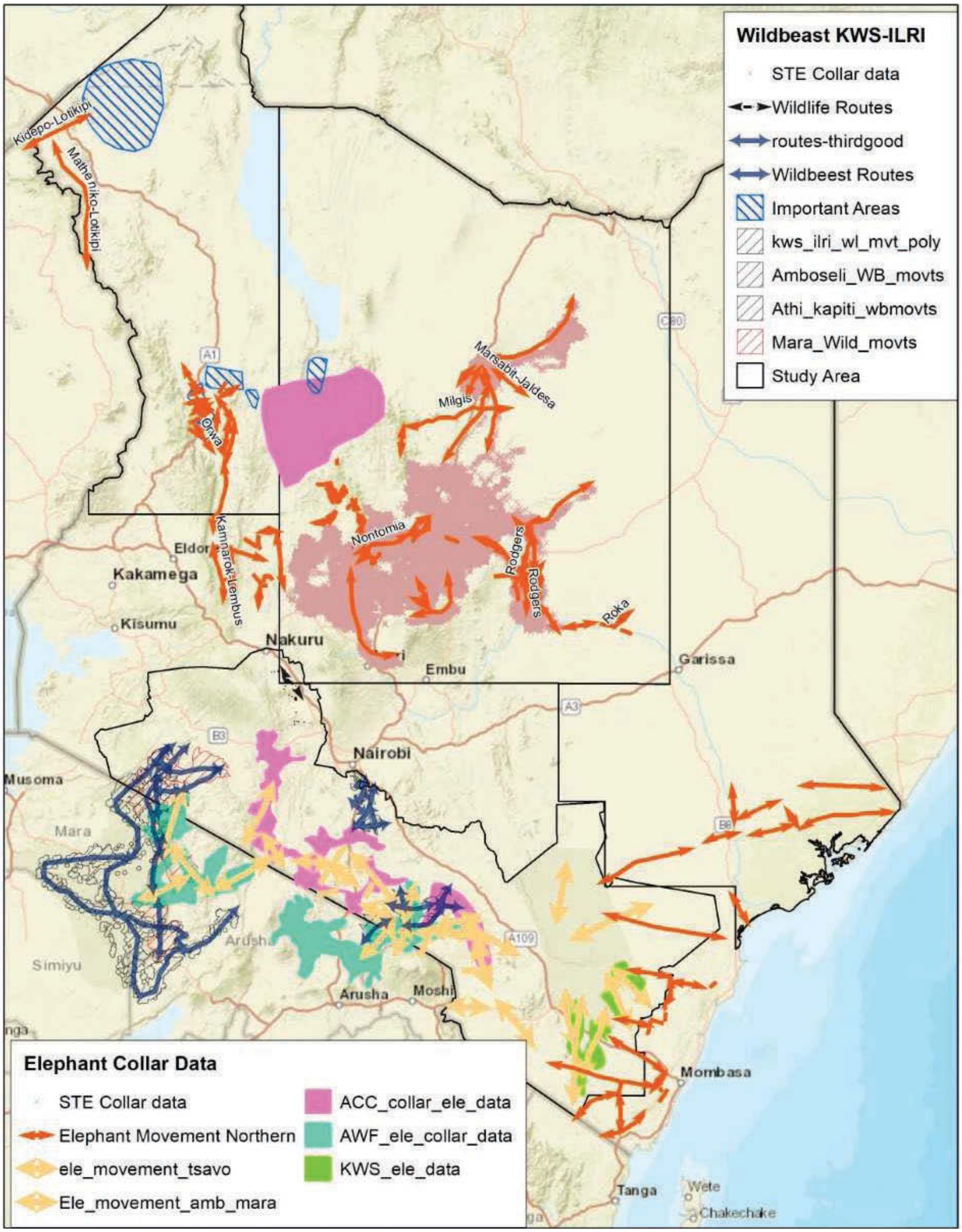
Fine-tuning the model

The results presented above come with a few caveats. More than definitive results, the value of this exercise lies in its original approach—developing a tool that could be used to inform decision making and to understand the trade-offs between wildlife protection and economic opportunities. The model developed could also be further refined to provide more fine-tuned policy messages. The protection of wildlife corridors has become a critical aspect for wildlife protection in Kenya, as most are under intense threat of conversion for other land use. Similar to the way wildlife density data were introduced into the model, data on wildlife routes could also be included. Precise information on these routes is being gathered by leading experts in Kenya and could become a valuable source of information for this model (Figure 3.7).[12] In addition, though the model built in this instance was trained to prioritize road improvement in order to connect the highest number of people to the network, a similar model could be adjusted to connect the area with the highest agricultural potential to the network, or areas with the highest poverty rates to the network. This would constitute a fine-tuning of the model but would not change the central message: huge opportunities exist to extend Kenya's road network and to protect wildlife at the same time.

In sum, smarter, greener approaches to infrastructure are also economically more beneficial. Achieving this outcome is not impossible, and it requires policy makers to properly identify areas where roads should not be constructed.

12 Among other refinements, we should note the possibility of varying the functional form of the objective function of the algorithm—the size of the buffers built around each road for which we assume an impact on wildlife (here 20 kilometers). It could be 10 kilometers in a "more aggressive scenario" or 30 kilometers in a "more conservative scenario."

FIGURE 3.7: Mapping elephant and wildebeest routes in Kenya



Source: Ojwang et al. (2017).

REFERENCES

Iimi, A., F. A. K. Ahmed, E. C. Anderson, A. S. Diehl, L. Maiyo, T. Peralta Quiros, and K. S. Rao. (2016). *New Rural Access Index : Main Determinants and Correlation to Poverty*. Washington, D.C. The World Bank.

Mikou, M., J. Rozenberg, E. Koks, C. Fox, and T. Peralta Quiros. (2019). *Assessing Rural Accessibility and Rural Roads Investment Needs Using Open Source Data.* Washington, D.C. The World Bank.

Ojwang, Gordon O., et al. (2017). *Wildlife Migratory Corridors and Dispersal Areas: Kenya Rangelands and Coastal Terrestrial Ecosystems*.

Roberts, P., S. KC, and C. Rastogi. (2006). *Rural Access Index: A Key Development Indicator.* Washington, D.C. The World Bank.

CHAPTER 4

THE WAY FORWARD AND NEXT STEPS

A 70 percent decline in wildlife, within thirty years, is a sobering statistic. As Kenya's population grows, its infrastructure needs expand, and climate change makes rainfall more erratic, and the pressures on wildlife and natural habitats will intensify in regions that are already under environmental stress and will spread to other parts of the country. The journey along the current policy path has failed to halt the degradation and fragmentation of natural habitats, and it is unlikely to do so in the future when pressures expand and competition for land, water, and other natural resources intensifies. This suggests an urgent need for a careful reassessment of pressures, policies, and future prospects.

Wildlife in Kenya, especially in the North of the country, represents a lucrative economic asset whose contribution has been underestimated and potential unrealized. The CGE assessment indicates that every dollar invested in conservation and wildlife tourism could generate benefits that range from $3 to $20. For comparison, it is instructive to note that in the United States and Brazil, $1 invested in protected areas generates approximately $6–$8 as a return (do Val Simardi Beraldo Souza, 2017). Table 4.1 illustrates that in Kenya the economic benefits from investments in wildlife tourism rise with the amount that is invested. Such increasing returns likely reflect the ecological importance of connected natural habitats that are more productive in terms of the ecosystem services that they provide and are also more resilient to droughts and other weather extremes (Haddad et al. (2015). In the remote and arid North of the country there are few other investments that could yield a comparable economic return.

TABLE 4.1: GDP multipliers for investments (in million USD) in conservancies

		10	50	100	500	1,000
Investment in conservancies	North	3.13	3.16	3.19	3.52	4.02
	South	5.43	5.63	5.89	9.07	20.2

Realizing this economic potential will call for a significant shift in two key policy areas. First, it will require changes in the way in which intrusive infrastructure is planned and located to avoid the fragmentation and conversion of natural habitats with economic potential. Second, there is a need to create the enabling conditions to realize the economic potential through investments in conservancies at scale. Neither approach will be sufficient on its own and both will need to work in tandem: the first to prevent the loss of economic opportunities by land conversion, and the second to harness economic potential through investments. The remainder of this chapter discusses critical elements of this approach.

Smart infrastructure

Where ecotourism potential exists, it is important that infrastructure investments are done with consideration of ecotourism's impacts on these assets. The fact that much remains to be built creates an opportunity to build "right." Getting infrastructure "right" is critical because infrastructure choices have long-lived and difficult-to-reverse impacts on land, wildlife, water, and future patterns of development. Infrastructure decisions influence the type and location of development and, as such, create substantial inertia in economic systems, with irreversible consequences that need to be weighed against alternatives.

Recognition of these complex issues suggests the need for a different approach to infrastructure needs with a focus on "building right" rather than simply "building more." Building right typically brings benefits that accrue over the longer term. The fact that infrastructure needs are so large implies that there are wide opportunities to build right—garnering benefits while minimizing or avoiding possible negative impacts on the country's comparative advantage.

The right infrastructure also offers substantial co-benefits that could enhance the productivity and earning capacity of the country's natural capital. The trade-offs and synergies from infrastructure and roads are considerable and warrant closer examination in decision making. This is especially important for remote parts of Kenya with a limited natural comparative advantage for arable agriculture. Where appropriately managed, there are considerable synergies between wildlife tourism and cattle ranching, both of which offer climate resilient livelihood opportunities in areas with limited economic potential. As human population densities increase throughout Africa, there will be a growing premium on places that offer such experiences. Destroying this economic potential could be a short-sighted strategy.

Development of large strategic infrastructure to promote connectivity can be consistent with efforts to conserve natural assets, which also contribute to economic growth. As illustrated in Chapter 3, tools are available that allow planners to predict the impacts of their decision on wildlife—a key economic asset. The same tools can be used to predict how to meet other development objectives more effectively. Through careful and strategic planning, spending on infrastructure can be rendered more effective and more conducive to growth and poverty reduction, and less impactful on wildlife and the economic opportunities that they bring (Box 4.1). The additional complexity and cost of planning, such as in infrastructure, would be justified by the vastly greater benefits that would accrue to the country.

Realizing economic opportunities through conservancies

Conservancies could play a crucial role in halting the collapse of wildlife in Kenya by extending the areas under protection around parks, reconnecting habitats, and limiting overcrowding in parks. And more than that, conservancies offer levers to boost and diversify economic

BOX 4.1: Smart Infrastructure and Spatial Planning

The lack of spatial planning when combined with inadequate investment in infrastructure can create dynamics that are unsustainable and non-inclusive. There are significant deficiencies with the piecemeal and project-by-project assessment of each investment alternative in isolation.

One obvious consequence is that options which generate higher benefits may be overlooked since the focus is on a single project.

Another and seldom recognized problem is that of "dynamic inconsistency": where the first project unleashes consequences for other projects. For instance, suppose that the first project diminishes environmental quality in a protected area. This makes it more likely that another intrusive structure will "pass" a cost-benefit test. The first project therefore unleashed a dynamic that leads to complete transformation of the landscape, which was not considered at the outset. This is termed dynamic inconsistency and leads to poor decision making and economically unwarranted destruction of natural assets.

Against this background of escalating and suboptimal land conversion, two new concepts of spatial planning are advancing, both require prioritizing ecosystem services (forests, rural areas, watersheds, urbanized vast areas, etc.). One approach uses physical measures in GIS models to avoid damage and build synergies with ecosystems, as illustrated in Chapter 3.

The other takes a more economic approach by adopting a set of values or shadow prices that make the land use scale hierarchical and compatible with the functionality of potential ecological networks. This requires prioritizing ecosystem services (forests, rural areas, watersheds, etc.) by adopting a set of values or shadow prices that make the land use scale hierarchical and compatible with the functionality of potential ecological networks. Combined with higher capacity for project management, implementing the new concept of infrastructure is a promising strategy to invest wisely and more effectively.

In sum the idea is to make aspirations for "smart" infrastructure into a reality by using tools to combine functional efficiency, technology, and ecosystem conservation.

activities in some of the most remote parts of the country. In places where ranching and agriculture are under stress due to shifting weather patterns, land degradation, or overstocking, conservancies offer more sustainable livelihood options that will inevitably increase in value as wildlife numbers and wilderness viewing opportunities shrink across the globe. In sum a strategic expansion of conservancies offers an opportunity to complement the government's current focus

More generally, conservancies represent projects that offer a platform to integrate ecological and economic functions, which contrasts with the segregated conventional approaches of conservation and development. By allowing an array of organizational forms based on the coexistence of activities involving agriculture, livestock, conservation, and different forms of culture and nature-based activities, conservancies widen the menu of choices and offer a promising strategy to end the chaotic process of landscape fragmentation and wildlife extirpation.

There are currently around 160 conservancies in Kenya, spread across 28 counties, under the umbrella of Kenya Wildlife Conservancies Association (KWCA). These cover around 11 percent of the country's territory, with 3.7 million hectares in the North and 2.1 million hectares in the South (Figure 4.1). By comparison, the terrestrial national parks and reserves cover 4.7 million hectares.

Conservancies significantly increase the share of wildlife living in legally protected areas. Around 22 percent of the total ungulate wildlife biomass is found in conservancies. This represents a significant complement to the 38 percent of ungulate wildlife biomass found within Kenya's national parks. Perhaps of greater importance, 18 out of 20 zones with the highest wildlife density are found in conservancies rather than in parks. For example, Olare Orok, located next to the Maasai Mara, is the conservancy with the highest density of wildlife biomass. Key species such as the Grevy's zebra are mostly found in conservancies, while lion populations in the conservancies of the Maasai Mara are among the highest on the continent (Elliot and Gopalaswamy 2017; Ogotu et al. 2017). The data suggest that there is a lag in the recovery of ungulate biomass in conservancies with the greatest increase occurring in conservancies that were created in the 1980s (Figure 4.2).

The contribution of conservancies to the tourism industry remains modest—it accounts for a meager 1.3 percent of earnings in the industry, suggesting considerable potential and scope for expansion in a specialized market that caters to the high-value and low-volume tourists. A survey of 13 regional associations and 160 conservancies registered under KWCA suggests that there are around 2,510 beds available in lodges within conservancies, and most (97 percent) are found in the southern conservancies. The average conservancy in the sample has 28 beds, but with considerable variation ranging from 6 in Machakos, with its conservancies being in the early stages of development, to over 1,000 in Narok, which abuts the overcrowded Maasai Mara.

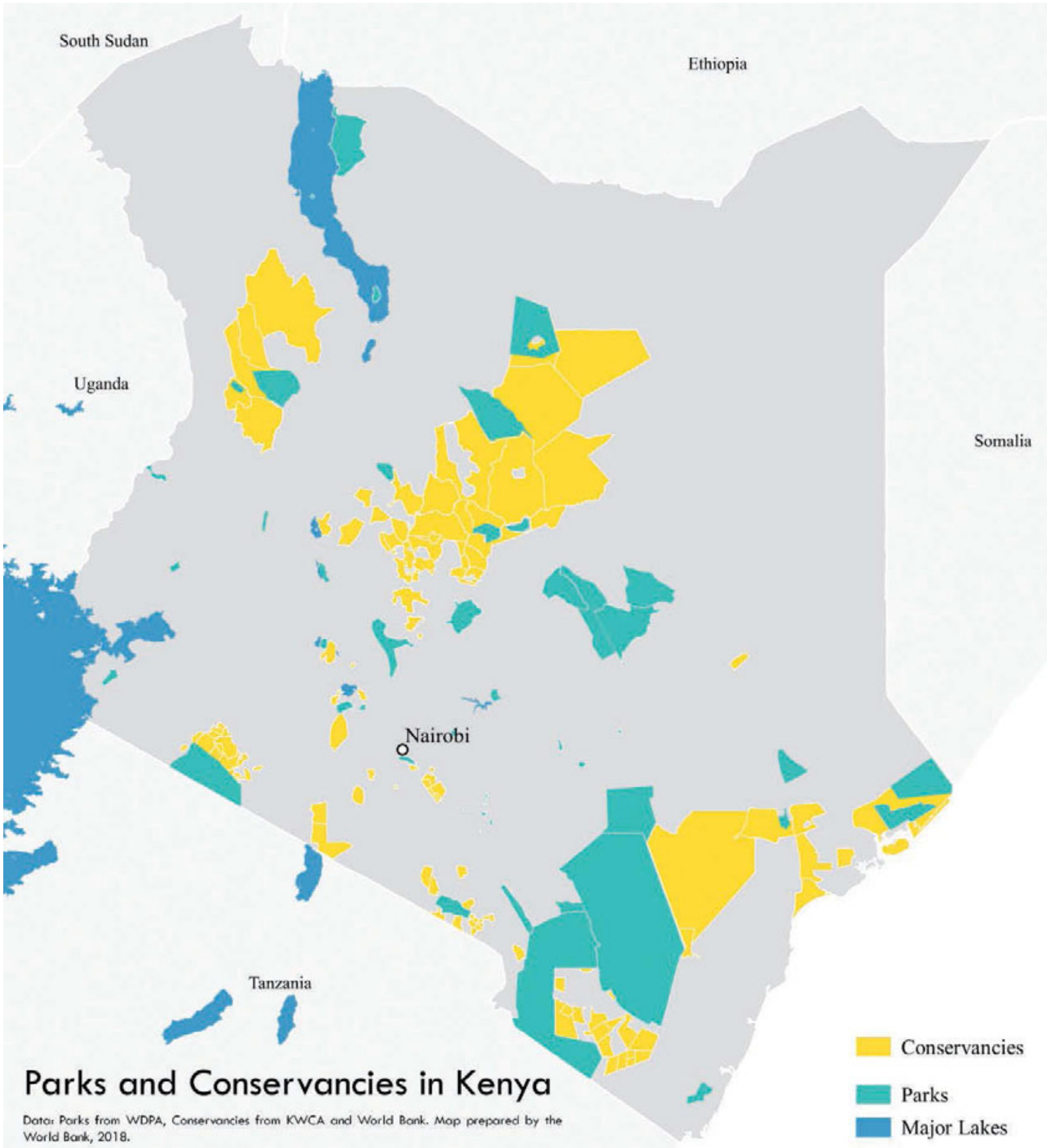
Tourism is the most significant source of income for conservancies, contributing an average of 83 percent of commercial income with buoyant growth in recent years.[13] Cattle ranching has, over the past years, gained prominence and offers a way to diversify income sources. A key challenge is to keep livestock herds in balance with wildlife numbers in cultural contexts where livestock is more than an economic asset. Iconic animal conservation programs (of species such as rhino, elephant, Grevy's zebra, chimpanzee) and other payment for environmental service programs are also a significant contributor to incomes, with conservancies earning an average of Kenya shilling (Ksh) 12.8 million in 2016 and Ksh 11 million in 2017 from conservation fees.

For communities who live within or near conservancies, there are significant benefits. The survey indicates that the 160 conservancies hired around 2,600 people, and provide bursaries and educational support especially to women, and are a significant source of income for food and other provisions required by tourists. Income from conservancies is the only drought-proof source of revenue that is available to many of the poor and vulnerable communities.

Despite these benefits, investments in conservancies carry high risks and as such require patient capital. This is because investors must gamble not only on the prospects of attracting tourists to a new location, but must also engage in a host of investments to build community support and fill crucial infrastructure gaps. This may suggest

13 NRT, 2018, *State of Conservancies Report, 2017*.

FIGURE 4.1: Map of parks and conservancies in Kenya (2018)



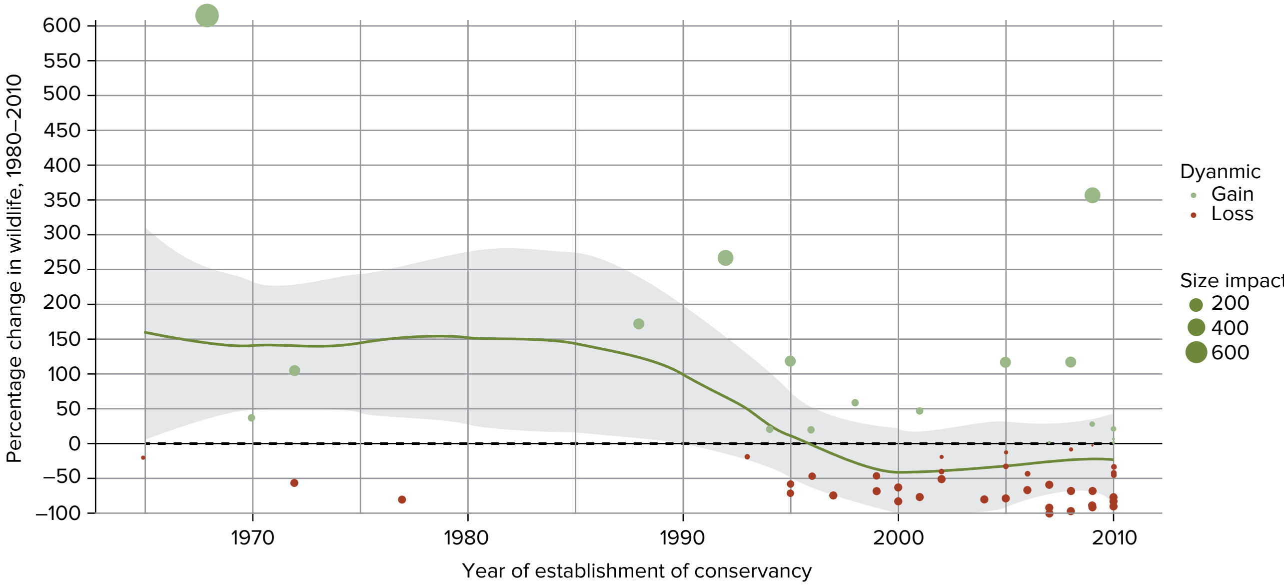
Source: Authors.

the need for innovative investment mechanisms such as green bonds and risk guarantees to shift the risk-reward balance, especially in areas that confer high ecological benefits. Recognizing that the conservancies confer public benefits, there is a case to be made for enabling policy support—for example through investments in marketing strategies aimed at both local and international travelers.

The presence of wildlife in conservancies has been the single most important determinant of success, though this is not sufficient to assure success. The establishment and promotion of conservancies offers the most scalable avenue in ensuring wildlife habitats are secured and migration corridors are established. Wildlife hot spot areas, such as the Mara, Amboseli, and Laikipia regions, indicate that high wildlife densities can lead to significant wildlife-based tourism operations outside of national parks.

To further promote the development of tourism outside of national parks and reserves, the national and county

FIGURE 4.2: Wildlife generally increased in the older conservancies and decreased in areas where conservancies were established after 1995



Source: Authors using DRSRS data and conservancies data developed in this report.

governments need to recognize the role conservancies play as custodians of wildlife and in developing synergistic livelihood enhancement programs. Integration of conservancy management plans in the county development plans acts as a first step to foster this recognition.

REFERENCES

do Val Simardi Beraldo Souza, T. T. (2017). Economic impacts of tourism in protected areas of Brazil. Journal of Sustainable Tourism, 1–15.

Elliot, Nicholas B., and Arjun M. Gopalaswamy. (2017). “Toward accurate and precise estimates of lion density.” Conservation Biology 31.4: 934–943.

Haddad, N. M., Brudvig, L. A., Clobert, J., Davies, K. F., Gonzalez, A., Holt, R. D., . . . and Cook, W. M. (2015). Habitat fragmentation and its lasting impact on Earth’s ecosystems. *Science Advances* 1(2), e1500052.

Ogutu, Joseph O., et al. (2017). “Wildlife population dynamics in human-dominated landscapes under community-based conservation: the example of Nakuru Wildlife Conservancy, Kenya.” PloS one 12.1: e0169730.

Olare Orok Conservancy.” Master’s thesis, University of Oslo.

APPENDIX A

CONSERVANCIES—AN OVERVIEW

The history of conservancy development in Kenya was founded upon conservation practices introduced by the British colonialists in the 1800s and 1900s. These altered the traditional land tenure system and enabled commercial harvesting of wildlife, leading to significant declines in wildlife numbers. The 1933 "London Convention" represented a turning point that marked the beginning of the end to commercial wildlife harvesting, and it vested authority to a central body for wildlife management. In 1946, the National Park Ordinance resulted in the establishment of Nairobi, Tsavo, Mount Kenya, and Aberdares National Parks. Game hunting and an increase in human-wildlife conflict in the 1950s and 1960s led to the centralization of wildlife management. Non-state protected areas—as they were called before the term conservancies was coined—emerged at this time, with the creation of the Solio, Ol Jogi, Sangare, Sergoit, and Taita Hills protected areas for rhinos and other wildlife species.

Momentum for conservancies gained traction in the 2000s with the formation of regional conservation groups such as The Northern Rangelands Trust (NRT) and the South Rift Association of Landowners (SORALO). The establishment of a national association in 2012—the Kenyan Wildlife Conservancies Association (KWCA)—helped to further promote the approach.[14]

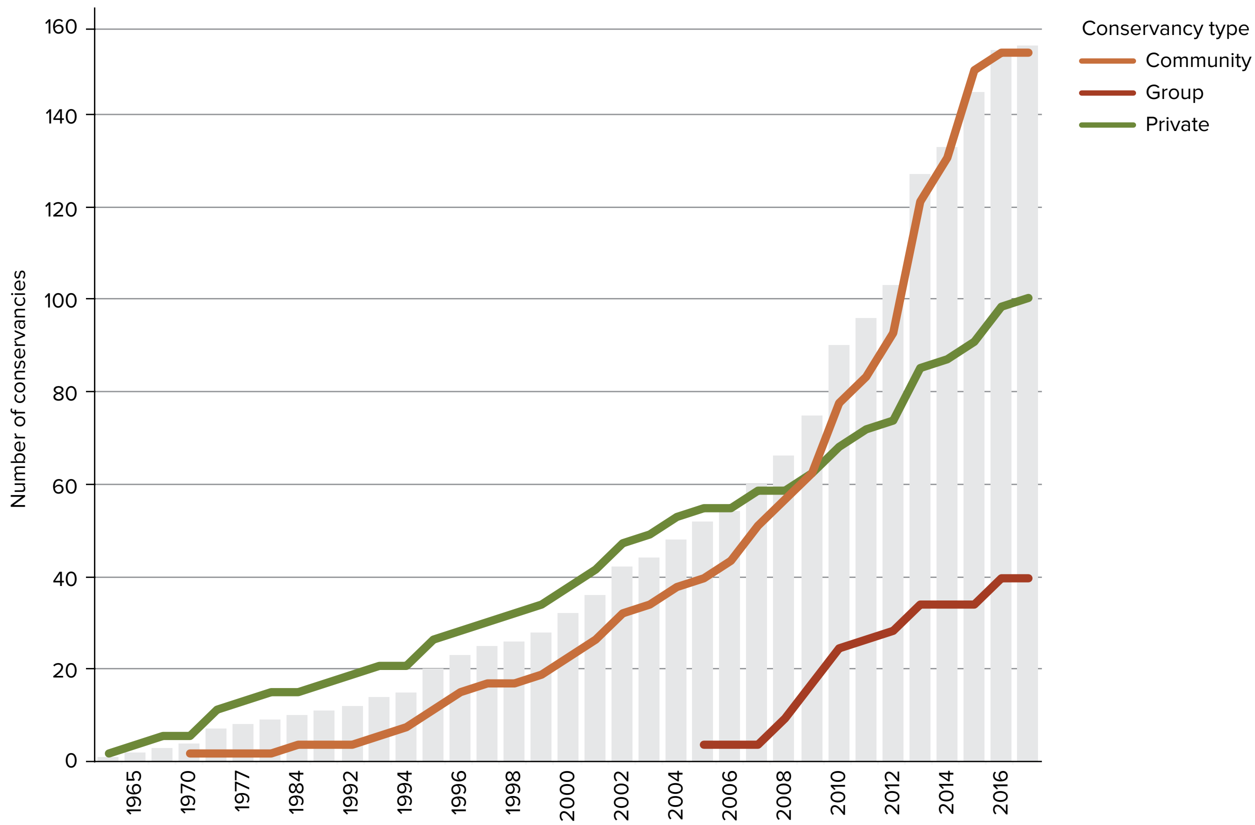
There are currently more than 160 conservancies in Kenya, spread across 28 counties, under the umbrella of KWCA. The overwhelming majority of these conservancies (137) are located in the country's South, with Kajiado and Taita Taveta counties being home to the largest number of conservancies, each hosting 25 conservancies, with Narok (16) and Nakuru (14) following suit. The northern counties of Samburu, Isiolo, Marsabit, Turkana, Garissa, and Mandera host a much smaller share of Kenya's conservancies (23), while 19 counties located in the Central and Western regions of Kenya do not host any conservancies at present

Of the 160 conservancies, 107 are currently operational, 44 are emerging, and 9 are proposed. As seen in Figure A.1, the three types of conservancies found in Kenya include (i) community conservancies—those set up by a community on community land for the purpose of livelihood development and wildlife conservation; (ii) private conservancies—those set up on private land by a private individual or corporate body for the purpose of wildlife conservation; and (iii) group conservancies—those which include the creation of a single conservancy by private landowners who pool land for the purpose of wildlife conservation.

Community conservancies first appeared in Kenya in the mid-1990s with support from nonprofits, neighboring private conservancies, and conservation-oriented corporations as a way of incentivizing landowners and communities to be custodians of wildlife. The success of establishing Kimana in 1992, Namunyak and Koiyaki-Lemek Wildlife Trust in 1995, and Il Ngwesi in 1996, all of which offered direct economic benefits from wildlife-related activities to landowners, catalyzed the growth of the community conservation model (Figure A.1). The establishment of group conservancies in the southern counties in the 2000s was catalyzed by the need to create wildlife dispersal areas and ensure connectivity of subdivided lands outside the Maasai Mara National Reserve and the Amboseli National Park. This also created an opportunity to sell an exclusive wildlife experience to visitors, promoting high-end, low-impact safari-based tourism, an alternative to the mass

14 This was driven by the draft Wildlife Conservation and Management Bill of 2011 and the Conservancy Regulations of 2012, which both explicitly recommended devolution of rights to landholders and the institutionalization of the wildlife industry in Kenya (Kenya Wildlife Conservancies Association, "Our Story," https://kwcakenya.com/about-us/our-story/). A study tour to the Namibian Association of Community Based Natural Resource Management Support Organization (NACSO), consultative meetings with over 600 stakeholders, followed by a national consultative forum, enabled the endorsement and registration of KWCA in December 2012 and April 2013, respectively.

FIGURE A.1: The rapid growth of conservancies in Kenya



Source: KWCA Conservancy Database, 2018.

tourism experience in the neighboring national parks. Now classified as a conservancy, Sergoit Farm was the first privately owned area set aside for the conservation of rhinos outside of national parks and reserves in 1953. This was followed by Ol Jogi in 1965 and Wangalla Ranch in 1968. Following the hunting ban in the 1980s, other private entities turned to a combination of ranching and conservation, driving the growth of private conservancies in the Taita Taveta, Laikipia, and Rift Lakes regions up until the mid-2000s.

The majority of Kenya's conservancies (51 percent) are on community land, while 36 percent have been established on private land, and 13 percent exist on group lands (Table A.1). Because of the ability of wildlife and livestock to coexist, coupled with the expanse of conservancies and connectivity between them, communally owned pastoral lands host vast amounts of wildlife in Kenya. This has, by default, led to community conservancies offering significant conservancy potential and demonstrating the largest growth in the conservancy movement.

TABLE A.1: Typology of Kenyan conservancies

Conservancy type	Number and % of conservancies	Area (ha)	Area (%)
Community conservancy	82 (51%)	6,100,000	76
Private conservancy	58 (36%)	1,200,000	15
Group conservancy	20 (13%)	723,000	9

Note: Analysis is based on a sample of 130 conservancies assessed for this study.

The environmental promise of conservancies

Conservancies span more than 11 percent of Kenya's territory, over 5.8 million hectares, with the northern conservancies covering 3.7 million hectares and the southern conservancies covering 2.1 million hectares. By comparison, Kenya's terrestrial national parks and reserves cover 4.7 million hectares, spanning 16 counties. As the country develops, conservancies can play a significant role in securing a place for wildlife in Kenya's future.

Conservancies significantly increase the share of wildlife living in legally protected areas, A spatial assessment of biodiversity indicates that 22 percent of the total ungulate wildlife biomass is found in conservancies, according to DRSRS data. This represents a significant complement to the 38 percent of ungulate wildlife biomass found within Kenya's national parks. Perhaps of greater importance, 18 out of 20 zones with the highest wildlife density are found in conservancies rather than in parks. Olare Orok, located next to the Maasai Mara, is the conservancy with the highest density of wildlife biomass. Key species such as the Grevy's zebra are mostly found in conservancies, while lion populations in the conservancies of the Maasai Mara are among the highest on the continent. These figures highlight the crucial role conservancies can play in protecting wildlife and helping landscapes thrive.

More significantly, a growing body of evidence suggests that conservancies have been highly successful at protecting biodiversity. For instance, in Nakuru Wildlife Conservancy, Ogotu et al. (2017) found that populations of monitored wildlife in the conservancy had stabilized for some species and increased for most, in stark contrast to the declines observed elsewhere, including in the national parks.

The economic significance of conservancies

Kenya's tourism sector generated Ksh 99.7 billion in 2016, a figure that increased by 20.3 percent to Ksh 119.9 billion in 2017 (KNBS 2018). According to the Kenya Wildlife Service (KWS) Strategic Plan of 2012–2017, safari tourism accounts for 75 percent of national tourism earnings (Ksh 74.8 billion in 2016 and Ksh 90 billion in 2017). But the share of tourism income earned by conservancies amounted to a modest 1.3 percent, suggesting considerable potential and scope for expansion in a specialized market that most likely caters to the high-value and low-volume tourists.

Safari tourism—first established as hunting safaris and progressing to ecotourism—has been one of the top revenue earners for Kenya, with national parks historically playing a crucial role. It has offered income-generating prospects to pastoral households in the arid and semi-arid regions of Kenya, which are areas of low agricultural potential. Conservancies now offer key possibilities to extend and differentiate Kenya's tourism product. For the first time, this report has collected data on the economic contribution of conservancies through tourism (Box A1).

The 13 regional associations and 160 conservancies registered under KWCA were surveyed in 2018 to collect information on Kenya's tourism infrastructure and sources of income of conservancies in 2016 and 2017. Twenty-five tour operators were also approached to gather data on income paid to conservancies, bed-nights, benefit sharing mechanisms, and philanthropic activities supported within the conservancies.

BOX A.1: Some Key Figures on the Economics of Conservancies in Kenya

- More than **930,000 members** in conservancies
- **131** tourism facilities (~2,500 beds)
- **175,000 bed-nights** in 2017, a **30% increase** compared to 2016; occupancy of 20%.
- **2,620** locals directly employed (20% women)
- Tourism operators paid more than **Ksh 1.2 billion** in bed-nights to conservancies in 2017

Of the 160 conservancies documented in this study, 69 host a total of 131 tourism facilities within their borders (Table A.2). A total of 2,510 beds exist in lodges within the conservancies mapped, with 97 percent found in the southern conservancies. Of the total beds, 41 percent are located in Narok County, 13 percent each in Kajiado and Laikipia counties, 11 percent in Taita Taveta, and 9 percent in Nakuru. The Mara conservancies (located in Narok County) currently host the largest number of facilities outside of national parks and reserves (37 percent). It should be noted though that the scope for expansion of tourism activity is constrained by a limit on "bed-nights" (conservancies such as Olare Orok only allow a single bed per 300 acres) (Bedelian 2014). These limits are meant to assure an exclusive game viewing experience and build a differentiated market and product to the high-volume tourism in the parks. Table A.2 provides an overview of the scale of tourism operations in the conservancies surveyed.

TABLE A.2: An overview of tourism facilities in Kenya's conservancies

County	No. of conservancies	No. of tourism facilities	Average no. of beds per conservancy
Baringo	2	2	15
Elgeyo Marakwet	1	1	Under construction
Kajiado	11	13	28
Laikipia	11	23	31
Lamu	1	1	21
Machakos	2	2	3
Meru	2	7	57
Nakuru	9	15	26
Narok	14	49	76
Nyeri	1	1	24
Samburu	4	6	16
Taita Taveta	7	7	39
Tana River	1	1	14
Trans Nzoia	1	1	32
Vihiga	1	1	20
West Pokot	1	1	12
Total	**69**	**131**	28

In general, conservancies that neighbor highly frequented parks and reserves have higher average bed densities, as they take advantage of other attractions and better access. The average conservancy in the sample has 28 beds, with numbers ranging from 6 in Machakos, with its conservancies being in the early stages of development, to over 1,000 in Narok, which abuts the overcrowded Maasai Mara. The Amboseli and Laikipia regions are also wildlife hot spots, with a proximity to Mt. Kilimanjaro and Mt. Kenya adding an additional attraction for visitors.

Conservancies target the high-value international tourist, though there are a growing number of local visitors with much regional variation. In Nakuru County, about 60 percent of visitors are local, and in Narok and Taita Taveta the figure stands at 30 percent, which is close to the national average. On the other hand, in Laikipia, Samburu, Meru, and Kajiado, the percentage of local tourists is much lower (at around 15 percent)—these being destinations that are targeted to the international traveler.

TOURISM: THE PRIMARY SOURCE OF INCOME FOR CONSERVANCIES

Tourism is the most significant source of income for conservancies, contributing an average of 83 percent of commercial income (NRT 2018). There are signs that income from tourism is growing rapidly in relative and absolute terms. From 2016 to 2017, the 69 conservancies with tourism facilities experienced an 18 percent increase in their total income from tourism, earning a total of Ksh 1.15 billion (Figure A.2). This amounted to an average of Ksh 26.2 million per conservancy (a minimum of Ksh 20,000 and a maximum of Ksh 253 million). Growth in income was highest in the northern conservancies, who saw a 33 percent increase in tourism income, compared to a 23 percent increase among conservancies in the south.

Members of conservancies (i.e., the local households) share the benefits from tourism either directly as revenues from running tourism facilities or through a matrix of profit-sharing structures, conservation fees, bed-night fees, or lease-holding arrangements (Box A.2).

BOX A.2: Types of Benefit-Sharing Arrangements

Bed-night fee: A proportional fee paid per occupied bed to the conservancy.

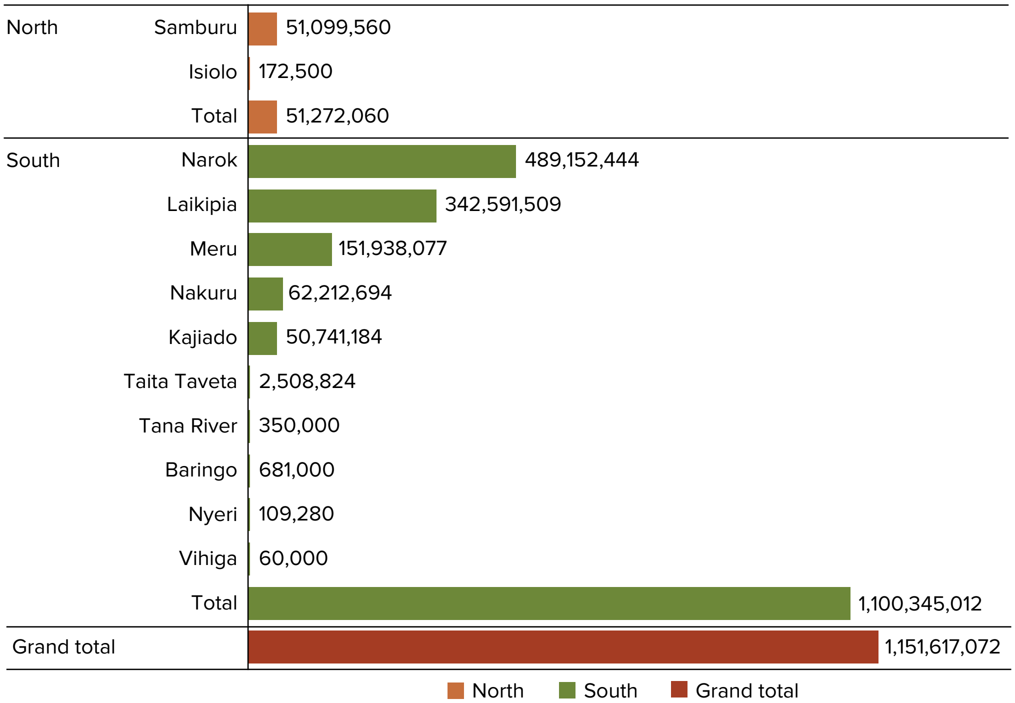
Lease-holding fee: A set monthly or annual fee paid out as rent for land or building infrastructure for an agreed-upon period.

Conservation fee: An additional fee paid per visitor or occupied bed as a payment for conservation services.

The bulk of income to conservancies (> 50 percent) is generated by fees earned from tourism-related benefit-sharing agreements, followed by livestock sales. Noncommercial activities, animal conservation (12 percent), and payments for ecosystem services (8 percent), together with livelihood activities, account for the rest of the income (Figure A.3).

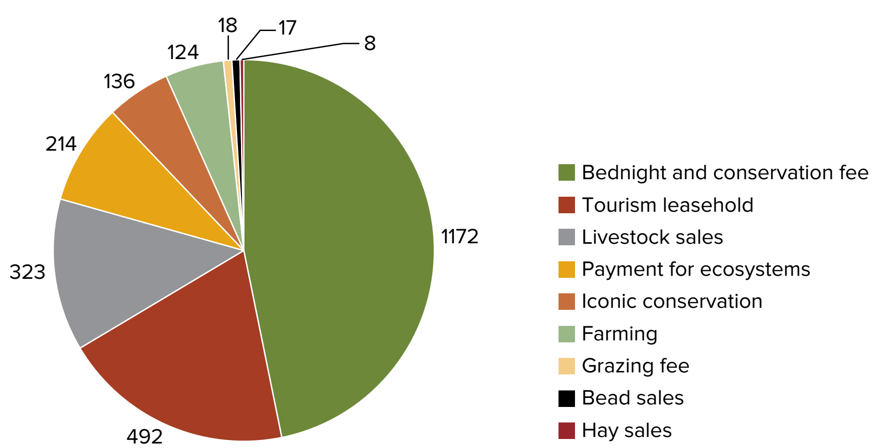
The expansion of cattle ranching and improved beef production has, over the past years, gained prominence

FIGURE A.2: Tourism income earned by conservancies (Ksh, 2017)



Source: Conservancies surveyed in this study.

FIGURE A.3: Proportion of conservancy income sources in 2017 (Ksh, millions)



Source: Conservancy survey.

within community and group conservancies, as the need for wildlife-compatible opportunities arises. However, this remains a challenge as grazing regimes need to be established, and an equilibrium between livestock and wildlife-carrying capacities needs to be determined and managed, keeping in mind cultural contexts of livestock being a measure of wealth within these communities.

Iconic animal conservation programs (of species such as rhino, elephant, Grevy's zebra, chimpanzee) are also a significant contributor to incomes, with conservancies earning an average of Ksh 12.8 million in 2016 and Ksh 11 million in 2017 from conservation fees paid by visitors to animal sanctuaries. Iconic animal conservation programs, which were the initial drivers of conservancy development in the 1960s, continue to attract tourists.

Payments for ecosystem services, particularly from carbon sequestration, have increasingly become an important revenue source for conservancies. In 2016, southern conservancies earned Ksh 30.4 million from carbon offsets (an average of Ksh 4.4 million per conservancy), and this figure increased by 605 percent in 2017 to reach Ksh 214.4 million (an average of Ksh 21.4 million per conservancy). This was mainly due to carbon-offset revenues from the Chyulu Hills REDD+ project, a multi-partner initiative aimed at reducing emissions from deforestation and degradation. As the international policy framework around land-based climate change strategies continues to mature, landscape-level conservation will offer opportunities to reap benefits from payments for ecosystem services.

OTHER BENEFITS TO COMMUNITIES

Tourism facilities within the conservancies hired 2,111 employees (12 percent women) in 2016 and 2,619 employees (17 percent women) in 2017. Most conservancies are located in pastoral areas where gender inequity exists in terms of access to education and economic opportunities, with traditional livelihood practices limiting women's opportunities outside the homestead. However, as gender empowerment through bursary and education support continues to be promoted through conservancy management structures, this trend may change.

The facilities also provide alternative sources of income to households through direct purchases of goods and services, which amounted to around Ksh 36.5 million in 2017, cultural activities such as visits to homesteads (Ksh 11.9 million in 2017), the purchase of livestock and food (Ksh 36 million in 2017), and the purchase of beadwork (Ksh 4 million). Tourism facilities have also invested in roads, education, health, and water-related infrastructure in some of the most remote regions of the country. In 2017, 11 conservancies had invested about Ksh 28.6 million in such activities, suggesting that the unaccounted impact of tourism in the form of social initiatives may be more significant than direct payments to conservancies in the form of tourism operations.

PUTTING THE NUMBERS IN PERSPECTIVE

The presence of wildlife in conservancies has been the single most important determinant of success, though this is not sufficient to assure success. Critically, there is a need for strong governance structures with transparent and equitable benefit-sharing structures. Investments in conservancies carry high risks and as such require patient capital. This is because investors must gamble not only on the prospects of attracting tourists to a new location, but also engage in a host of public good investments to build community support and fill crucial infrastructure gaps. This may suggest the need for innovative investment mechanisms, such as green bonds and risk guarantees, to shift the risk-reward balance, especially in areas that confer high ecological benefits, such as wildlife corridors.

Though tourism is the primary income-generating source for most conservancies, accounting for almost 83 percent of income (NRT 2018), conservancies and their regional associations are exploring ways to innovate and create income from other sources. The Chyulu Hills REDD+ project has demonstrated returns at scale from conservation through payments from ecosystem services. While cattle ranching also offers opportunities, it is more complex in the context of degraded land, increasing population numbers, and the need to balance livestock numbers with wildlife populations due to limited carrying capacity.

The southern tourist circuit in Kenya hosts a well-maintained infrastructure and offers opportunities for tourists to travel by road within a radius of one to five hours from Nairobi. It also hosts high wildlife densities and benefits from strong marketing. Such potential also exists in destinations such as Laikipia and in the North more generally, which also host some of the highest wildlife numbers in the country. This region, however, requires significant investments in marketing strategies aimed at both local and international travelers. Critically, as other chapters in this report have highlighted, there is also a need for infrastructure approaches that carry a lower negative footprint in order to catalyze and enable the economic opportunities that Kenya's natural assets bring.

Going further

Establishing stable or increasing wildlife population numbers is critical toward enhancing tourism income, with its potential for addressing high poverty in rural areas. The establishment and promotion of conservancies offers the most scalable avenue in ensuring wildlife habitats are secure and rehabilitated, and migration corridors are established. Wildlife hot spot areas, such as the Mara, Amboseli, and Laikipia regions, indicate that high wildlife densities can lead to significant wildlife-based tourism operations outside of national parks.

In addition to this, the assessment of policies and programs across all sectors that impact wildlife numbers should be established to ensure for wildlife-friendly national development plans.

To further promote the development of tourism outside of national parks and reserves, the national and county governments need to recognize the role conservancies play as custodians of wildlife and in developing synergistic livelihood enhancement programs. Integration of conservancy management plans in the county development plans acts as a first step to foster this recognition. Furthermore, financial support to strengthen proposed and growing conservancies on their path to sustainability will catalyze growth of the movement.

In line with Vision 2030, conservancies, which have already paved the way for exclusive wildlife-based tourism experiences, need to be incorporated into the country's parks and reserves plans to achieve the national goal of the country becoming a premium destination of high-end safari tourism. The triple bottom line of conservation, livelihoods, and economic sustainability provided by conservancies should be marketed as a unique wildlife experience within this portfolio. There is also a need to promote conservancies through Kenya Tourism Board (KTB) and Ministry of Tourism programs.

REFERENCES

Bedelian, Claire. (2014). *Conservation, Tourism and Pastoral Livelihoods: Wildlife Conservancies in the Maasai Mara, Kenya*.

Jenya National Bureau of Statistics (KNBS). (2018). *Kenya Economic Survey 2018*.

Northern Rangelands Trust (NRT). (2018). *"State of Conservancies Report, 2017*."

Ogutu, Joseph O., et al. (2017). "Wildlife population dynamics in human-dominated landscapes under community-based conservation: the example of Nakuru Wildlife Conservancy, Kenya." *PloS one* 12.1: e0169730.

APPENDIX B

ROAD EXTENSION AND WILDLIFE LOSS BETWEEN 1980 AND 2010: A DIFFERENCE-IN-DIFFERENCES APPROACH

In this appendix, we detail the methodologies and the results of the econometric model that estimate the impact roads had on wildlife in Kenya between the 1980s and the 2000s. Results echo the findings of a significant amount of literature including previous work by the World Bank, that shows a negative effect of roads on natural habitats—notably forests.

Data

WILDLIFE

Wildlife data come from the Department of Resource Surveys and Remote Sensing (DRSRS) of Kenya based on aerial surveys in the rangelands of Kenya since 1977. DRSRS conducted a total of 359 surveys from 1977 to 2016 covering 19 rangeland counties. Each county is partitioned into 5 km × 5 km UTM grids. Each 5-km transect segment is treated as an observation unit. Systematic transect lines are flown through the center of each grid on a north-south or east-west axis at a nominal height of 91–122 m (300 to 400 feet) aboveground. Widths of counting strips ranged between 224–490 m during 1977–2016. Two rear-seat observers count all wild and domestic animals the size of Thomson's gazelle (15 kg) and larger within each strip and record all counts on tape recorders. Animals in large herds of more than 10 are photographed and later counted under a binocular microscope (in earlier years) or on a large digital screen (currently) in digital photos. Refer for details to Norton-Griffiths (1978)[15] and for survey parameter (survey dates, aircraft settings, sampling fraction, and personnel involved) to Ogutu et al. (2016). Population estimates (PE) and their standard errors (SE) for each species are calculated from the sample fraction by treating each transect as a sample unit using Jolly's Method 2 (Jolly, 1969).[16] For computation limits, data were resampled at a 10 km afterwards.

To analyze how wildlife population has changed over time and spatially the data were aggregated into census periods covering surveys conducted between 1977–1989 (1980s), 1990–1999 (1990s) and 2000 and 2016 (2000s). For each grid, population estimates were calculated based on biomass (calculated in terms of Tropical Livestock Units where 250 kg is equivalent to 1 TLU) for the 18 common wildlife species[17] and were averaged for each of the counting periods. The average over the time period minimizes the influence of stochastic variation in the count totals and the distribution of animals.

WILDLIFE DYNAMICS

In the 1980s, wildlife was present in 53 percent of grid cells. In the 2000s, this number is of only 31 percent (Figure B.1). The densities of wildlife in the 1980s were highest in the southern rangelands, and the northern rangelands also had substantial wildlife distributed across the northern rangeland counties. The highest wildlife densities in the 1980s were observed in the counties of Narok, Kajiado, Taita, Lamu, and Laikipia. The 2000s distribution map indicates that the wild herds have shrunk in numbers and distribution, and have vanished rapidly in many counties including West Pokot, Turkana, Baringo, Kilifi, Lamu, Machakos, and Tana River (Said et al., 2016).[18]

ROADS

Kenya's road network has grown considerably over the last decades. We use Michelin maps of East Africa

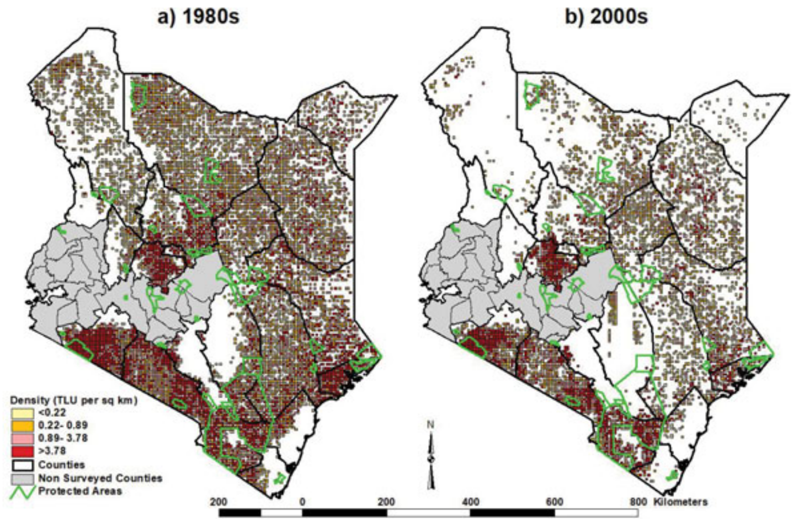
15 Norton-Griffiths, M. (1978). Counting animals. Nairobi: Africa Wildlife Leadership Foundation.

16 Jolly, G. M. (1969). Sampling methods for aerial censuses of wildlife populations. *East African Agricultural and Forestry Journal*, 34, 46–49.

17 Eighteen species are used in the analysis of the report: buffalo (*Syncerus caffer*), Burchell's zebra (*Equus burchelli*), Coke hartebeest (*Alcelaphus buselaphus*), eland (*Taurotragus oryx*), elephant (*Loxodonta africana*), gerenuk (*Litocranius walleri*), giraffe (*Giraffa cemelopardalis*), Grant's gazelle (*Gazella granti*); Grevy's zebra (*Equus grevyi*), impala (*Aepyceros melampus*), lesser kudu (*Tragelaphus imbermbis*), oryx (*Oryx gazelle beisa*), ostrich (*Struthio camelus*), Thomson's gazelle (*Gazella thomsoni*), topi (*Damaliscus lunatus korrigum*), warthog (*Pharcoerus africanus*), waterbuck (*Kobus ellipsiprymnus*), and wildebeest (*Connochaetes taurinus*).

18 Said, M. Y., Ogutu, J. O., Kifugo, S. C., Makui, O., Reid, R. S, and de Leeuw, J. (2016). Effects of extreme land fragmentation on wildlife and livestock population abundance and distribution. *Journal for Nature Conservation*, 34: 151–164.

FIGURE B.1: Kenya's wildlife populations have shrunk dramatically since the 1980s, becoming fragmented, and almost vanishing in some counties, such as in West Pokot, Baringo, Turkana, Machakos, Kwale, and Mandera



to highlight these changes and study the impact of road expansions on wildlife. For this study, all available Michelin maps for Kenya were digitized and transformed into GIS files. In 1978, the maps recorded about 7,000 kilometers of paved and improved roads, and the entire north of the country only featured improved gravel roads at the time. In the subsequent 40 years, Kenya's road network has increased by 50 percent to cover around 11,000 kilometers of improved and paved roads as of 2017. The network of roads has become denser in the South but has also been extended in the North to connect the major urban center in the region, an example being the recent paving of roads leading to Marsabit and Turkana counties.

The model

A "difference-in-differences" specification is used to determine the impact of roads on wildlife loss. It follows best practices, followed by recent studies such as Asher, Garg, and Novosad (*The Economic Journal,* forthcoming). The model exploits the expansion of the road network in Kenya in the 1980s–1990s.

The Euclidean distance between each grid cell and the nearest paved or improved road was calculated for each decade from the 1980s to the 2000s. These distances were then categorized into different bins depending on whether a cell was less than 5, 10, 15, 20, or 50 kilometers from a road. Simultaneity bias may be a significant threat when studying the impact of roads on wildlife since wildlife distribution and road placement are jointly determined. Difference-in-differences models are an effective method to overcome this challenge.

Cells that were originally (1980s) far from a road (50–100 km) are kept in the analysis. Among these cells, the model looks at how the loss of wildlife differed between cells that became closer to a road (treatment groups, 5 km, 10 km, 51 km, 20 km, and 50 km to test for the robustness of the estimates) and cells that remained far from a road (control group, >50 km). Roads here include both paved and improved roads. Formally, the model is:

$$Wildlife_{i,t} = \beta\ Cell\ Close\ from\ Road_{i,t} + \gamma Post_{i,t} + \omega\, Cell\ Close\ from\ Road * Post_{i,t} + \mu_t \times Province + PA_{i,t} + \epsilon_{i,t}$$

Where $Wildlife_{i,t}$ is the total biomass of wildlife in cell *i* during decade *t* (*t* = 1980, 1990, 2000), *Cell Close from Road* measure whether the cell has become 5, 10, 15, 20, or 50 km closer to a road during the period. *Post* is a dummy variable for periods post 1980s (i.e., once most cells became close to a road). The interactive term $Cell\ Close\ from\ Road * Post_{i,t}$ captures the difference-in-difference impact of roads on wildlife. $\mu_t \times Province$ is a province specific time fixed effect. $PA_{i,t}$ is a time varying variable that equals one if the cell belong to a Protected Area during a given decade. Cells at the borders of Kenya have a smaller area than cells which do not touch the border. Therefore, observations are weighted regarding the area of each cell. Finally, standard errors are clustered at the cell level to account for heteroskedasticity.

The main results are presented in Table B.1. In addition to showing the robustness of the results to different distance thresholds, we also show their robustness in the standard parsimonious difference-in-difference model:

$$Wildlife_{i,t} = \beta\ Cell\ Close\ from\ Road_{i,t} + \gamma Post_{i,t} + \omega Cell\ Close\ from\ Road * Post_{i,t} + \mu_t + \epsilon_{i,t}$$

Results

NON-PARAMETRIC EVIDENCE ON ROADS AND WILDLIFE

Figure B.2 plots a local smoothing regression (LOWESS) between the total wildlife loss in Kenya between the 1980s and the end of the 2000s, and the Euclidean distance to the nearest road. Wildlife decreased at a faster pace closer to roads. It highlights that wildlife loss was higher close to roads (5 to 10 km). 100 km from a road, results are no more significant.

DIFFERENCE-IN-DIFFERENCE ESTIMATES

Table B.1 presents results of the main model approach. Results from the statistical model suggest that cells located close to a road are associated with a significant decrease in wildlife, following construction of the road. The closer a cell is to a road, the larger the impact. Results in Table B.1 reveal that a cell that was once 50 kilometers away from a road, and which subsequently had a road built less than 5 kilometers away from it, lost an additional 217 TLU (or 217 × 250 = 54,250 kg) of wildlife biomass over a decade compared to cells that remained 50 kilometers from a road. Given that the average wildlife biomass in a cell between 1980 and 2009 was 266 TLU, the impact of roads has been significant: It amounts to a 78 percent additional decrease of wildlife. Twenty kilometers from a road, the impact, although two times smaller, remains ecologically significant.

Table B.2 shows the results of the standard parsimonious difference-in-differences model in which results remain robust.

FIGURE B.2: Distance to roads and wildlife loss

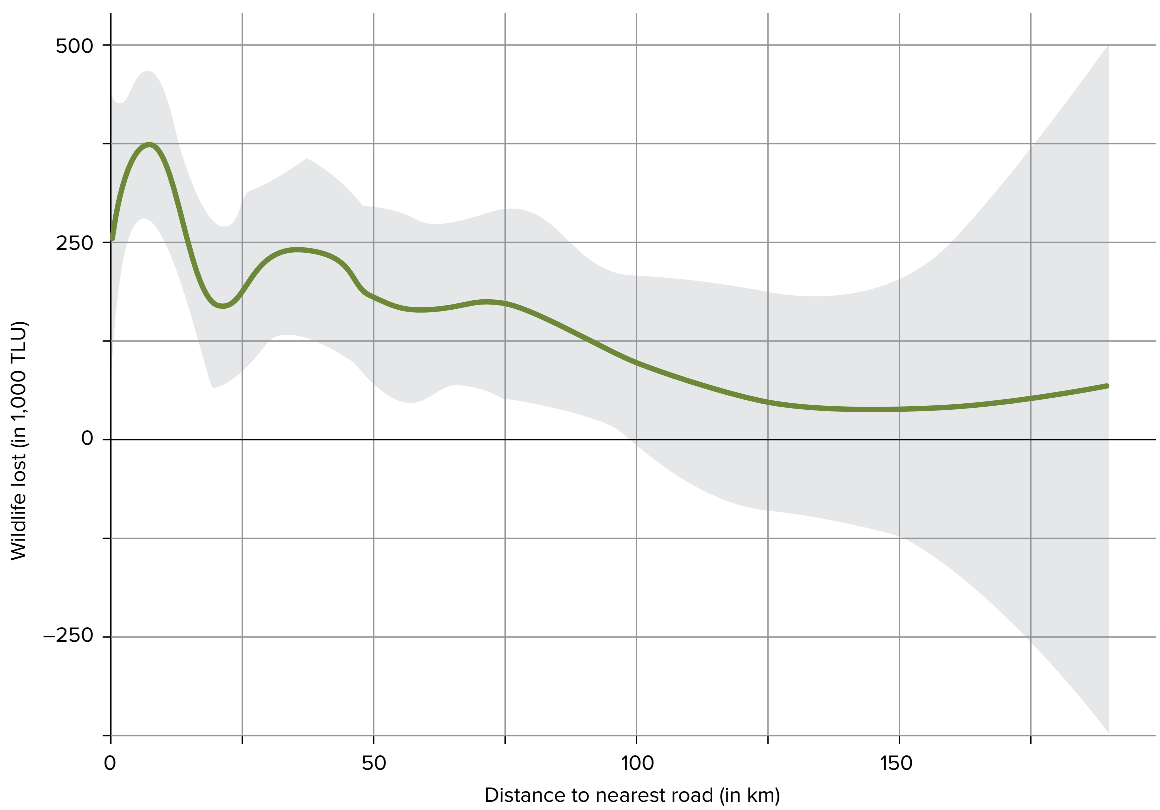


TABLE B.1: Main model

	(1) Less than 5 km	(2) Less than 10 km	(3) Less than 15 km	(4) Less than 20 km	(5) Less than 50 km
Treated × post	−217.369*	−185.138**	−134.558*	−114.494*	−65.554
	(121.325)	(85.765)	(79.109)	(65.091)	(44.057)
Post	−358.628***	−389.410***	−345.288***	−326.846***	−530.919***
	(101.365)	(100.153)	(110.082)	(105.581)	(143.272)
Observations	2,586	2,730	2,868	3,027	4,029
Number of cells	862	910	956	1,009	1,343
Treatment	Road becomes <5 km	Road becomes <10 km	Road becomes <15 km	Road becomes <20 km	Road becomes <50 km
Control	Road 50 to 100 km from cell	Road 50 to 100 km from cell	Road 50 to 100 km from cell	Road 50 to 100 km from cell	Road 50 to 100 km from cell

Note: * = p<0.05, ** = p<0.01, *** = p<0.001.

TABLE B.2: Parsimonous model

	(1) Less than 5 km	(2) Less than 10 km	(3) Less than 15 km	(4) Less than 20 km	(5) Less than 50 km
Treated × post	−207.072*	−177.400**	−134.719	−122.465*	−97.502*
	(125.676)	(88.791)	(83.136)	(70.353)	(56.474)
Post	−157.666***	−163.580***	−165.305***	−164.635***	−165.006***
	(16.259)	(16.427)	(16.704)	(16.633)	(16.338)
Observations	2,586	2,730	2,868	3,027	4,029
Number of cells	862	910	956	1,009	1,343
Treatment	Road becomes <5 km	Road becomes <10 km	Road becomes <15 km	Road becomes <20 km	Road becomes <50 km
Control	Road 50 to 100 km from cell	Road 50 to 100 km from cell	Road 50 to 100 km from cell	Road 50 to 100 km from cell	Road 50 to 100 km from cell

Note: * = p<0.05, ** = p<0.01, *** = p<0.001.

REFERENCE

Ogutu, J. O., Piepho, H. P., Said, M. Y., Ojwang, G. O., Njino, L. W., Kifugo, S. C., & Wargute, P. W. (2016). Extreme wildlife declines and concurrent increase in livestock numbers in Kenya: What are the causes? *PloS one, 11*(9), e0163249.

WORLD BANK GROUP

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