Tackling Climate Change, Land Degradation and Fragility:

Diagnosing Drivers of Climate and Environmental Fragility in Burundi's *Colline* Landscapes: Towards a Multi-Sector Investment Plan to Scale up Climate Resilience

World Bank Advisory Services and Analytics (ASA) Final Report

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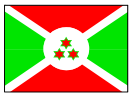

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Contents

Acronyms

AfDB	African Development Bank
ASA	Advisory Services and Analytics
CHIRPS	Climate Hazards Group InfraRed Precipitation with Stations
CORDEX	Coordinated Regional Downscaling Experiment
FCV	Fragility, conflict, and violence
GDP	Gross domestic product
GIS	Geographic information system
IDP	Internally displaced person
InVEST	Integrated Valuation of Ecosystem Services and Tradeoffs
IOM	International Organization for Migration
IPCC	Intergovernmental Panel on Climate Change
NBS	Nature-Based solutions

Executive Summary

Burundi produces less than 0.02 percent of global greenhouse gas emissions, but is deeply vulnerable to climate change impacts. Burundi is a Least Developed Country, one of the most densely populated in Africa, highly indebted and profoundly fragile. About three-quarters of its 11.6 million people live in extreme poverty, and 86 percent are employed in agriculture, mainly as subsistence farmers. Natural resource-dependent and climate-sensitive sectors also account for the vast majority of gross domestic product (GDP). Climate change impacts are already significant and disproportionately affect women, children, elders, and other marginalized groups, such internally displaced persons, refugees, and people with disabilities.

Climate change is already the main driver of internal displacement in Burundi, with climate-related hazards, chiefly floods and landslides, disproportionately affecting women and children living in the country's rural *collines* (a term that means both hills, and local administrative units). Since 2018, the World Bank has been supporting landscape-approach interventions to build resilience in Burundi's rural *collines*, with interventions set to reach 31 *collines* by 2023. There is a clear need to scale up landscape restoration and climate resilience activities to the more than 2,600 remaining *collines*, but first it is crucial to address significant knowledge and data gaps, particularly at the local level. This Advisory Services and Analytics (ASA) diagnostic aims to fill those gaps and inform a scale-up of interventions in Burundi.

Mean temperatures have risen and are set to rise further in Burundi. Analysis for this report found that from 1979 to 2018, the mean temperature in Burundi rose by an average of 0.31°C per decade. At the same time, hot days have become hotter, and cold nights have become milder. Future climate projections from this report indicate that Burundi could be 0.5–1.0°C warmer, on average, by 2040–2060, relative to 1981–2000 baseline levels.

Burundi has naturally variable rainfall, but extreme precipitation appears to be occurring more frequently. Rainfall data for Burundi show that mean annual total rainfall varies, with some decades drier or wetter than others, but there have been many instances of intense rainfall events recorded in recent years. Future rainfall projections from this report indicate uncertainty in the models, but an overall pattern of wetting in the north and drying in the south of Burundi is discernible.

Flood risks—due to heavy rainfall and to overflowing lakes and rivers—are significant, with implications for people, infrastructure, and land degradation. The flood analysis found the western and easternmost parts of the country are at particularly high risk. Near- and long-term trends in flood hazards will be influenced by land degradation, deforestation, and potential increases in extreme rainfall due to climate change. Population and infrastructure exposure to flood hazards is found to be highest in urban areas (mainly around Bujumbura Mairie, where people and assets are most concentrated), but cropland is also frequently destroyed by landslides and heavy rainfall, leaving rural communities destitute.

The ASA model results show severe and worsening land degradation, which in turn significantly impacts economic growth. A 2017 World Bank analysis estimated that Burundi loses almost 38 million tonnes of soil per year, at a cost of $120 million in 2014, or 3.9 percent of GDP. From 2017 to 2020 alone, more than 33,000 ha—1.2 percent of Burundi's land area—experienced acute degradation. This includes 10,800 ha of productive lands (1 percent of total land area). Soil erosion is getting worse; if projected trends continue, sediment loss could increase by 69 percent by 2030 from 2020 levels, and by as much as 200 percent by 2050. Land cover

has shifted significantly over the past two decades, with clear signs of urbanization; large areas have bare soil or only light vegetation cover, which makes them more prone to erosion.

Much of Burundi is at high risk of landslides, but nature-based solutions (NBS) could help protect some of the most imperiled areas. The most serious risks are concentrated in Burundi's mountainous areas, where the slopes are steepest, and there is significant overlap between communes and *collines* that are at high risk of soil erosion and landslides. The modeling shows very large potential for NBS to reduce these risks, however. Increasing vegetation cover could provide crucial protection from landslides during heavy rains, and it is also essential for preventing erosion and for protection of bare soils during droughts.

Sectoral Implications

Burundi needs to implement a multi-sector approach to building climate resilience to ensure it can successfully rebuild its economy and lift its people out of poverty. Climate change poses significant threats to Burundi's socio-economic development in Burundi and could easily overwhelm efforts to recover from the impacts of conflict and COVID-19. The analysis highlights significant risks that climate change and land degradation pose to food production and to natural ecosystems, for instance, including in Burundi's remaining forests. Burundi urgently needs to implement NBS and climate-smart agriculture at scale, as swiftly as possible, to restore degraded lands, protect ecosystems, and boost crop productivity.

Historical impacts of cyclical conflict and displacement—and the traumas they induced— exacerbate economic, social and environmental vulnerabilities in Burundi. Land scarcity is already causing intercommunal conflicts, and those conflicts could increase as arable land becomes increasingly unproductive due to climate change impacts and land degradation. This is a particular risk if Burundi's population continues to grow rapidly in the absence of new livelihood options that are less dependent on natural resources. Climate change could also compound unaddressed trauma from past conflicts, creating more fragility and fraying social cohesion.

A key way in which climate change could act as a threat multiplier is by driving displacement. Several *collines* identified as hotspots of climate risk also have concentrations of internally displaced persons (IDPs) and refugees, emphasizing the complexity of these multi-risk hotspot settings. Public health risks are also escalating with climate change, including deaths and injuries resulting from extreme events; changes in the extent and seasonality of climate-related health hazards (such as decreased water quality); and the incidence of water-borne diseases, such as cholera, and vector-borne diseases, such as malaria.

Hotspots of Risk and Recommendations

Overall, the modeling shows important variations in the current and projected climate change and land degradation-related risks across Burundi. Many different factors affect the vulnerability and adaptive capacity of each *colline*—from its landscape, to its proximity to major roads and urban centers, to poverty levels, to ongoing interventions, such as reforestation projects. This means it is important to tailor solutions for each geographic area within Burundi based on its profile, prioritizing the most vulnerable.

A *colline*-level risk assessment for this report found 347 *collines* to be at very high risk from compounded climate, land degradation and conflict risks, while another *1,780*

collines were found to be at high risk. An additional 489 *collines* were classified as facing medium *risk*. No *colline* was scored in the low or very low risk classes, meaning all of Burundi *collines* face some substantial risks.

The 347 very high-risk *collines* are hotspots of climate and environmental fragility and need to be prioritized for investment. As much as all of Burundi needs stepped-up efforts to build climate resilience, these *collines* require the most urgent attention. By starting with these highly vulnerable communities, then scaling up interventions to benefit the entire country, Burundi can prevent human suffering and displacement and help ensure that its investments in human development and economic growth have long-lasting benefits.

The analysis presented in this report underscores the urgent need to accelerate resilience-building in Burundi. This requires strengthening institutions and building capacities within the Government and mainstreaming climate change adaptation in the design of all sectoral policies and plans. This report ends with recommendations to address key institutional, policy, knowledge and financing barriers, summarized in Table ES-1. These recommendations are meant to serve as the basis for additional dialogue with stakeholders in Burundi, with the goal of developing a multi-donor resource mobilization platform to support the Government of Burundi in scaling up financing to achieve climate resilience in all of Burundi's *collines.*

Table ES-1. Recommendations to Address Barriers to Climate Resilience in Burundi's Colline Landscapes

Institutional Barriers	**Solutions**
Limited capacity at both national and local levels to identify and act on climate and land degradation risks, and their complex interactions with pre-existing post-conflict fragility. The analysis presented in this report highlights the urgent need to accelerate resilience-building efforts, by strengthening institutions and building capacities within the Government, to enable them to mainstream climate change adaptation in all sectoral policies and plans.	First, **strengthen institutional capacities** to monitor, assess and act on climate and land-related risks and communicate risk information. **Improve climate monitoring**, which is a prerequisite for effective data collection, prioritization, and analysis, and for improving Burundi's Early Warning System for multiple risks. **Support institutions to act on climate information, including from risk monitoring systems**, and use that information to enhance environmental protection and help rural *colline* communities adapt to climate change. For farmers, along with weather data, another crucial service is epidemiological monitoring, with an early warning system for crop and livestock diseases and pests.
Policy Barriers	**Solutions**
Lack of integrated climate change strategies in sectoral policies, plans, and programs; **lack of land tenure security**, which may undermine investment at the *colline* level; the **absence of contingency plans** at the *colline* Level, and **lack of incentives for green jobs and private sector investment in land restoration and climate adaptation**. The report recognizes that the Government of Burundi is taking steps to reduce climate risks, halt land degradation,	First, **develop *colline*-level, multisectoral action plans to build climate resilience, as well as local contingency plans**. Such plans could be integrated into local development planning processes to ensure that climate impacts are considered across all relevant sectors and embedded in development planning, from the local to the national level. Contingency plans are particularly important for areas that face the highest risk from land degradation, floods, and droughts. The analysis presented in this report shows that climate hazards, vulnerabilities, and coping capacities are unevenly distributed across Burundi. Even though many of the intervention types needed are the same—from nature-based solutions, to improved disaster preparedness and poverty

and restore landscapes for productive uses. The key is to scale up efforts to match the urgency of Burundi's needs.	alleviation—it is important to tailor responses to needs of each colline, and leave no community behind. Second, **make climate resilience a priority in land use and infrastructure planning**. Thoroughly consider climate risks in the design of infrastructure—from roads, to sanitation systems, to hydropower plants, schools and health facilities — and build for resilience. Create national and provincial master plans for land use planning, with appropriate risk-informed zoning regulations. Finally, **prioritize equity, inclusion, and social cohesion as essential ingredients for achieving social resilience in the face of multi-risk fragility.** Put the inclusion of marginalized groups, including women, internally displaced persons, refugees, ethnic minorities, youth, and people with disabilities, among others, at the heart of the country's development and design of resilience-building strategies. Providing space for community dialogue and addressing conflict-related trauma further reduces social conflict risks and fosters inclusion, enhancing social resilience.
Financial Barriers	**Solutions**
Significant gap between investment needs to achieve climate resilience at scale in Burundi and available funding through the national budget, donors, and impact investors. The estimated cost derived from the *colline*-level Climate Action Plan (CCAP) stands at $1.5 million per *colline.* Multiplied by the 2,639 collines of Burundi, this leads to a staggering national resilience investment cost of close to US$4 billion. Targeting only the most critical hotspots of multi-risk fragility identified in this report (347most at risk *collines*) brings this investment cost down to a minimum of $535 million.	**Convene a multi-donor roundtable for large-scale resource mobilization** to tackle drivers of climate fragility in Burundi's *collines*, with the aim to mobilize global climate financing and secure development finance from the World Bank Group, UN agencies, bilateral and multilateral partners, the private sector, and non-governmental organizations operating in Burundi. The mobilized resources would support targeted investments in climate resilience: • Leveraging nature-based solutions (NBS) to address landslide, erosion, and flood risks. • Restoring landscapes and adopting climate-smart agriculture to improve and diversify livelihoods and food security, • Protecting freshwater resources and improving water storage, including rainwater harvesting.
Knowledge Barriers	**Solutions**
Lack of technical knowledge about adaptation measures and nature-based solutions; lack of climate and disaster risk impact data, limited assessment of climate change impacts on sustainable economic growth and poverty reduction; and lack of a national climate platform for creating dialogue and sharing knowledge.	**Build capacities at all levels of government** to identify climate risks, diagnose their impacts on sector and national development, and develop appropriate policy responses. **Establish a national climate database** to track climate change impacts, including disasters, at the province and *colline* levels. **Build strong monitoring, evaluation, and learning systems**. Development partners can provide support to ensure high-quality data gathering and analytics to evaluate the effectiveness of interventions and keep improving them.

1. Context

Burundi is a small, landlocked Least Developed Country, one of the most densely populated in Africa,[1] home to an estimated at 11.9 million people in 2020,[2] growing by 3 percent or more per year over the past two decades.[3] Nestled in the Great Lakes region, Burundi is so hilly and mountainous that local administrative units are called *collines*—French for "hills." The population is overwhelmingly rural, with only about 14 percent in urban centers, mainly in the capital, Bujumbura.[4] The vast majority of the workforce is in agriculture,[5] mostly in subsistence farming, cultivating an average of 0.5 hectares (ha) per household.[6]

The economic context, combined with cycles of violent conflict in the past decades, has left Burundians with limited resources and opportunities. The country's gross domestic product (GDP) has grown far more slowly than the population, constrained by several structural challenges, including restricted public space for public investments, low capital accumulation, low productivity in agriculture and across the economy, and limited economic diversification. Burundi's exports—mainly gold, coffee, and tea—are very limited, valued at just US$218 million in 2020 (against $912 million in imports).[7] GDP per capita was just $239 as of 2020—less than one-sixth the average for Sub-Saharan Africa, according to the latest World Bank data, and lower than in any other country measured.[8]

Poverty is widespread, particularly in rural areas. About three-quarters of Burundians live on $1.90 or less per day,[9] and the latest national household survey found 43.7 percent of

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[1] At 463 persons per km^2, Burundi's population density is almost 10 times the average for Sub-Saharan Africa, but still below its neighbor Rwanda's population density of 525 per km^2. See https://data.worldbank.org/indicator/EN.POP.DNST?locations=ZG-BI.

[2] See https://data.worldbank.org/indicator/SP.POP.TOTL?locations=BI.

[3] See https://data.worldbank.org/indicator/SP.POP.GROW?locations=BI.

[4] UN DESA. 2018. "World Urbanization Prospects 2018." New York: United Nations Department of Economic and Social Affairs, Population Division. http://esa.un.org/unpd/wup/.

[5] The International Labour Organization (ILO) estimates that 86 percent of Burundi's workforce was employed in agriculture as of 2019. See https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?locations=BI.

[6] Baramburiye, J. et al. 2013. "Burundi." In *East African Agriculture and Climate Change A Comprehensive Analysis*, edited by M. Waithaka et al., 55–88. Washington, DC: International Food Policy Research Institute. doi:10.2499/9780896292055.

[7] See Observatory of Economic Complexity data: https://oec.world/en/profile/country/bdi. OEC ranks Burundi No. 175 out of 226 countries for exports and 178 out of 226 for imports. Note that OEC estimates are higher than those from the UN; see UNCTAD. 2022. "General Profile: Burundi." General Information for 2020. Geneva: United Nations Conference on Trade and Development. https://unctadstat.unctad.org/CountryProfile/GeneralProfile/en-GB/108/GeneralProfile108.pdf.

[8] GDP per capita is given in current US$; for Sub-Saharan Africa as a whole, the value was $1,502. The data indicate that Burundi's GDP per capita has actually declined; it was $305.50 in 2015. See https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=ZG-BI. In purchasing power parity (PPP) terms, or current international dollars, Burundi's per capita GDP in 2020 was $771, while the region's was $3,909—a roughly fivefold difference.

[9] The Sustainable Development Report indicators database estimates the extreme poverty rate (living on less than $1.90 per day, in purchasing power parity terms), at 74.87 percent as of 2022, roughly the same as it has been since 2016: https://dashboards.sdgindex.org/profiles/burundi/indicators.
The United Nations Development Programme estimated the extreme poverty rate at 71.8 percent as of 2016–2017. See UNDP. 2020. "Burundi: Human Development Report 2020 – The Next Frontier: Human Development and the Anthropocene." Country briefing note. New York: United Nations Development Programme. https://hdr.undp.org/sites/default/files/Country-Profiles/BDI.pdf.

households lived on less than 576,751 FBu (about US$280) per year per adult equivalent.[10] Personal remittances from abroad provide some help, but amounted to just 1.53 percent of GDP in 2020.[11] Food insecurity is chronic: 54 percent of children under age 5 display signs of stunting,[12] and 5 percent, of wasting.[13] As of early 2021, an estimated 1.33 million people in Burundi, mainly in southern and eastern communes along the Tanzanian border, were considered to be in "high acute food insecurity."[14]

Rural *collines* in Burundi are hubs of vulnerability, with high concentrations of women and children, precarious livelihoods, and very limited services. Nationwide, women and children under 15 years old made up more than 73 percent of the population as of 2019,[15] and the share is even larger in rural areas, because men are far likelier than women to migrate to cities for work. Only 3.5 percent of rural residents had access to electricity as of 2020,[16] and roads, water and sanitation infrastructure, and health care and education facilities are all underdeveloped.

Burundi has endured fragility, conflict, and violence for generations. It began in the 1960s, when the monarchy was replaced by a republic, and leaders, inheriting divide-and-rule colonial practices, began to fracture society along ethnic lines, which led to iterative cycles of violence.[17] Successive leaders imposed a strong military rule in which ethnic affiliation became a critical factor in determining alliances, thereby eroding traditional caste-based governance mechanisms. In 1972, following Hutu uprisings in the south, Tutsi forces killed many Hutus. From then on, Burundian society was divided in a Manichaean fashion. In 1992, a new constitution led to unrest between the two communities, and in 1993, following the assassination of President Ndadaye (the first Hutu and first democratically elected president) by Tutsi officers, violence became generalized. Hence, conflicts of the second part of the 20th century were primarily driven by political considerations that trickled into civilian strife.

The traumas of past conflicts continue to affect Burundians and have not been fully addressed. Psychological wounds run deep in society, as all Burundians have experienced some form of trauma and loss. The violence in 2015 deeply affected the youth and echoed memories of their elders, including killings in previous decades and some deep-seated grievances from the 1970s and the 1990s. Burundians evoke conflicts of the 1990s as still present in the minds of the people. Mental healthcare remains a blind spot in public policy and a challenge to capitalize on

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[10] Agence Burundaise de Presse. 2021. "43,7% des ménages sont pauvres selon une enquête intégrée sur les conditions de vie des ménages au Burundi de 2019-2020." December 28, 2021. https://abpinfo.bi/2021/12/28/437-des-menages-sont-pauvres-selon-une-enquete-integree-sur-les-conditions-de-vie-des-menages-au-burundi-de-2019-2020/.

[11] UNCTAD, 2022, "General Profile: Burundi."

[12] See World Bank and UN data: https://data.worldbank.org/indicator/SH.STA.STNT.ZS?locations=BI.

[13] See World Bank and UN data: https://data.worldbank.org/indicator/SH.STA.WAST.ZS?locations=BI.

[14] FAO. 2021. "Burundi: Humanitarian Response Plan 2021." Rome: Food and Agriculture Organization of the United Nations. https://www.fao.org/emergencies/appeals/detail/en/c/1372797/.

[15] Authors' analysis of data from UN DESA. 2019. "World Population Prospects 2019." New York: United Nations Department of Economic and Social Affairs, Population Division. http://esa.un.org/unpd/wpp/. As of 2019, an estimated 45.4 percent of Burundi's population was under the age of 15, and girls and women aged 15 and older made up another 27.9 percent of the population.

[16] See https://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS?locations=BI-ZG.

[17] Baltissen, G., and T. Hilhorst, eds. 2012. *Renforcement de La Gouvernance Locale Au Burundi. L'expérience Des Institutions Collinaires et Communales*. Amsterdam: KIT Publishers. https://www.researchgate.net/publication/299260438_Renforcement_de_la_gouvernance_locale_au_Burundi_L'experience_des_institutions_collinaires_et_communales/.

peace and reconciliation in a society once fractured and still not fully healed. Psychological wounds therefore add to climate-related fragility and weaken social cohesion.

Burundi also has a long history of displacement for generations, but today it is climate change, not conflict, that is the main driver. Hundreds of thousands of Burundians who fled the violence in the 1990s began to return after the ceasefire in 2003, and the role of conflict in internal displacement has greatly diminished since 2015.[18] Displacements due to climate-related disasters have surged, however, exceeding 113,000 in the past four years, including more than 35,700 in 2021 alone; torrential rains and floods were the main causes (Figure 1).[19] As of February 2022, the International Organization for Migration counted 84,373 internally displaced persons (IDPs) across Burundi, or 19,413 households. Children under 18 made up 56 percent of the IDP population, and adult women, another 21 percent. Excepting recent returnees from abroad, 92 percent of the IDPs has been displaced by disasters.[20]

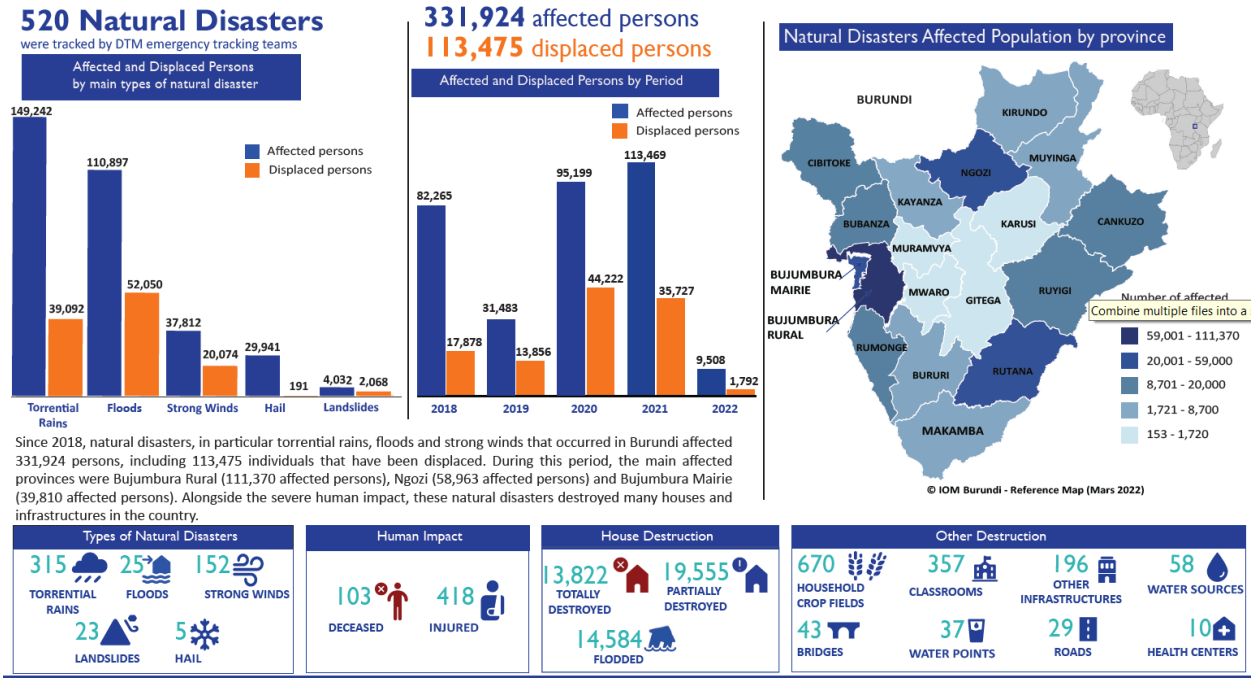

Figure 1. Disasters linked to climate-related hazards in Burundi, January 2018–March 2022. Source: IOM, 2022. Note that because of the central role of human activities in disaster risks, the term "natural disaster," as used in this graphic, is increasingly avoided by many experts. [21]

[18] See Burundi country profile by the Internal Displacement Monitoring Centre (IDMC): https://www.internal-displacement.org/countries/burundi.
[19] IOM. 2022. "Burundi – Emergency Tracking Overview – Natural Disasters: January 2018–March 2022." International Organization for Migration. https://dtm.iom.int/reports/burundi-%E2%80%94-natural-disasters-overview-january-2018-march-2022.
[20] IOM. 2022. "Burundi – Internal Displacement Dashboard." International Organization for Migration. https://displacement.iom.int/reports/burundi-internal-displacement-dashboard-february-2022.
[21] IOM, 2022, "Burundi – Emergency Tracking Overview – Natural Disasters: January 2018–March 2022."

Burundi's high exposure to climate-related disaster risks is closely linked both to its geography and its landscapes. The country's 2,638 *collines*[22] span mountainous areas as well as a central plateau and low plains in the east and south. The west side of the country is defined by the Great Rift Valley, plunging steeply into Lake Tanganyika. There are several smaller lakes as well, and a dense web of rivers. This exacerbates flood and landslide risks, and in recent years, Burundi has recorded an increase in extreme rainfall, landslides, and floods—both from rain and from river and lake swells. Trees and vegetation can provide protection, but very rapid deforestation during the conflict years and continued land conversion for farming have left the country with less than 10 percent forest cover.[23] The Government has sought to reduce risks through watershed management; the national reforestation program *Ewe Burundi Urambaye*; protection of water sources and buffer zones; and landscape restoration. A new strategy for landscape restoration was endorsed by the government in 2022. Still, climate-related disasters continue to recur, including recent catastrophic floods along Lake Tanganyika.[24]

Burundi contributes less than 0.02 percent of the globe's total greenhouse gas (GHG) emissions but will be disproportionately impacted by their consequences. Burundi emitted just 8.35 million tonnes of CO_2 equivalent (CO_2e) in 2018.[25] In per capita terms, its emissions were just 0.8 tonnes CO_2e in 2018—less than a quarter the average for sub-Saharan Africa, and one-ninth the per capita emissions of the European Union. The energy sector, which produces three-quarters of total GHGs globally, accounts for just 14.5 percent of Burundi's emissions. Instead, the top-emitting sectors are agriculture (37 percent) and land-use change and forestry (38.7 percent), reflecting the makeup of Burundi's economy and the continued conversion of forests and grasslands to cropland.[26]

At the same time, Burundi is widely recognized as particularly vulnerable to climate change. Burundi was ranked 168th out of 182 countries classified on the ND-GAIN Index in 2021.[27] Although Burundi's ND-GAIN profile does note increasing flood hazards, the country's very high vulnerability is almost entirely a function of human factors, including Burundi's largely rural, natural resource-dependent population, low and declining crop productivity, poor health

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[22] This is the most commonly cited number, but there is no official database of *collines.* The analysis presented later in this report relies on a database from the UN Office for Coordination of Humanitarian Affairs (OCHA), which actually lists 2,616 *collines.*

[23] World Bank Group. 2017. "Burundi Country Environmental Analysis: Understanding the Environment within the Dynamics of a Complex World—Linkages to Fragility, Conflict, and Climate Change." Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/28899.
Recent data from the UN Food and Agriculture Organization show 10.9 percent forest cover; see https://data.worldbank.org/indicator/AG.LND.FRST.ZS?locations=BI.

[24] Wolfe, L.M., A. Nkunzimana, and A. Christino. 2021. "As the World Discusses Climate Change, Burundi's Displaced Cannot Afford to Wait." *International Organization for Migration: The Storyteller* (blog). November 11, 2021. https://storyteller.iom.int/stories/world-discusses-climate-change-burundis-displaced-cannot-afford-wait.

[25] Climate Watch. 2019. "Global Historical Emissions." Washington, DC: World Resources Institute. https://www.climatewatchdata.org/ghg-emissions. Global GHG emissions in 2018 are estimated at 49.8 billion tonnes CO_2e.
Note that the spelling "tonne" is used in this report to clearly denote metric tons.

[26] See Republic of Burundi. 2019. "Third National Communication on Climate Change." Bujumbura: Ministry of Environment, Agriculture and Livestock. https://unfccc.int/documents/201148. Note, however, that the Climate Watch estimates of agriculture and land-use change and forestry emissions are significantly higher than the Government's, which group both categories together and show a negative value for 2015.

[27] The Notre Dame Global Adaptation Initiative (ND-GAIN) Index is widely respected for taking into account a broad range of factors that, together, shape vulnerability, as well as economic, governance, and social factors that measure adaptation readiness. See https://gain.nd.edu/our-work/country-index/rankings/.

conditions, inadequate infrastructure; and low social, governance, and economic readiness. This means that the task of building climate resilience in Burundi involves socio-economic development as much as targeted climate adaptation measures. Such an approach would be consistent with the Government's vision for "a State that promotes development that is resilient to the harmful effects of climate change."[28]

The Government of Burundi has taken several steps to address climate change and land degradation. Key national strategies, plans, and other policy documents include:

- *Nationally Determined Contribution – 2020 Update* (CDN, July 2021) https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Burundi%20First/CDN%20%20%20Burundi%20ANNEXE%201.pdf
- *Third National Communication on Climate Change* (TCNCC) https://unfccc.int/documents/201148
- *Intended Nationally Determined Contribution* (INDC, 2015) https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Burundi%20First/Burundi_INDC-english%20version.pdf
- *National Development Plan* (PND, June 2018) https://www.presidence.gov.bi/strategies-nationales/plan-national-de-developpement-du-burundi-pnd-burundi-2018-2027/
- *Vision 2025* (June 2011) https://www.presidence.gov.bi/strategies-nationales/vision-2025/
- *Strategic Guidance Document for Watershed Management And Erosion Control* (DOSBVLA, March 2022) – publication pending
- *National Drought Control Plan* (PNS, July 2020) https://bi.chm-cbd.net/fr/implementation/strategies-plans-nationaux/plan-lut-contre-secheresse-bi
- *Action Plan for Integrated Water Resources Management* (PAGIRE, March 2003) http://documentation.2ie-edu.org/cdi2ie/opac_css/doc_num.php?explnum_id=41
- *Environmental, Agricultural and Livestock Policy Guidance Document* (DOPEAE, July 2020) https://www.ifad.org/documents/38714182/42083598/Doc+orientation+ESPP+Burundi15.9.2020.pdf/027ec64a-ac8e-ddd8-f279-cc3e6081d110
- *Integrated Farming Plan* (PIP, 2014)[29]
- *National Security Strategy* (June 2013) https://www.presidence.gov.bi/strategies-nationales/strategie-nationale-de-securite/

Since 2018, at the Government's request, the World Bank has been supporting landscape-approach interventions to build resilience in rural Burundi, with interventions set to reach 31 *collines* by 2024. The work includes the $30 million Burundi

[28] Republic of Burundi. 2015. "Intended Nationally Determined Contribution (NDC)." Bujumbura: Ministry of Environment, Agriculture and Livestock. https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Burundi%20First/Burundi_INDC-english%20version.pdf.

[29] The PIP approach (Plan Integré du Paysan) was developed by Wageningen University with Burundi, and has since been applied in other countries as well. To learn more, see https://www.wur.nl/en/Research-Results/Research-Institutes/Environmental-Research/Programmes/Sustainable-Land-Use/Sustainable-agricultural-production-systems/The-PIP-approach-building-a-foundation-for-sustainable-change.htm.

Landscape Restoration and Resilience Project (2018–2024), covering 22 *collines*,[30] and $6 million in additional financing through the Global Environment Facility (2021–2024) to cover another nine *collines.*[31] There is a clear need to scale up landscape restoration and climate resilience activities to the remaining 2,608 *collines,* but there are significant knowledge and data gaps concerning climate hazards, interactions, and sector-specific impacts, particularly at the local level. The World Bank thus initiated the present Advisory Services and Analytics (ASA), funded by the PROGREEN Trust Fund, to diagnose drivers of climate and environmental fragility in Burundi. The results will inform and build the case for mobilizing large-scale investment to scale-up climate resilience interventions in Burundi's *collines*. The ASA has three main activities, as shown in Figure 2.

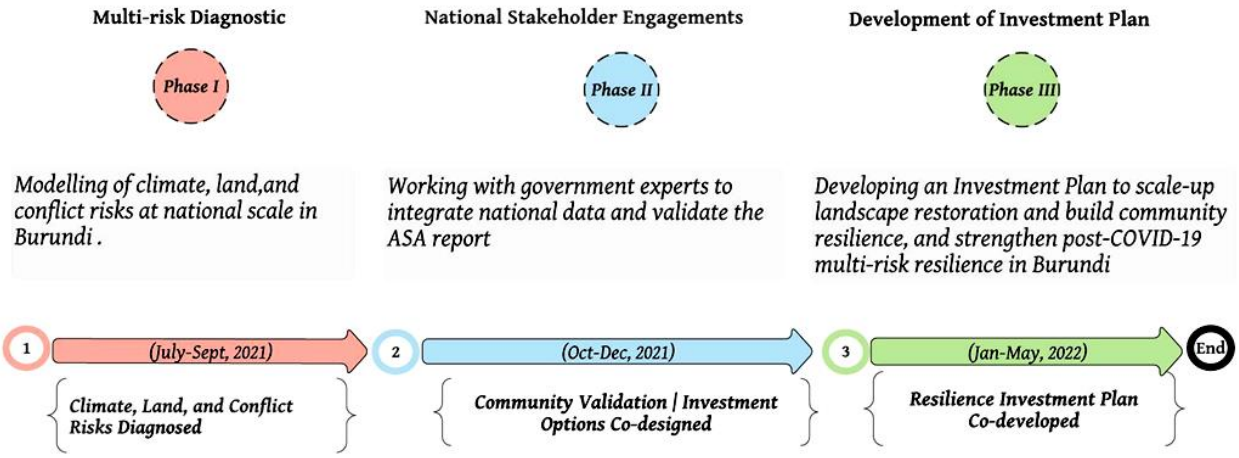

Figure 2. Project components and timeline for the Burundi Climate and Fragility ASA.

The analytical work conducted during the ASA's first phase focused on filling knowledge gaps on Burundi's current and projected climate outlook, differentiated vulnerabilities, and interactions between climate and non-climate hazards. It shed light on the exposure of critical infrastructure and key productive assets to climate change impacts, as well as on combined effects of climate change and acute land degradation, deforestation, and natural resource depletion, and the potential role of climate change as a risk multiplier. The analysis also examined how climate change might fuel conflicts over land and displacement, as well as threats to key sectors in Burundi, including agriculture, livestock, fisheries, environment, ecosystems, health, forestry, energy, infrastructure, human settlements, and water resource management. By building this evidence base, the ASA aims to facilitate consensus-building with national and international stakeholders and make the case for scaled-up investment in adaptation and landscape restoration efforts.

[30] See https://projects.worldbank.org/en/projects-operations/project-detail/P160613.
[31] See https://projects.worldbank.org/en/projects-operations/project-detail/P171745.

1.1 Study methods and report structure

The ASA diagnostic asked three overarching questions:

1. Are impacts from climate change and environmental degradation in Burundi increasing, and what is the longer-term outlook under different climate scenarios?
2. How might those impacts affect people's lives and livelihoods, and Burundi's development gains?
3. Is there a strong correlation between climate change impacts and forced displacement in Burundi, and what would that mean for projections of expected future conflict/displacement?

To answer those questions, new analysis and modelling was conducted between February 2021 and March 2022, led by Stanford University's Natural Capital Project, the Red Cross Red Crescent Climate Centre, and a national team of experts, all using the latest available national, regional and global scientific data and applying cutting-edge tools and techniques. This synthesis report combines findings from three technical reports prepared by those teams. More detailed descriptions of the data, methodologies, and study findings can be found in the underlying technical reports, accessible on the ASA online knowledge platform.[32]

To produce multi-risk national hotspot maps, the ASA utilized a multi-hazard compounded risk assessment methodology. At the core of the analysis are four complementary layers of technical modeling conducted at the national level:

- Temperature and precipitation trends, changes and hotspots;
- Land conflict risk and forced displacement hotspots;
- Land degradation, landslide, and soil erosion risks;
- Fluvial (river-related) and pluvial (rain-related) flood risks.

A summary of the methodology is provided in Annex 1 (and detailed in Technical Report 1).[33] The resulting climate fragility hotspot maps identify the *collines* that are most vulnerable to multiple, compounded, and cascading risks from climate change, land degradation and conflict risks. The compound risk analysis is based on an enhanced version of the INFORM index created by the Joint Research Centre of the European Commission.[34] Risk data were analyzed along three dimensions: exposure to climate hazards, vulnerability, and coping capacity. Box 1 at the end of this section explains how each of those terms is understood in this report, the indicators used, and how the interplay of risks—a significant concern for development planning in Burundi—is reflected in the hotspot maps.

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[32] Jaime, C. et al. 2021. "Diagnosing Drivers of Climate and Environmental Fragility in Burundi's Colline Landscapes – Climate and Conflict Risks." Burundi Climate and Fragility Advisory Services and Analytics, Technical Report 1, prepared by researchers from the Red Cross Red Crescent Climate Centre, the University of Cape Town, and 510 Initiative of the Netherlands Red Cross. Washington, DC: World Bank; Vogl, A.L., J. Leon, and N.K. Dampha. 2021. "Landslide/Soil Erosion Risks and the Potential for Nature-Based Solutions for Burundi's Colline Landscapes." Burundi Climate and Fragility Advisory Services and Analytics, Technical Report 2. Washington, DC: World Bank.

[33] Jaime et al., 2021, "Diagnosing Drivers of Climate and Environmental Fragility in Burundi's Colline Landscapes – Climate and Conflict Risks."

[34] Joint Research Centre (European Commission) et al. 2017. *Index for Risk Management - INFORM: Concept and Methodology, Version 2017*. Luxembourg: Publications Office of the European Union. https://data.europa.eu/doi/10.2760/094023.

Lastly, a community-level validation mission was conducted in May 2022 to cross-validate the findings of the national-level hotspot assessment at the *colline* level. The objective of the community-level validation exercise was to confirm the INFORM ranking and develop sample costed *colline*-level climate action plans (CCAPs) in four *collines* representative of the very high, high, and medium risk categories used in the hotspot analysis. The sample CCAPs will serve as the basis for defining and costing a proposal for scaling up resilience investments across all of Burundi's *collines*, based on a *colline*-level package of interventions.

The rest of this report is structured as follows: Section 2 summarizes the results of the climate and land degradation analyses. **Section 3** puts those results in context by examining the implications for key sectors in Burundi, as well as for fragility, conflict, and violence (FCV) risks. **Section 4** presents the maps of multi-risk hotspots and an analysis of vulnerabilities and coping capacities in these hotspots. **Section 5** provides sector-by-sector and overarching policy recommendations, linking them to Burundi's existing priorities as outlined in its updated nationally determined contribution (NDC), and describes next steps.

Box 1. Key terms and indicators used in the risk analysis

The terminology used in this analysis conveys specific meanings with implications for policy responses. We characterize climate risk as a function of hazards, exposure, and vulnerability, following the approach first adopted by the Intergovernmental Panel on Climate Change (IPCC) in its 2012 special report on extreme events, which continues to be used today.[35]

Climate risk is the potential for adverse consequences for human or ecological systems due to the impacts of climate change (or human responses), such as death or injury; harm to health and well-being; and loss or damage to economic, social and cultural assets and investments, infrastructure, ecosystems, and natural resources. When those impacts occur suddenly, they can disrupt the normal functioning of a community or a society, requiring an immediate emergency response to meet critical human needs. Others occur over time, slowly but sometimes profoundly altering living conditions.

A common mistake is to confuse climate risk with **climate hazards**—the physical processes or trends caused by climate change, such as rising temperatures, erratic precipitation, sea-level rise, and more frequent and intense extreme weather events. The potential for harm (the risk) results from the interaction of hazards with the exposure and vulnerability of affected human and ecological systems.

Exposure is simply the presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected by a hazard.

Vulnerability is the propensity or predisposition of a person, community, or system to be adversely affected by a hazard, for any of several reasons, such as the climate-sensitivity of someone's livelihood (farming is more climate-sensitive than factory work, for example), poverty, and marginalization.

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[35] IPCC. 2012. "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D."
See also IPCC. 2022. "Summary for Policymakers." In *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by H.-O. Pörtner et al. Cambridge, UK, and New York: Cambridge University Press (in press). https://www.ipcc.ch/report/ar6/wg2/.
The definitions presented here roughly follow the wording used in the draft Glossary for the Sixth Assessment Report, lightly adapted for clarity and ease of understanding.

Coping capacity is the ability of people, institutions, organizations, and systems, using available skills, values, beliefs, resources, and opportunities, to manage and overcome adverse conditions. It is closely linked to the concept of resilience (which refers to the ability to withstand and recover from shocks without significant lasting harm or changes).[36]

Figure 3 shows how the interaction of hazards, exposure, and vulnerability results in climate risk, as well as some of the questions that may be asked in assessing climate risk in a given context.

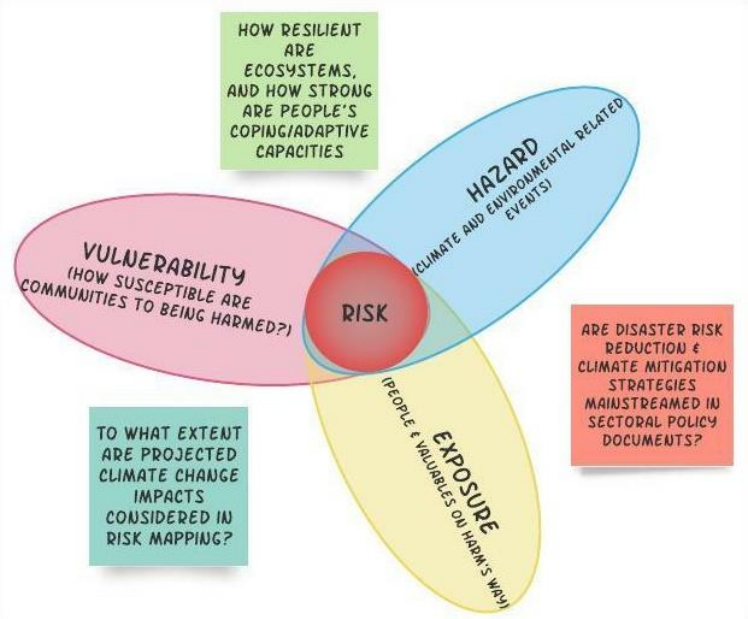

Figure 3. A conceptual framework of risk as a function of hazard, exposure, and vulnerability, in line with the IPCC's definition of climate risk. The questions on the "sticky notes" are placed at random and are only examples of relevant issues to consider when conducting risk mapping and when introducing climate mitigation and adaptation strategies.

The ASA analysis also accounts as much as possible for different hazard types, dynamics, and interactions. For example, changes in temperature and precipitation (rainfall) are the primary (first-order) climate hazards examined in this analysis. They not only cause direct harm, but also trigger the occurrence of multiple secondary (second-order) hazards or cascade into causing other hazards. For instance, hotter temperatures lead to droughts, and droughts, in turn, increase the probability of wildfires. They also harden the soil, increasing the risk of floods the next time there is heavy rainfall. All this can affect people's lives and livelihoods as well as ecosystems in Burundi.

We also factor in compound hazard interactions. This is when two different climate extremes occur simultaneously or successively, or when extremes are combined with background conditions that amplify their overall impacts. This analysis examined multiple cascading and compound hazards, including extreme temperature, heavy rainfalls, floods, erosion, landslides, droughts, violent winds, wildfires, lightning, hailstorms, and land conflict.

[36] The IPCC (2022) uses "coping capacity" in a more near-term and reactive sense, and "adaptive capacity" in a broader sense—the latter defined as the ability "to adjust to potential damage, to take advantage of opportunities, or to respond to consequences." The ASA does not delve into that distinction, but focuses on coping capacity.

2. Burundi's Climate Outlook

Burundi has a tropical highlands climate, defined to a great extent by its topography.[37] Temperatures in Burundi in given locations are characterized by minimal oscillations during the year. The warmest parts of Burundi, at lower elevations, have a mean temperature of about 23°C, while at high elevations, the mean temperature is 16°C. Mean annual rainfall is highest over the central parts of the country and lowest over the northeast and the lower elevation of the southwest, with ranges from 1,000 to 1,750 mm/year.

The country has two main seasons: the dry season, from June to August, and the rainy season, from September to May. The latter has a distinct bimodal regime, with peak rainfall concentrated in March–May (the "long" rainy season) and October–November (the "short" rainy season). Burundi's climate is influenced by the north–south movement of the Intertropical Convergence Zone (ITCZ), as well as remote factors such as the El Niño Southern Oscillation and the Indian Ocean Dipole. The movement of the ITCZ is the key factor controlling rainfall patterns over Burundi.

2.1 Temperature trends and projections

Globally and in Africa, the climate is warming at an accelerating pace. The global surface temperature in 2011–2020 was about 1.09°C higher than in 1850–1900, with almost twice the increase over land (1.59°C) as over the ocean (0.88°C).[38] Faster warming has been observed in many parts of the world, however. The latest IPCC assessment found temperatures rose "rapidly" over Africa from 1961 to 2015, with "significant increases in all regions of 0.1°C–0.2°C per decade," and even faster warming in some northern, eastern and southwestern regions.[39]

In Burundi, analysis for this report shows that from 1979 to 2018, the mean temperature rose by an average of 0.31°C per decade (0.18–0.41°C), as shown in Figure 4.[40] This is consistent with the findings of a recent analysis of weather station data in 1950–2014.[41] At the same time, hot days have become hotter, and cold nights have become milder. Annual daily maximum and minimum temperatures have both increased significantly since 1979,

[37] This brief profile of Burundi's climate summarizes a longer description in Technical Report 1. See Section 3 of Jaime et al., 2021, "Diagnosing Drivers of Climate and Environmental Fragility in Burundi's Colline Landscapes – Climate and Conflict Risks."

[38] IPCC. 2021. "Summary for Policymakers." In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by V. Masson-Delmotte et al. Cambridge, UK, and New York: Cambridge University Press. https://www.ipcc.ch/report/ar6/wg1/.
The estimates range from 0.95°C to 1.20°C overall, from 1.34°C to 1.83°C over land, and from 0.68°C to 1.01°C over the ocean.

[39] IPCC et al. 2021. "Atlas." In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by V. Masson-Delmotte et al. Cambridge, UK, and New York: Cambridge University Press. https://www.ipcc.ch/report/ar6/wg1/.

[40] For more details, see Jaime et al., 2021, "Diagnosing Drivers of Climate and Environmental Fragility in Burundi's Colline Landscapes – Climate and Conflict Risks."

[41] Lawin, A.E., C. Manirakiza, and B. Lamboni. 2019. "Trends and Changes Detection in Rainfall, Temperature and Wind Speed in Burundi." *Journal of Water and Climate Change* 10 (4): 852–70. doi:10.2166/wcc.2018.155.

with minimums rising faster. Those findings are consistent with a recent analysis that found extreme temperature and heatwaves have increased in East Africa region.[42]

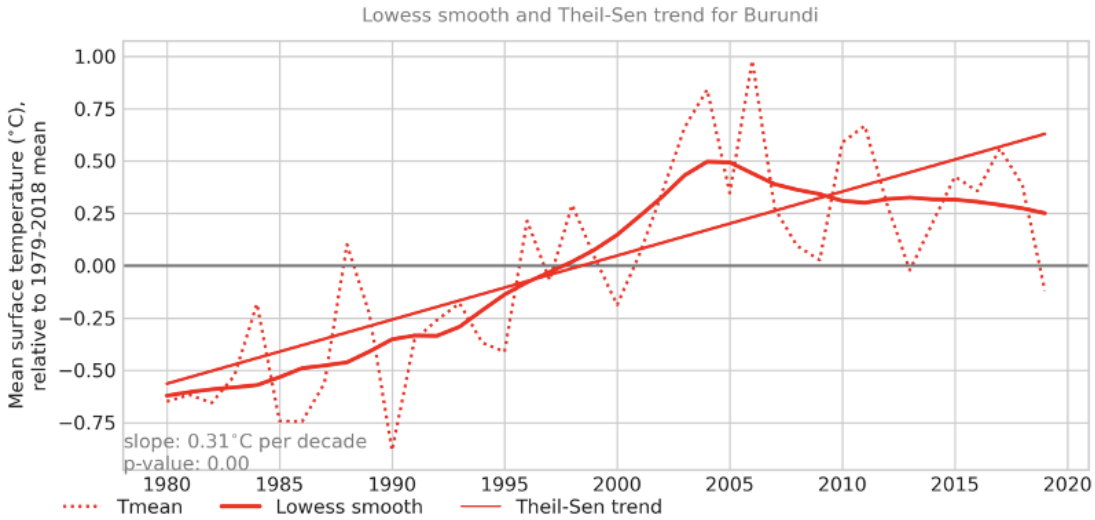

Figure 4. Long-term trends and variability in annual mean temperature (averaged over Burundi watershed). Data source: WFDEI-CRU.

Figure 5 shows Burundi's weather stations for which maximum and minimum temperature trend data could be analyzed, noting which show significant upward trends. Appendix 2 provides the actual trend graphs for each of the stations.

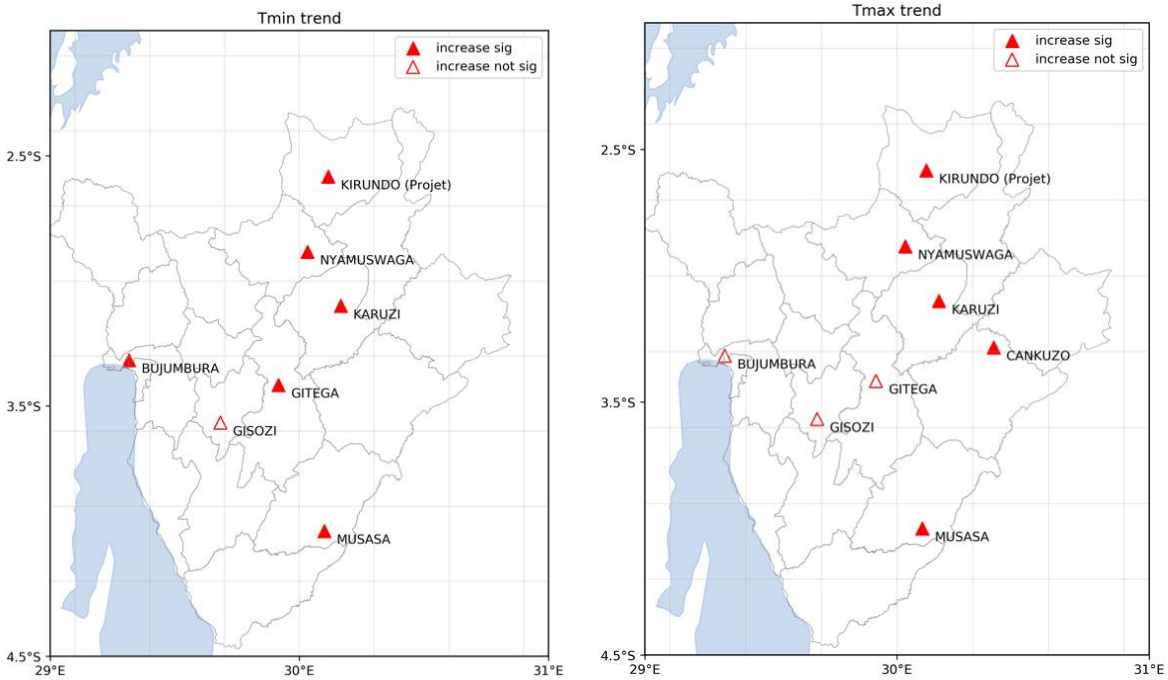

Figure 5. Weather stations across Burundi, indicating with filled red triangles those that show significant increases in annual daily maximum (left) and minimum (right) temperatures. Data source: IGEBU.

[42] Engdaw, M.M. et al. 2022. "Changes in Temperature and Heat Waves over Africa Using Observational and Reanalysis Data Sets." *International Journal of Climatology* 42 (2): 1165–80. doi:10.1002/joc.7295.

Future climate projections from the analysis indicate that Burundi could be 0.5–1.0°C warmer, on average, by 2040–2060, relative to 1981–2000. Appendix 1.1 provides a summary of the modeling methodology, which is described in more detail in Technical Report 1.[43] Projections were made for the near term (2020–2040) and the medium term (2040–2060), using a moderately low-emissions scenario (RCP 4.5) and a very high emissions scenario (RCP 8.5). There was high agreement in the model results that temperatures would rise. In general, Burundi is projected to warm significantly faster in the high-emissions scenario, with the difference between scenarios widening over time. Figure 6 shows projections for the annual daily maximum and minimum temperatures.

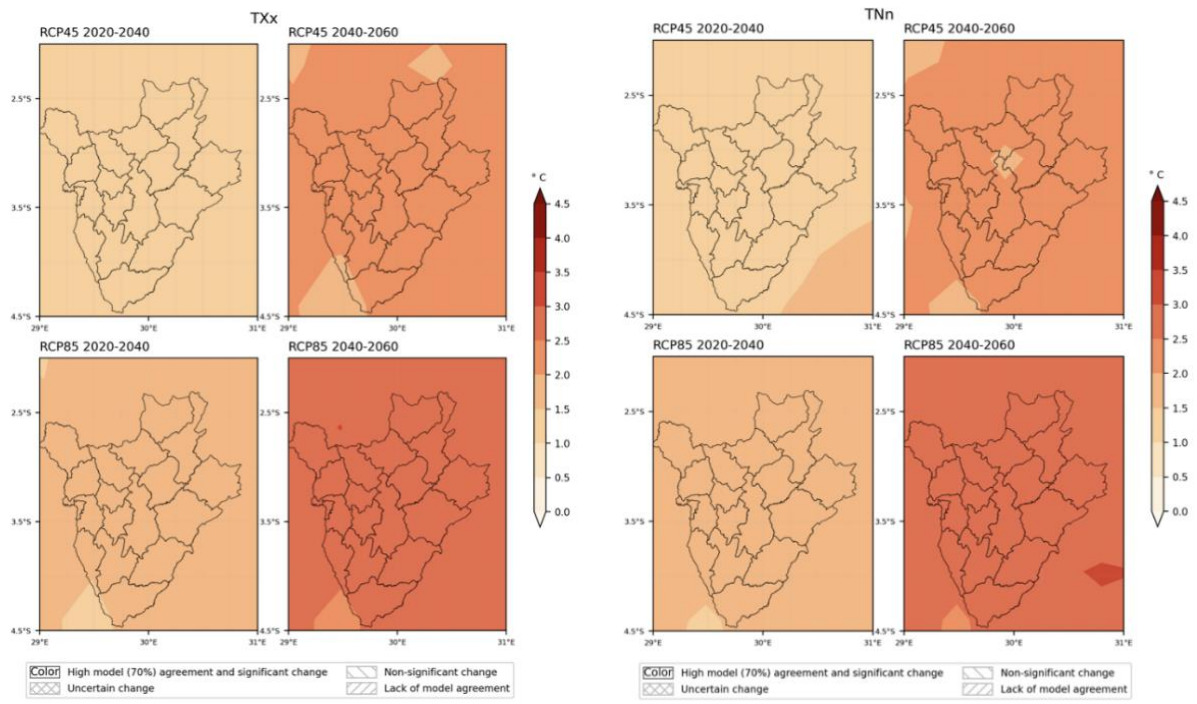

Figure 6. Multi-model mean of temporally averaged changes in the annual daily maximum (hottest day, left) and minimum temperature (coldest night, right) over the time periods 2020–2040 and 2040–2060, displayed as differences in °C.

2.2 Rainfall trends and projections

Rainfall data for Burundi show a history of variability in mean annual total rainfall, with some decades drier or wetter than others (Figure 7).[44] An analysis of Climate Hazards Group InfraRed Precipitation with Stations (CHIRPS)[45] data showed no statistically significant long-term trend—only what appeared to be large natural variability. The period 1990–2010 had only a handful of wet years, and otherwise was drier than the 1980s. Figure 8 summarizes the results of a similar analyses of weather station data, showing statistically significant increases at

[43] Jaime et al., 2021, "Diagnosing Drivers of Climate and Environmental Fragility in Burundi's Colline Landscapes – Climate and Conflict Risks."
[44] Jaime et al., 2021.
[45] Funk, C. et al. 2015. "The Climate Hazards Infrared Precipitation with Stations—a New Environmental Record for Monitoring Extremes." *Scientific Data* 2 (1): 150066. doi:10.1038/sdata.2015.66.

three stations, and no statistically significant trends in the others (though most show an increase in total annual rainfall). Graphs for the weather stations are provided in Appendix 2.

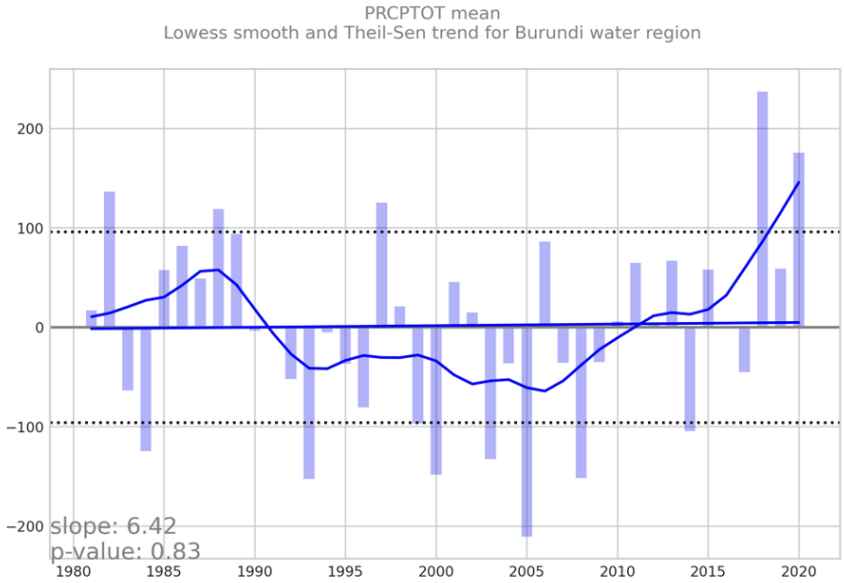

Figure 7. Total mean annual rainfall anomalies relative to the mean for the period analyzed. The dotted horizontal line represents one standard deviation from the mean. The curved line represents the lowess smooth. Data source: CHIRPS.

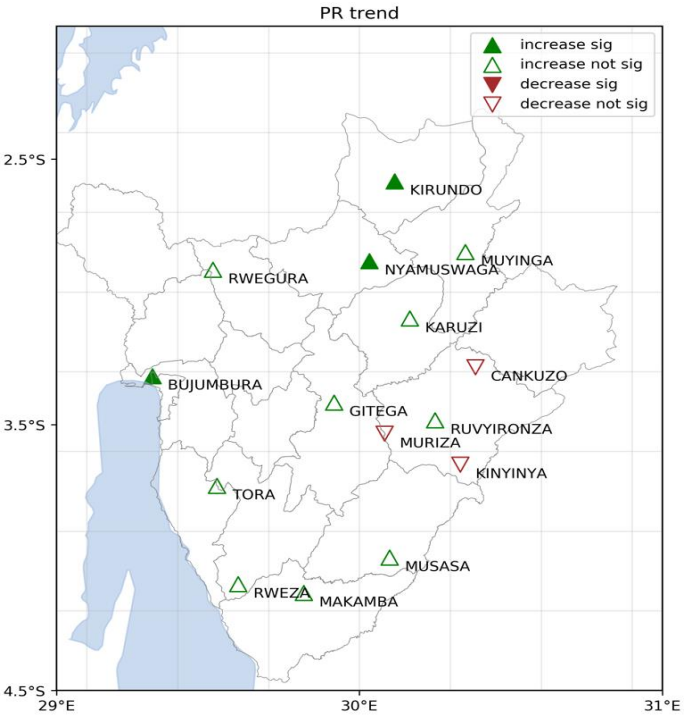

Figure 8. Summary of analysis of total annual precipitation data and trends at Burundi's weather stations. Significant trends are represented with filled triangles. Data source: IGEBU.

Although natural variability makes it difficult to discern any trends in precipitation extremes, numerous intense rainfall events have been recorded in recent years. CHIRPS data show strong decadal variability in the period 1981–2019 in indices for rainfall intensity, by

different measures (for example, maximum one-day or five-day precipitation, average amount of rainfall on days exceeding 1mm, and maximum length of a dry spell. No significant long-term trend was detected, which is consistent with a prior analysis based of other datasets.[46] An earlier study using 1950–2014 data from two weather stations had suggested a downward trend, but the analysis did not cover 2015–2020, a period when overall rainfall was high, and there were multiple extreme precipitation events.

Future precipitation projections prepared for this report show uncertainty in the models, but an overall pattern of wetting in the north and drying in the south (Figure 9).[47] However, those projections are not considered robust for the majority of Burundi, as there is a lack of model agreement and the changes are not statistically significant—that is, they could still be masked by natural variability. Significant changes in future precipitation are projected for Rutana province as well as the eastern province of Ruyigi and central province of Gitega for both periods and scenarios considered.

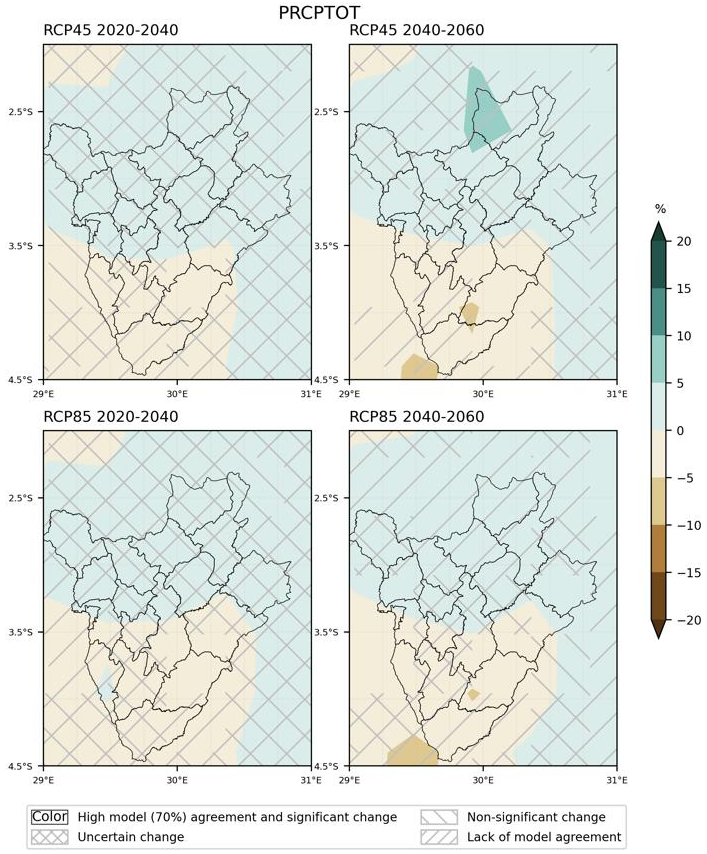

Figure 9. Multi-model mean of temporally averaged changes in mean annual total precipitation (PRCPTOT) over the time periods 2020–2040 and 2040–2060, displayed as differences (in %) relative to the reference period (1981–2000) for RCP 4.5 (top) and RCP 8.5 (bottom). Data source: CHIRPS.

[46] Nkunzimana, A. et al. 2019. "Spatiotemporal Variation of Rainfall and Occurrence of Extreme Events over Burundi during 1960 to 2010." *Arabian Journal of Geosciences* 12 (5): 176. doi:10.1007/s12517-019-4335-y.
[47] Jaime et al., 2021, "Diagnosing Drivers of Climate and Environmental Fragility in Burundi's Colline Landscapes – Climate and Conflict Risks."

2.3 Flood risk

The flood analysis found that large areas of Burundi are highly susceptible to both fluvial (river) and pluvial (rainfall) flood hazards (Figure 10).[48] As described briefly in Appendix 1.2, and in detail in Appendix I of Technical Report 1, a spatial multi-criteria evaluation was conducted. The western and easternmost parts of the country are at particularly high risk. Overall, 11 percent of Burundi's landscape was found to face the "highest" level of flood risks; 13 percent, "high"; 46 percent, "moderate"; and 25 percent, "low"; only 5 percent of the country's total landmass fell into the "lowest" risk category.

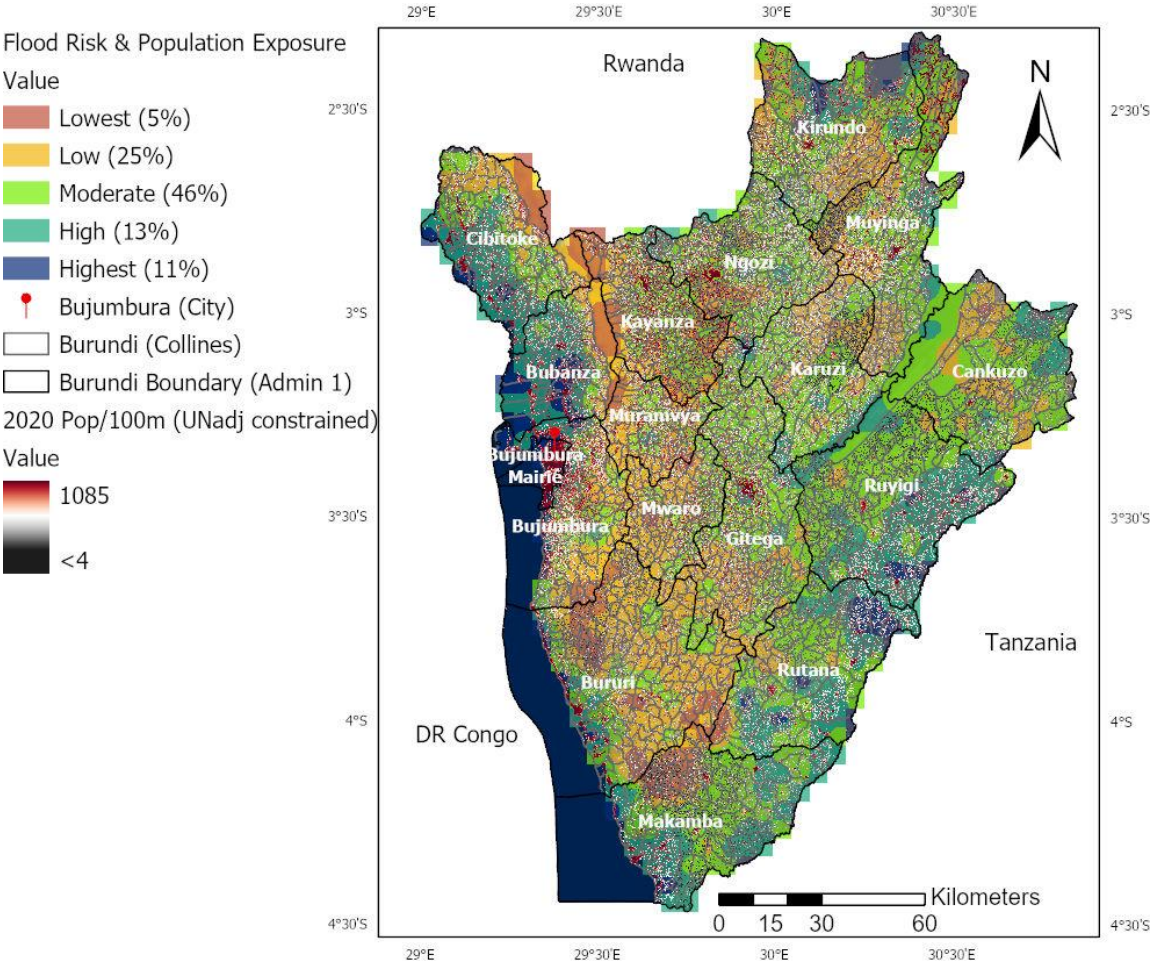

Figure 10. Population exposure to flood hazards, by colline, showing flood risk hotspots.

Near- and long-term trends in flood hazards will be influenced by land degradation, deforestation, and potential increases in extreme rainfall due to climate change. Floods are a particularly serious concern because they are already taking a devastating toll. In the past four years, the International Organization for Migration (IOM) has tracked over 52,000 people displaced by floods and over 39,000 displaced by torrential rains.[49] Together, the two closely related hazards account for more than 80 percent of total displacements in that period.

[48] Jaime et al., 2021.
[49] IOM, 2022, "Burundi – Emergency Tracking Overview – Natural Disasters: January 2018–March 2022."

Population and infrastructure exposure to flood hazards is highest in urban areas of Burundi, but cropland is also frequently destroyed. Among the most affected places are Bujumbura Mairie, as well as other communities in Bujumbura province (e.g., Mushasha), and urban areas in Bubanza province (e.g., Ruyange, Gifurwe), Cibitoke province (e.g., Buganda), and Makamba province (e.g., Mukungu). This is due mainly to the presence of large impervious surfaces, as well as to densely settled areas that often lack the infrastructure needed to manage rainwater. Urban floods cost lives, disrupt livelihoods, and cause extensive damage to property and infrastructure in many developing countries, not just in Burundi.[50] In rural areas, meanwhile, flood damage to agricultural lands can also exacerbate food insecurity.

Several areas identified in the model as facing "highest" or "high" flood risks are already experiencing severe floods. Some of the worst impacts have occurred in Bujumbura Mairie and province, as well as in Rutana and Ngozi provinces (see Figure 1 in the introduction to this report). In April 2020, for instance, torrential rains in the Bujumbura region caused the Rusizi River to burst its banks; 27,000 people were affected by the floods. In April 2021, another round of torrential rains caused Lake Tanganyika to rise to dangerous levels, flooding homes and requiring mass evacuations; six weeks later, a dike on the Rusizi River near Gatumba burst, causing more catastrophic flooding, including of an IDP camp, where the houses were washed away; altogether, more than 47,000 people were affected.[51] Mapping all the sites of severe floods was beyond the scope of this study, but other flood risk maps reviewed validate the accuracy of flood hotspot locations (see Technical Report 1).[52]

2.4 Land degradation in Burundi: Landslide and soil erosion risks

Land cover has shifted significantly in Burundi over the past two decades, with clear signs of urbanization, but also a sharp decline, then partial recovery of some natural ecosystems.[53] The share of urban and built-up areas, though still only 0.4 percent in 2020, is double what it was in 2010 and 10 times the share in 2000. Both forest and savanna cover declined from 2000 to 2015, but have since increased, to 4.32 percent and 28.1 percent, respectively. The share of land classified as croplands has dropped dramatically, by 59 percent since 2000 and 38 percent since 2010, but the share of cropland/natural vegetation mosaics has grown by 74 percent since 2000 (mainly in 2000–2005), to 905,442 ha as of 2020, or 36.01

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[50] See, for example, Nkwunonwo, U.C., M. Whitworth, and B. Baily. 2020. "A Review of the Current Status of Flood Modelling for Urban Flood Risk Management in the Developing Countries." *Scientific African* 7 (March): e00269. doi:10.1016/j.sciaf.2020.e00269; Dampha, N. 2020. "Ecosystem Services and Coastal Adaptation to Climate Change: An Interdisciplinary Science-Based Application in The Gambia." Ph.D. dissertation in Natural Resources Science and Management. University of Minnesota. https://hdl.handle.net/11299/217791; Brito, M.M. de, M. Evers, and A.D.S. Almoradie. 2018. "Participatory Flood Vulnerability Assessment: A Multi-Criteria Approach." *Hydrology and Earth System Sciences* 22 (1): 373–90. doi:10.5194/hess-22-373-2018; Adelekan, I.O. 2010. "Vulnerability of Poor Urban Coastal Communities to Flooding in Lagos, Nigeria." *Environment and Urbanization* 22 (2): 433–50. doi:10.1177/0956247810380141.

[51] The numbers of affected people are from the EM-DAT database: https://public.emdat.be. Descriptions are based on: IFRC. 2022. "Burundi: Floods and Landslides April 2021 Final Report - DREF Operation N° MDRBI018." International Federation of Red Cross and Red Crescent Societies. https://reliefweb.int/report/burundi/burundi-floods-and-landslides-april-2021-final-report-dref-operation-n-mdrbi018; ACAPS. 2020. "Burundi Floods." Briefing Note. Geneva: ACAPS. https://reliefweb.int/report/burundi/acaps-briefing-note-burundi-floods-28-april-2020.

[52] Jaime et al., 2021, "Diagnosing Drivers of Climate and Environmental Fragility in Burundi's Colline Landscapes – Climate and Conflict Risks."

[53] Vogl, Leon, and Dampha, 2021, "Landslide/Soil Erosion Risks and the Potential for Nature-Based Solutions for Burundi's Colline Landscapes."

percent of Burundi's total land area, making it the top land cover type in the country. This could indicate shifting cultivation patterns driven by declining yields on previously intensively cropped lands, or it could be due to shifts in rainfall affecting the local vegetation. The analysis therefore treats these mosaics as productive landscapes in the risk analysis. Table 1 shows the results of the analysis, which are then displayed on a map in Figure 11.

Table 1. Area in each land cover class and its share of total area, by time period of the analysis.

	Area in ha (% of total area)				
Land use/Land cover class	**2000**	**2005**	**2010**	**2015**	**2020**
Evergreen broadleaf forests	119 253 (4.74%)	84 714 (3.37%)	104 537 (4.16%)	99 696 (3.97%)	108 523 (4.32%)
Savannas: tree cover 10–30%	574 856 (22.87%)	600 604 (23.89%)	508 946 (20.24%)	475 074 (18.90%)	706 478 (28.10%)
Grasslands: dominated by herbaceous annuals	744 815 (29.63%)	545 715 (21.71%)	527 301 (20.97%)	652 563 (25.96%)	562 744 (22.38%)
Permanent wetlands	2 092 (0.08%)	3 136 (0.12%)	4 830 (0.19%)	6 149 (0.24%)	8 360 (0.33%)
Croplands	446 228 (17.75%)	438 422 (17.44%)	433 235 (17.23%)	295 221 (11.74%)	184 066 (7.32%)
Cropland/Natural vegetation mosaics	520 385 (20.70%)	753 943 (29.99%)	793 786 (31.57%)	903 039 (35.92%)	905 442 (36.01%)
Urban, built-up, or exposed soil	986 (0.04%)	4 413 (0.18%)	5 005 (0.20%)	7 721 (0.31%)	10 059 (0.40%)
Barren: at least 60% of area is non-vegetated	89 563 (3.56%)	67 991 (2.70%)	121 315 (4.83%)	61 669 (2.45%)	17 622 (0.70%)
Water bodies	15 659 (0.62%)	15 199 (0.60%)	15 183 (0.60%)	13 004 (0.52%)	10 843 (0.43%)

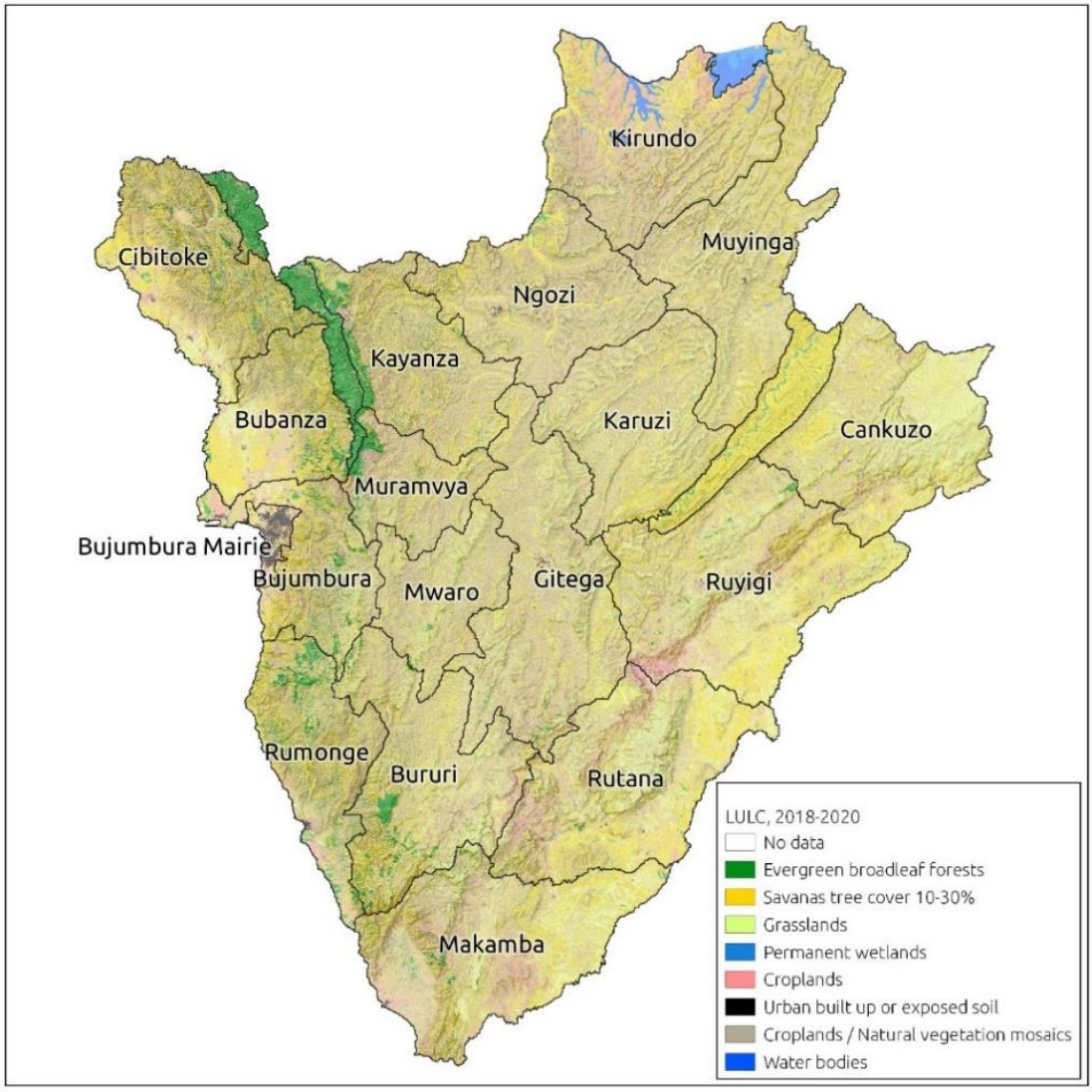

Figure 11. Land cover classification for the year 2020.

Burundi has very large areas with bare soil or only light vegetation cover. Bare and lightly vegetated areas are more prone to erosion, as the wind can easily blow away soil—and water can wash it away, particularly in areas with steep inclines. A 2017 World Bank analysis estimated that Burundi loses almost 38 million tonnes of soil per year, particularly from croplands.[54] In the agro-ecological zone of Mumirwa, an estimated 3 percent of the soil is being lost each year, so farming could become impossible within three decades. The 2017 analysis found that erosion was particularly acute in the steep sloped areas of Mumirwa, the Congo Nile ridge, and the highest points of the Central Plateau. Figure 12 shows the results of a bare soil index analysis for this report.

[54] World Bank Group, 2017, "Burundi Country Environmental Analysis: Understanding the Environment within the Dynamics of a Complex World—Linkages to Fragility, Conflict, and Climate Change."

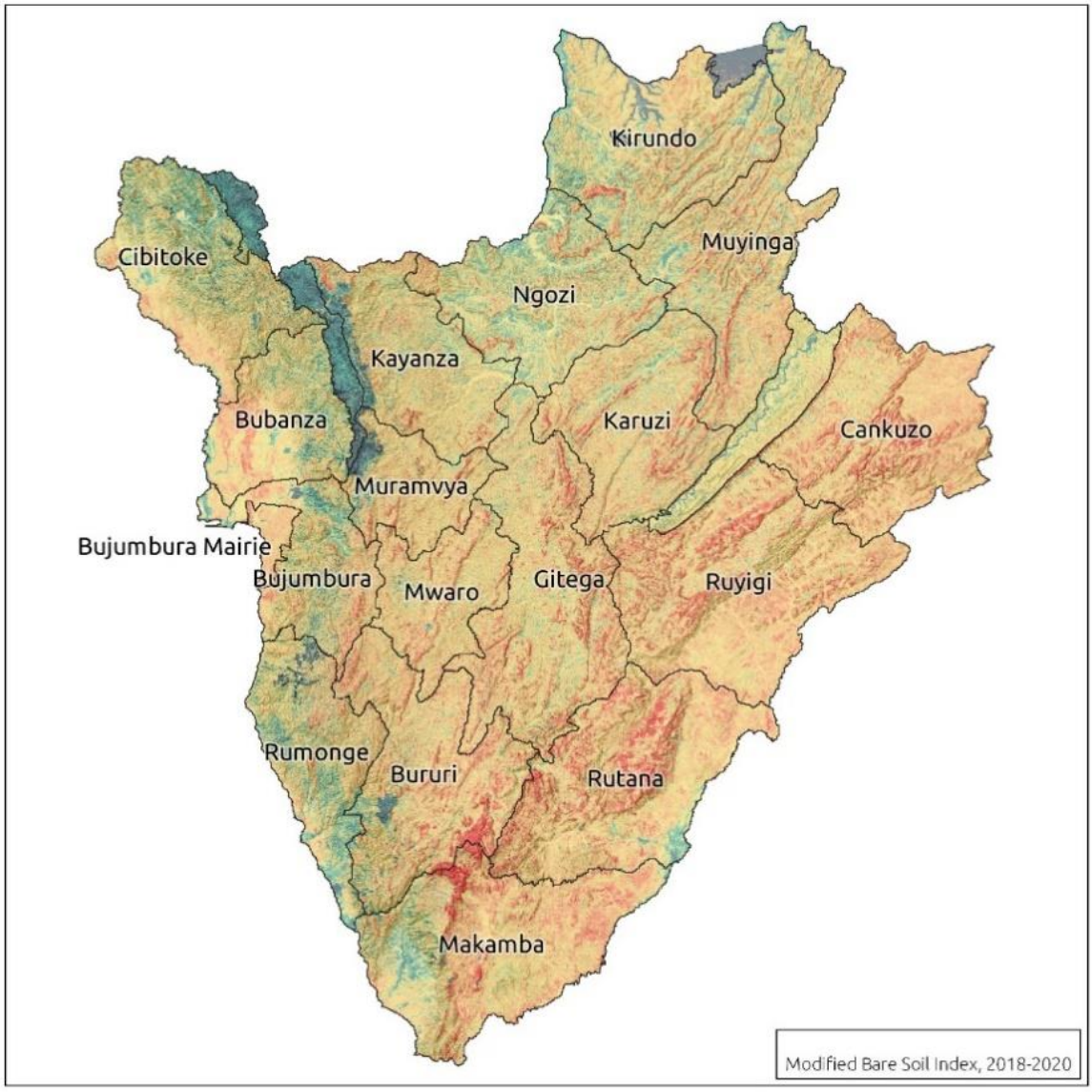

Figure 12. Modified bare soil index, derived from Landsat imagery for the year 2020. Red shades correspond to areas with greater soil exposure or little to no vegetation cover.

Landslide risk

Our analysis shows that significant portions of Burundi's population and *collines* are exposed to landslides and landslide runout hazards.[55] Landslide hazards can exacerbate the effects of climate change impacts such as extreme precipitation on people, agriculture, and infrastructure (particularly roads). Figure 13 maps current exposure to landslide hazards across Burundi, while Figure 14 shows where modeling for this report shows the greatest increases in exposure to landslide and runout hazards by 2030 and by 2050. Not surprisingly, the highest-risk

[55] Vogl, Leon, and Dampha, 2021, "Landslide/Soil Erosion Risks and the Potential for Nature-Based Solutions for Burundi's Colline Landscapes."

areas are concentrated in the most mountainous parts of Burundi, where the slopes are particularly steep.

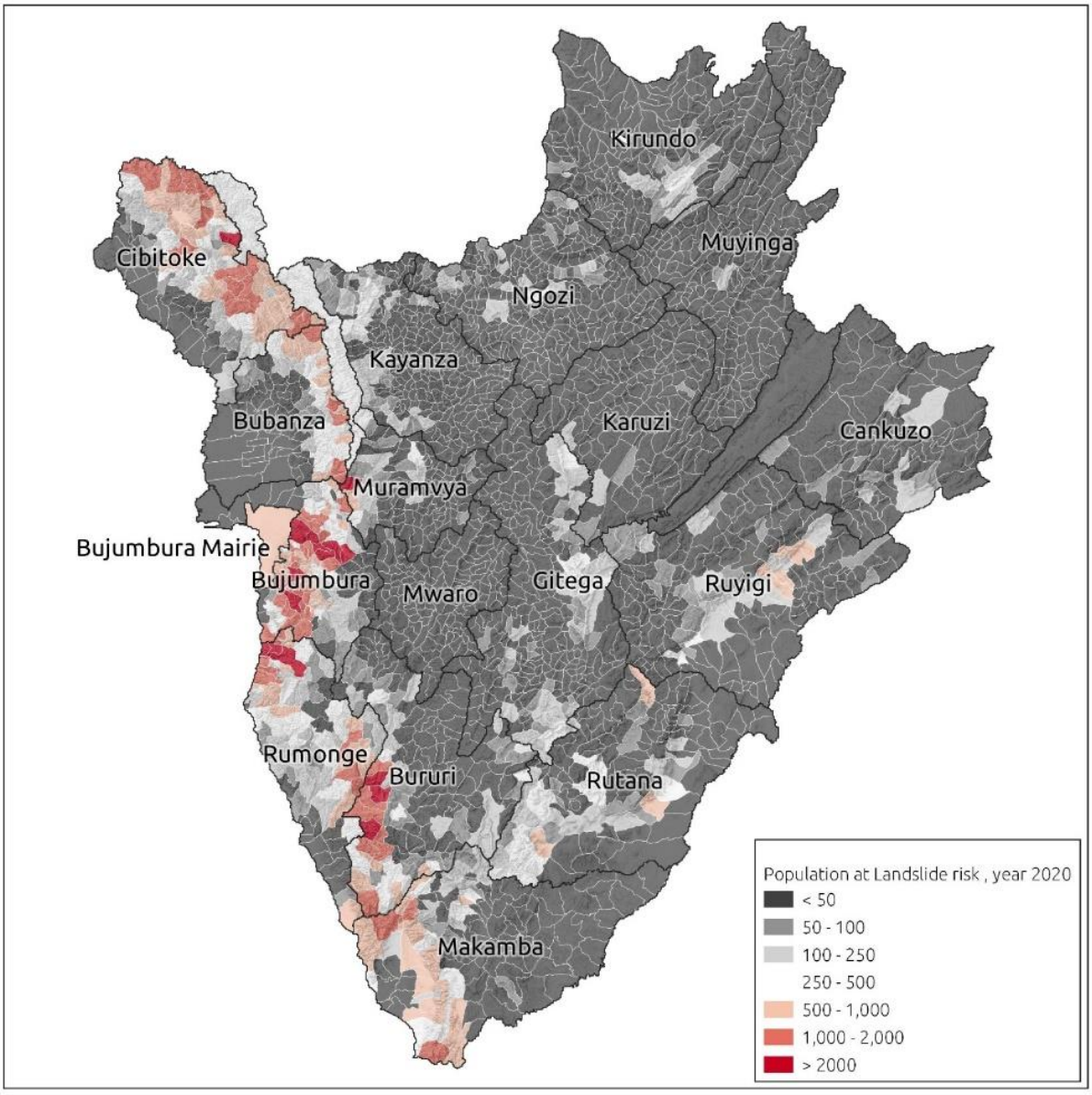

Figure 13. Population (total) exposed to landslide risks, by colline, in the baseline year (2020).

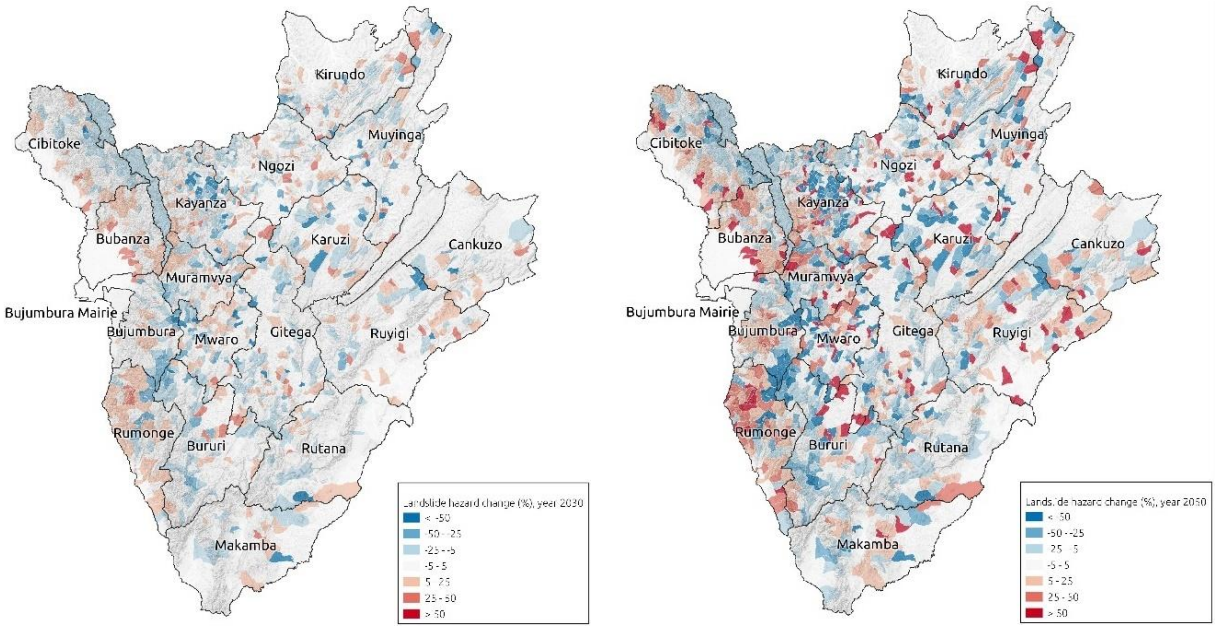

Figure 14. Landslide and runout hazard trends by colline, shown as the projected change from 2020 to 2030 (left) and to 2050 (right).

Soil erosion risks and future projections

Soil erosion is getting worse, and if the detected trends continue, sediment loss could increase by 69 percent by 2030 from 2020 levels, and by up to 200 percent by 2050.[56] As described in Appendix 1.3, the analysis used the InVEST Sediment Delivery Ratio (SDR) to map current patterns of erosion and to assess historical trends.[57] Due to data availability constraints, the analysis did not consider cropping practices or other human factors, such as road construction, but only the roles of climate, topography, soils, land cover, and land management in generating erosion hazards. Still, the analysis shows large areas in the two highest erosion rate categories, with soil loss of at least 22.4 tonnes per ha each year (Figure 15). There is significant overlap between communes and *collines* that are at high risk of soil erosion and landslides. Bujumbura Mairie, Bujumbura province, Cibitoke, and Rumonge have some of the highest erosion rates. Figure 16 shows projections to 2030 and 2050, highlighting the great risk of worsening soil loss in the absence of effective interventions.

[56] Vogl, Leon, and Dampha, 2021.
[57] Sharp, Richard et al. 2020. "InVEST 3.9.0 User's Guide." The Natural Capital Project, Stanford University, University of Minnesota, The Nature Conservancy, and World Wildlife Fund. https://invest-userguide.readthedocs.io/en/latest/.

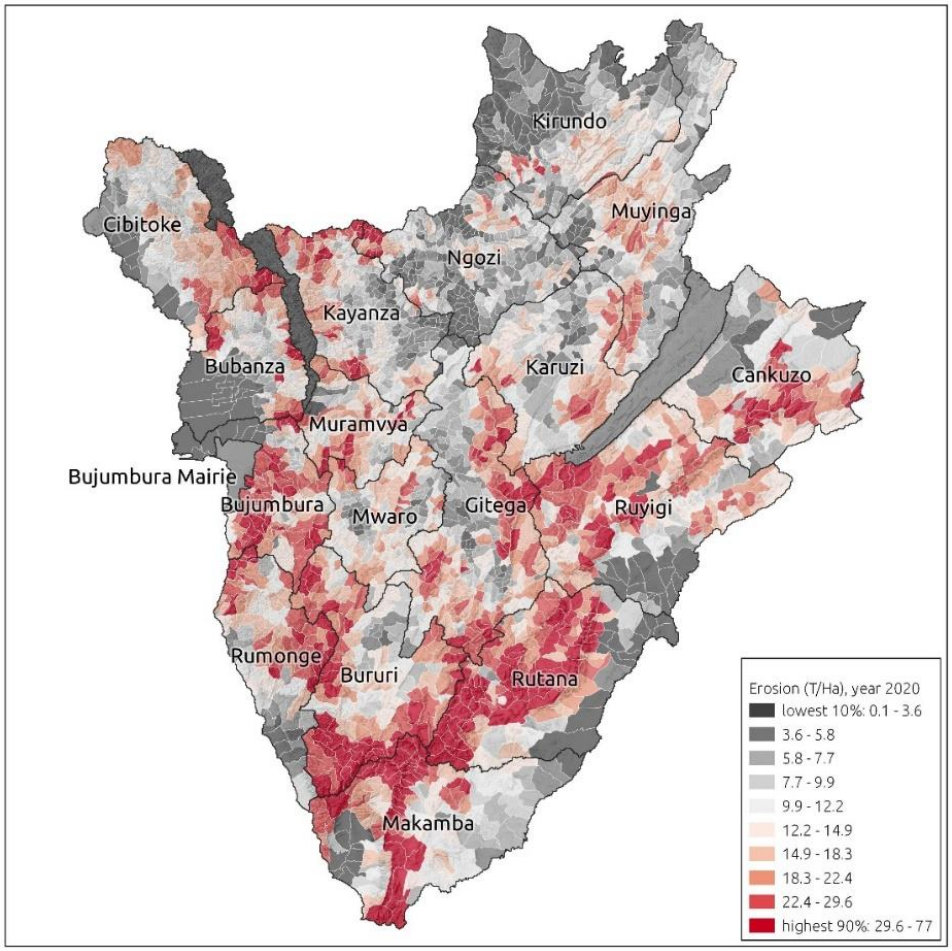

Figure 15. Soil erosion rates by colline in 2020, based on results from the InVEST-SDR model.

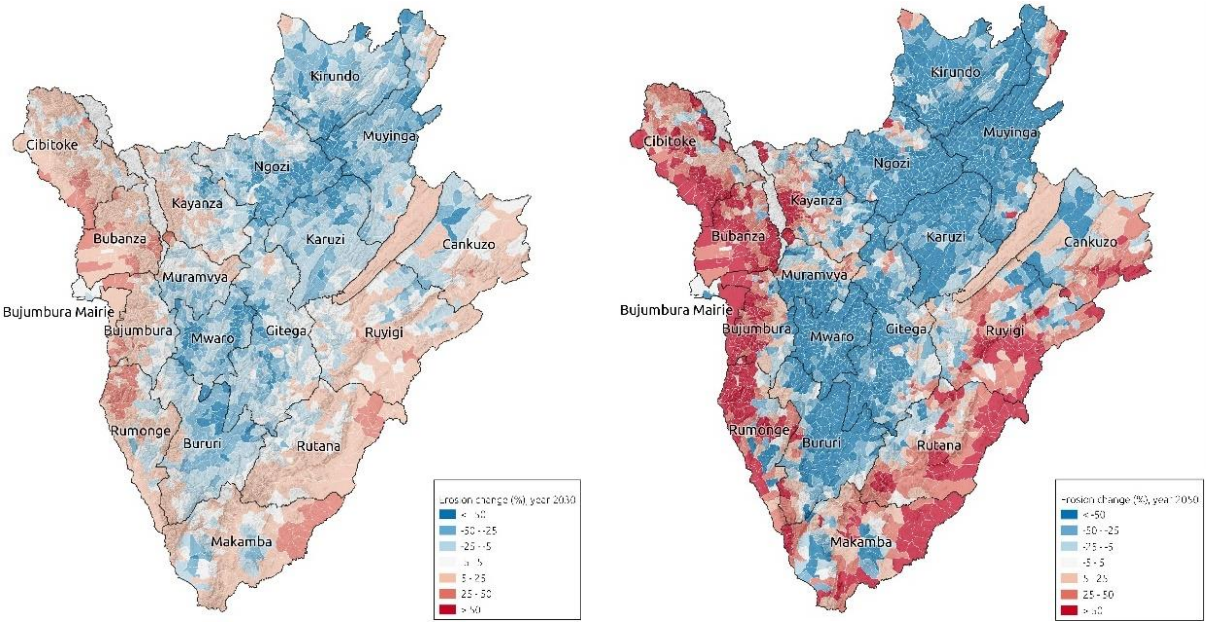

Figure 16. Projected increase (in red) or decrease (in blue) in annual soil erosion rates, by colline, as relative change from 2020 to 2030 (top) and to 2050 (bottom), based on results from the InVEST-SDR model.

Hotspots of land-related risks to people, livelihoods, and infrastructure

Landslide and erosion hazards pose significant risks to people, food supplies, livelihoods, and road infrastructure in large areas of Burundi, especially where the slopes are steepest.[58] The final step in the land-related risk analysis was to construct a multi-hazard index that compared the physical risks (and trends) with the presence of people, cropland, and roads. Figure 17 shows the results of the analysis for 2020, highlighting the very significant risks that already exist—which are on track to get much worse.

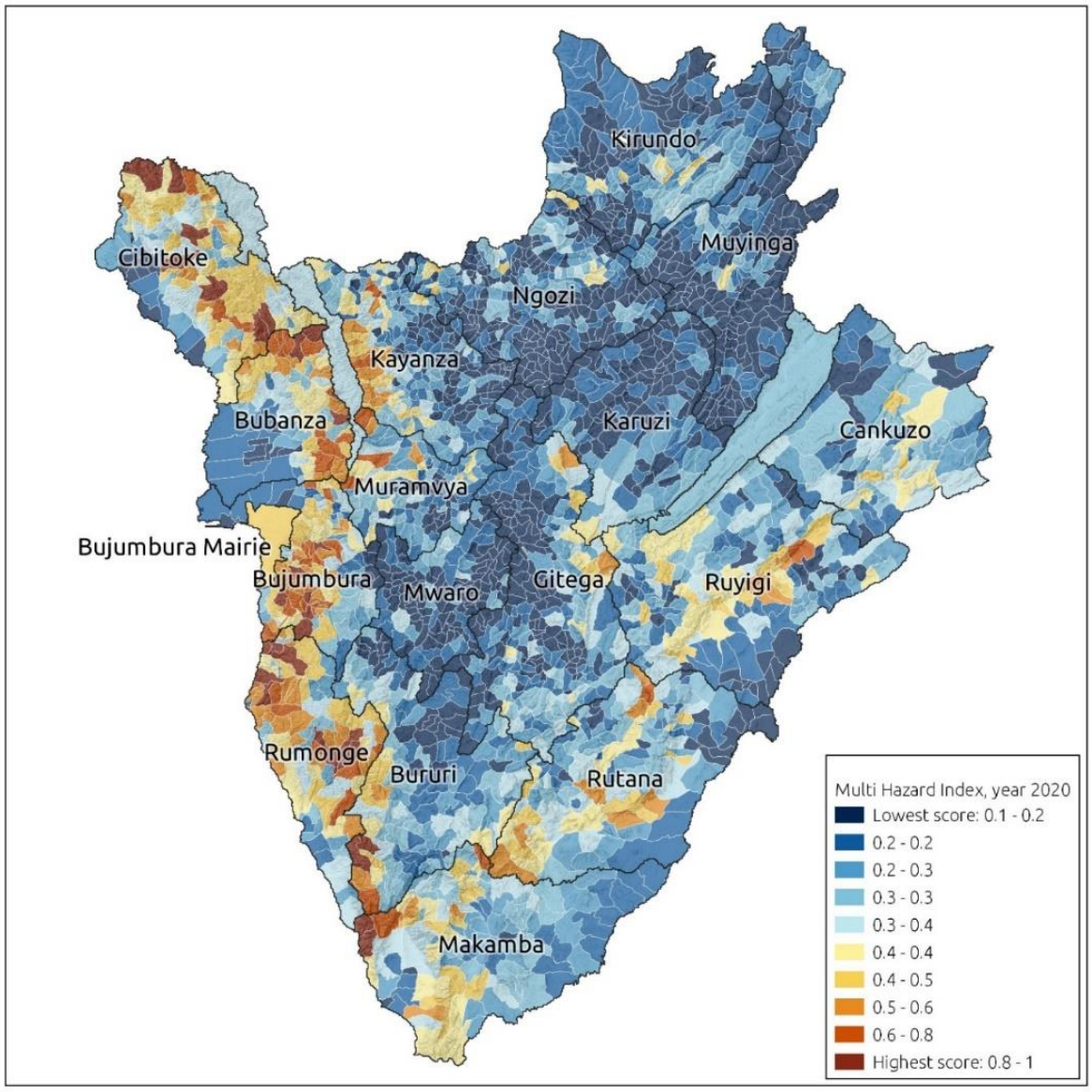

Figure 17. Multi-hazard index score for 2020, reflecting the interplay of erosion and landslide hazards and the presence of settlements, cropland, and transportation infrastructure that could be affected.

[58] Vogl, Leon, and Dampha, 2021, "Landslide/Soil Erosion Risks and the Potential for Nature-Based Solutions for Burundi's Colline Landscapes."

The potential for nature-based solutions

The good news for Burundi is that there is very large potential for nature-based solutions (NBS) to reduce these risks.[59] Moreover, there is significant overlap between the most imperiled areas and those that show the greatest potential for NBS. Landslides are usually caused by unstable slopes being disturbed by excessive rains, physical cuts (e.g., for road construction), or vegetation removal. As Burundi knows from experience, water is the most important factor affecting slope stability, and vegetation—particularly when it is well rooted—can provide crucial protection. Vegetation cover is also essential for preventing erosion and for protection during droughts, when bare soil can become dry and hard. As described in Appendix 1.3, an NBS potential index was developed to estimate how much NBS could mitigate the risks covered by the multi-hazard index. Two scenarios were modeled: one with vegetation cover fully intact ("NBS") and another with little to no vegetation cover ("degradation").[60] Figure 18 shows the results, which to a great extent mirror those of the multi-hazard analysis. For hard-hit areas such as Cibitoke, Bujumbura Mairie, Bujumbura province, Rumonge, and the most mountainous areas of Bururi and Makamba provinces, investments in NBS could make an enormous difference.

[59] Vogl, Leon, and Dampha, 2021.

[60] The analysis made no assumptions about the specific NBS to be employed—just that they would be locally appropriate and achieve improved vegetation cover and structure.

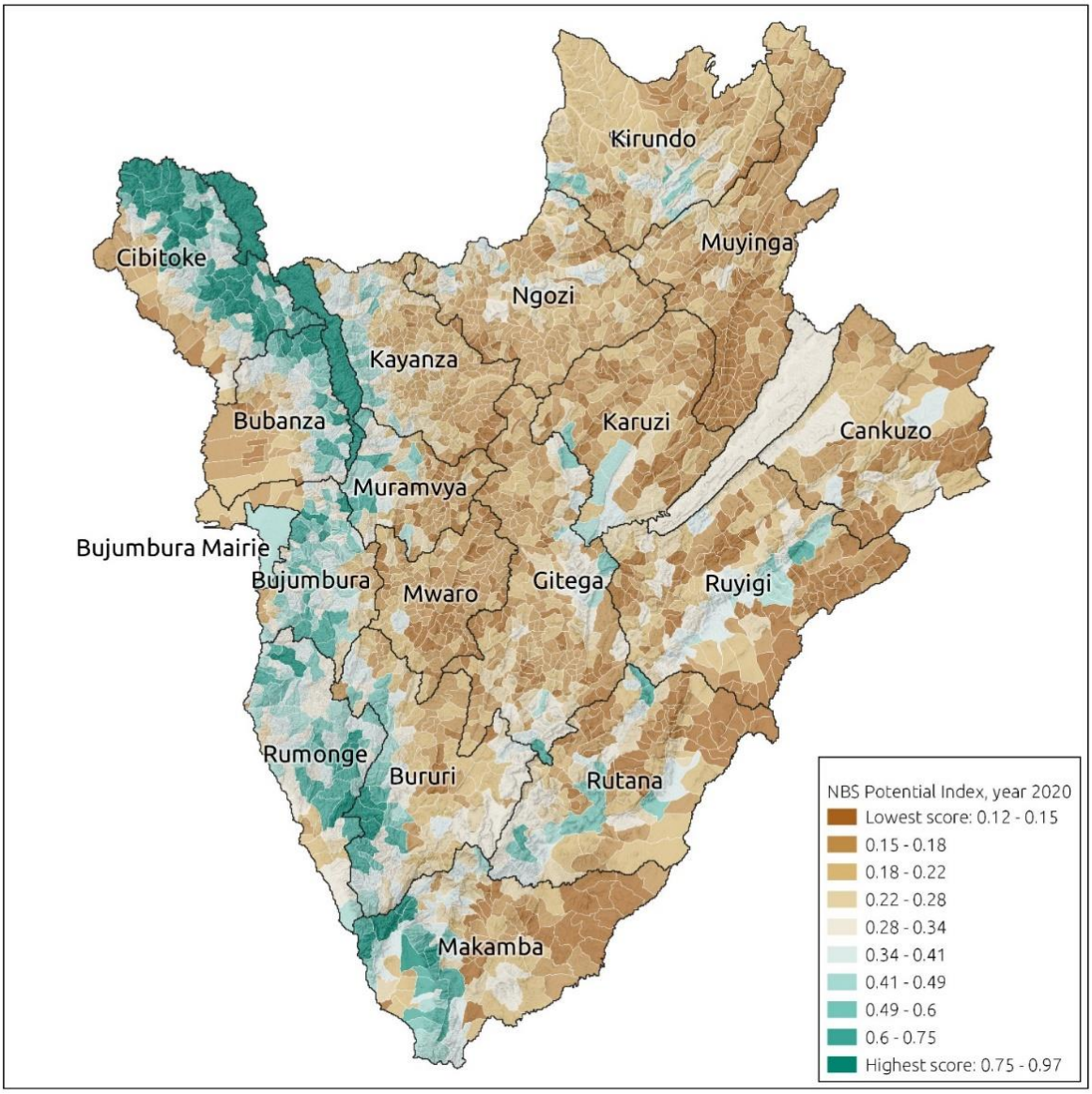

Figure 18. Potential for NBS to mitigate risks of erosion and landslide risk to people, food/livelihoods, and transportation infrastructure, by colline; the areas with the greatest opportunities are in green.

3. Sectoral Climate and Land Degradation Impacts

Climate change and land degradation pose high risks not only because the hazards are so significant, but because of Burundi's economic structure and social fragility. As described in the introduction, Burundi has an overwhelmingly rural population, and agriculture is by far the largest source of employment, with millions of people still engaged in subsistence farming. Decades of conflict stifled development, and although significant progress has been made since 2005, Burundi has a great deal of ground to cover in order to achieve the Sustainable Development Goals (SDGs).[61] The 2020 Human Development Index (HDI) ranked Burundi No. 185 out of 189 countries scored, and found 75.1 percent of the population to be experiencing multi-dimensional poverty, well above the average for developing countries.[62] Burundi also scores low (0.4 out of 1) on the World Bank's Human Capital Index,[63] which measures the overall skills, health, knowledge, and resilience of the population.

Burundi's nationally determined contribution (NDC) acknowledges these challenges.[64] It notes that the country's economy is dominated by the primary sector—which accounts for nearly half of GDP and close to 80 percent of export income. The secondary sector represents just 17–18 percent of GDP, and the tertiary sector, only about one-third. From a jobs perspective, the shares are even lower: by international estimates, only 3 percent of Burundian workers are employed in industry, compared with 11 percent across sub-Saharan Africa;[65] for services, the shares are 10 percent and 36 percent, respectively.[66] The NDC also notes that the current production structure, dominated by subsistence farming, "makes the economy very vulnerable and fragile due to its dependency on climate conditions" (p. 2). Electricity consumption, the NDC adds, is just 25 kWh per person per year, or 4 percent of the energy balance.

Burundi has strategies in place to address climate risks and foster green development, but several sectors still face substantial threats. The sections below provide brief overviews of priorities for resilience-building for agriculture and natural ecosystems; infrastructure and energy systems; and health, as well as potential implications for FCV risks.

3.1 Agriculture and natural ecosystems

The analysis highlights serious risks both to agricultural production, and to natural ecosystems in Burundi, including to its limited remaining forests. The model results show

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[61] See the Sustainable Development Report indicators database: https://dashboards.sdgindex.org/profiles/burundi/indicators.

[62] UNDP. 2020. "Human Development Report 2020 – The Next Frontier: Human Development and the Anthropocene." New York: United Nations Development Programme. http://hdr.undp.org/en/2020-report; see also the Burundi country briefing: 2020, "Burundi: Human Development Report 2020 – The Next Frontier: Human Development and the Anthropocene."

[63] See https://data.worldbank.org/indicator/HD.HCI.OVRL?locations=BI. By this measure, Burundi is roughly on par with many other countries in sub-Saharan Africa, however.

[64] This refers to Burundi's original NDC, submitted in 2015: Republic of Burundi, 2015, "Intended Nationally Determined Contribution (NDC)."
The NDC update submitted in 2021 does not provide additional information on the socioeconomic context. Republic of Burundi. 2021. "Contribution Determinée Au Niveau National 2020: Annexe." Bujumbura: Ministry of Environment, Agriculture and Livestock.
https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Burundi%20First/CDN%20%20%20Burundi%20ANNEXE%201.pdf.

[65] See modelled ILO estimates: https://data.worldbank.org/indicator/SL.IND.EMPL.ZS?locations=BI-ZG.

[66] See modelled ILO estimates: https://data.worldbank.org/indicator/SL.SRV.EMPL.ZS?locations=BI-ZG.

severe and worsening land degradation. From 2017 to 2020 alone, more than 33,000 ha (1.2 percent of Burundi's land area) experienced acute degradation—that is, at rates much higher than the national average. This includes 10,800 ha of productive lands (1 percent). The 2017 World Bank analysis cited earlier had estimated the cost of soil erosion alone at $120 million in 2014, or 3.9 percent of Burundi's GDP;[67] the country cannot afford for this trend to continue. Figure 19 shows land degradation is concentrated in 188 *collines*, which are shown as hotspots on the map, especially along the western and northern borders of the country (see Appendix 5 for a *colline*-level map). An analysis of longer historical trends (2000–2020) detected degradation on 330,000 ha of the total 2.5 million ha analyzed (12.85 percent of the country). Appendix 6 provides a map of land degradation hotspots for the entire two-decade period.

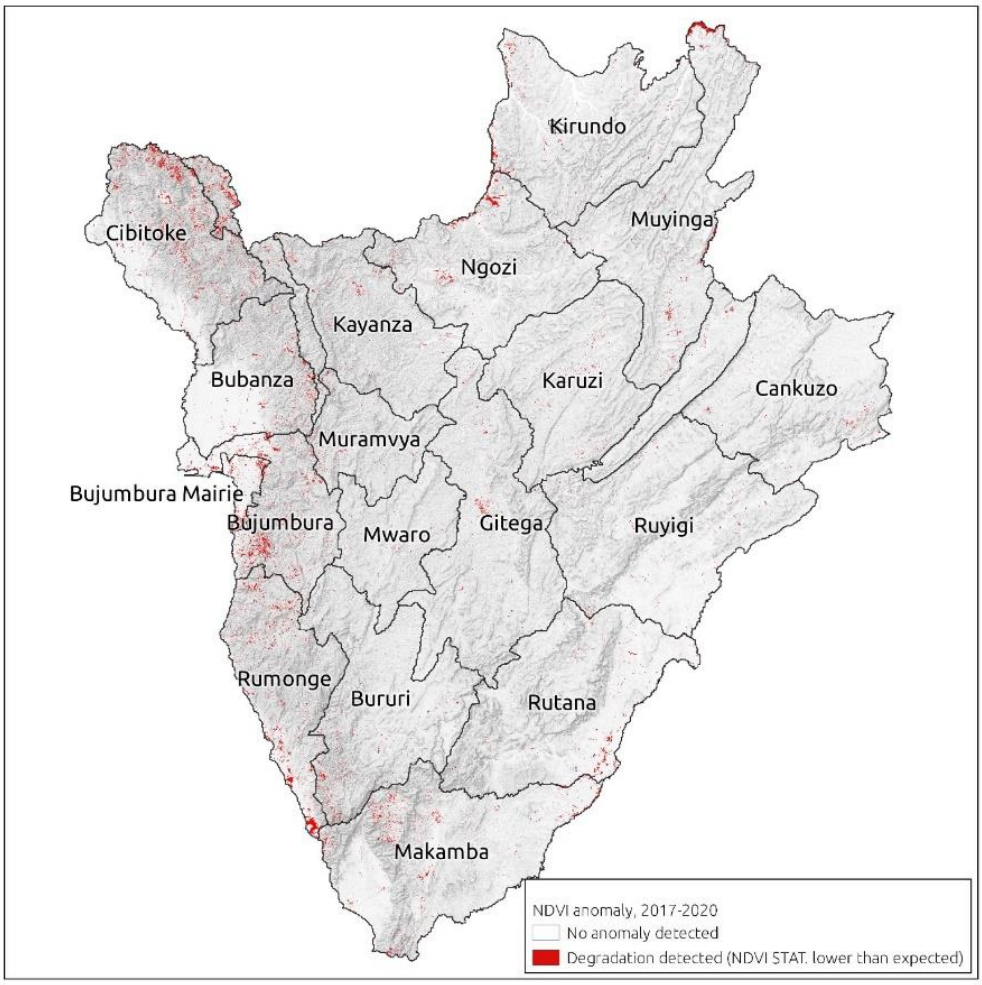

Figure 19. Results of the analysis of recent land degradation trends. Areas in red are those with a higher incidence of recent degradation than the 20-year mean; they are concentrated primarily in western and northern Burundi.

Land degradation poses direct risks to food production and agricultural livelihoods, even before considering the full effects of climate change. Figure 20 shows the *colline*-level results for landslide and erosion risks to croplands and livelihoods in 2020. The analysis

[67] World Bank Group, 2017, "Burundi Country Environmental Analysis: Understanding the Environment within the Dynamics of a Complex World—Linkages to Fragility, Conflict, and Climate Change."

shows that *collines* in Makamba, Bubanza, Bujumbura Mairie, Bujumbura, Cibitoke, and Rumonge communes are at particularly high risk. These modeling results can help the Government to prioritize sites for the implementation of NBS and other landscape management activities.

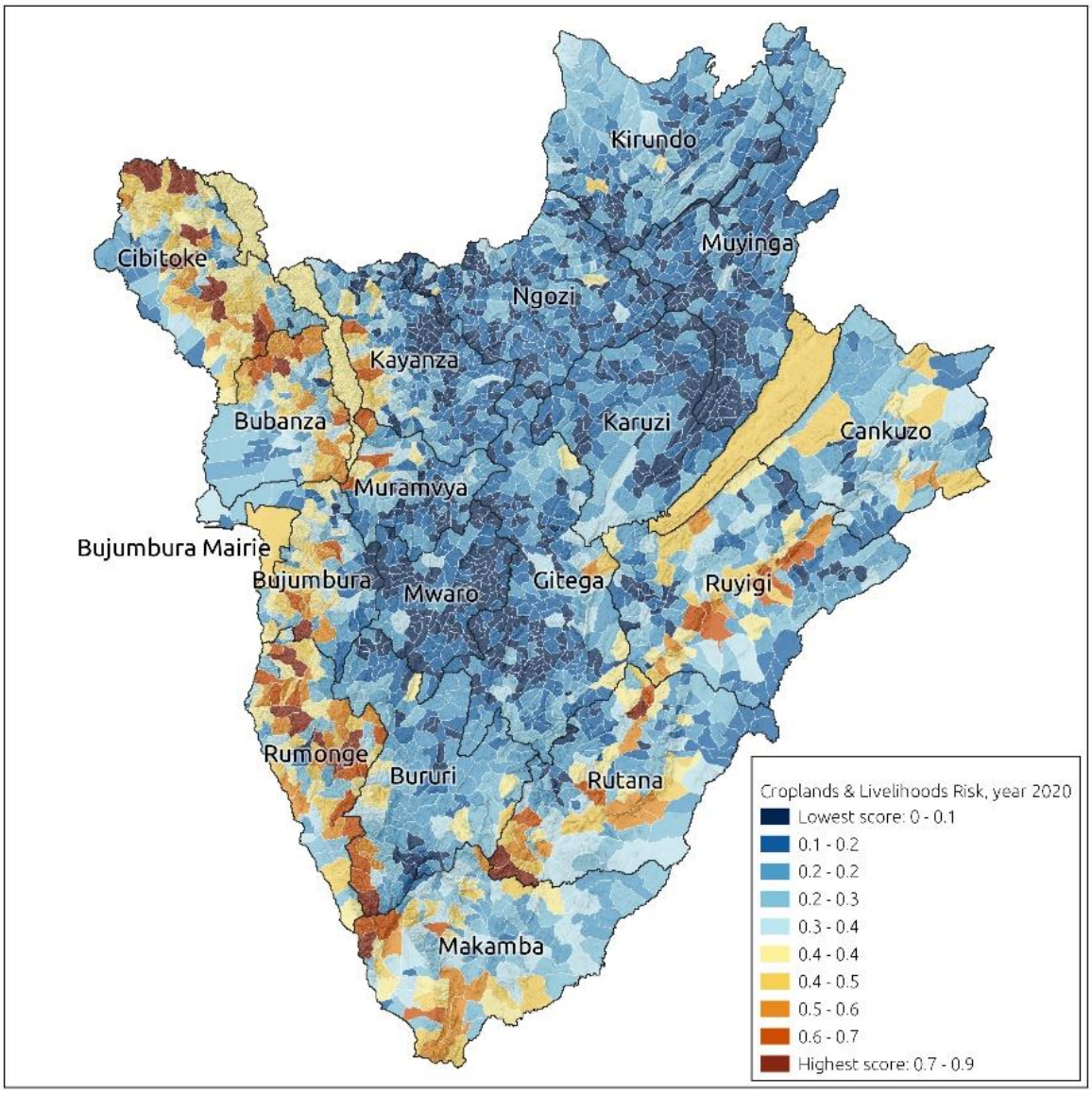

Figure 20. Food & livelihoods risk index, showing collines with the greatest area of croplands at risk of erosion and landslides, and also where these hazards have been increasing most over the 20-year period examined.

Given the urgency of threats to food production, Burundi needs to implement and scale up NBS as swiftly as possible. Two years of relatively good crops, combined with new social safety net programs and agricultural interventions, such as subsidized fertilizer sales and improved seeds, have reduced food insecurity for now, but the entire country is still considered to be food-"stressed," with hotspots of food "emergencies."[68] Many NBS can not only reduce

[68] FAO. 2021. "GIEWS Country Brief: Burundi." Global Information and Early Warning System. Rome: Food and Agriculture Organization of the United Nations. https://www.fao.org/giews/countrybrief/country.jsp?code=BDI.

these risks, but also build climate resilience and boost productivity. A selection of site-appropriate NBS is beyond the scope of this initial analysis, but widely used and successful approaches include sustainable soil management techniques[69] (often applied as a package known as "conservation agriculture"[70]) and agroforestry[71] and silvopastoralism[72] (incorporating trees into croplands and animal production systems).

Restoring degraded lands and protecting existing natural ecosystems can also benefit nearby farms, particularly in a changing climate. Land degradation, which is exacerbated by climate change impacts (for instance, when droughts make it easier for soil to blow away, or torrential rains destroy landscapes), affects critical ecosystem services. In a warming climate, and especially during heatwaves, livestock will benefit from having trees for shade. The loss of biodiversity can affect pollination, reduce available fodder for animals, and even make it easier for pests to thrive—even as warming temperatures increase pest and disease risks. Healthy ecosystems also store more carbon, nutrients, and water in the soil; purify the water; and absorb precipitation that might otherwise cause floods, erosion, and landslides. Forest disturbances can also increase the incidence of wildfires, which not only cause forest loss, but can damage nearby productive lands.

Climate change poses immediate and growing threats to agriculture in Burundi, making it crucial to intensify efforts to increase climate resilience. Burundi's coffee production—which is mostly smallholder-based, with low productivity,[73] is on the decline, with exports valued only at $43.9 million in 2020, down from $69.4 million in 2010.[74] Yields for food staple crops such as bananas are also low.[75] As noted above, Government interventions are already making a difference,[76] but there is much greater potential to further improve yields while making both crop and livestock production more resilient to rising temperatures and unreliable (and sometimes extreme) precipitation.

Women play a critical role in agriculture in Burundi and need particular attention in resilience-building interventions. As of 2019, 94 percent of female workers in Burundi were employed in agriculture, compared with 78 percent of men.[77] Women prepare the land, plant and

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[69] FAO. 2017. "Voluntary Guidelines for Sustainable Soil Management." Rome: Food and Agriculture Organization of the United Nations. http://www.fao.org/3/a-bl813e.pdf.
[70] Donovan, M. 2020. "What Is Conservation Agriculture?" *International Maize and Wheat Improvement Center (CIMMYT) Blog* (blog). January 23, 2020. https://www.cimmyt.org/news/what-is-conservation-agriculture/.
[71] See the wealth of resources provided by the World Agroforestry Centre: https://www.worldagroforestry.org/about/agroforestry.
[72] Jose, S., and J. Dollinger. 2019. "Silvopasture: A Sustainable Livestock Production System." *Agroforestry Systems* 93 (1): 1–9. doi:10.1007/s10457-019-00366-8.
[73] Feller, G. 2019. "For Burundi, Failure to Improve Coffee Production Is Not an Option." *Tea & Coffee Trade Journal*, January 14, 2019. https://www.teaandcoffee.net/feature/21719/for-burundi-failure-to-improve-coffee-production-is-not-an-option/.
[74] See Observatory of Economic Complexity data: https://oec.world/en/profile/country/bdi. Global commodity prices also affect the value of coffee exports, of course, but the low productivity and profitability of Burundi's coffee production are clearly the main factors.
[75] Baramburiye et al., 2013, "Burundi."
[76] FAO, 2021, "GIEWS Country Brief: Burundi."
[77] See ILO modeled estimates: https://data.worldbank.org/indicator/SL.AGR.EMPL.FE.ZS?locations=BI-ZG (women) and https://data.worldbank.org/indicator/SL.AGR.EMPL.MA.ZS?locations=BI-ZG (men).

tend to crops, and conduct the harvests, accounting for 62 percent of farm work hours.[78] Yet they lack formal inheritance rights, so they are far less likely than men to have secure land tenure. The ongoing Burundi Landscape Restoration and Resilience Project[79] has begun to address this in the 31 covered *collines,* helping procure land certificates for farmers, including many women (as sole owners or co-owners). Women also tend to have limited access to productive inputs, training on new agricultural technologies, or formal credit. Moreover, they are typically excluded from decision-making at both the community and household levels, especially when cash crops are involved.[80]

The prevalence of rainfed agriculture makes Burundi particularly vulnerable to droughts and to shifts in seasonal precipitation. Dependence on rainfall highlights another adaptation priority. As of 2012, Burundi had only 23,000 ha of irrigated cropland.[81] A comparison with the land cover data shown in Table 1 in Section 2 shows that is equivalent to just over 12 percent of the dedicated cropland found in the Landsat analysis, and just 2 percent of the total productive land. At workshops in four highly vulnerable *collines* conducted in May 2022 as part of this project, communities repeatedly mentioned water tanks for rainwater storage and irrigation as a priority. One of the technology transfer needs identified in Burundi's NDC is support for the development of both small- and large-scale irrigation, as well as for efficiency improvements.[82]

In general, Burundi has ample water supplies, but water availability varies seasonally and by region, with water scarcity as well as torrential rains and floods on the rise. Although the country's overall climate is tropical humid, but rainfall varies significantly, from an average of 2,000 mm at higher altitudes, to 1,000 mm in the depressions.[83] Rivers and lakes provide abundant (and sometimes dangerously excessive) amounts of water as well. As discussed in Section 2, Burundi has a history of alternating wet and dry periods, going back at least seven decades. There were severe droughts in 1999–2000 and in 2005, for instance, but severe floods in 2006 and 2007; the Government has previously estimated that each of those events cost Burundi 5–17 percent of its GDP.

The combined effect of climate hazards and land degradation are also increasing sedimentation in surface water bodies in Burundi, reducing water quality. Water pollution and sedimentation will severely harm water users and marine species. For instance, fisheries yields and economic productivity from the sector will decline, even as warming temperatures drive some species of fish to migrate. Lake Tanganyika, which is important to many Burundians' livelihoods and food security, faces a triple threat of climate change, water pollution, and overfishing.[84] Differential warming of the surface of the lake relative to the depths has led to an increased density gradient, which can reduce how much water from the upper levels of the

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[78] Rames, V., C. Bununagi, and C. Niyonzima. 2017. "USAID/Burundi Gender Analysis: Final Report." Produced for the U.S. Agency for International Development. Washington, DC: Banyan Global. https://banyanglobal.com/wp-content/uploads/2017/07/USAID-Burundi-Gender-Analysis-Final-Report-2017.pdf.

[79] See https://projects.worldbank.org/en/projects-operations/project-detail/P160613 and https://projects.worldbank.org/en/projects-operations/project-detail/P171745.

[80] Okonya, J.S. et al. 2019. "The Role of Women in Production and Management of RTB Crops in Rwanda and Burundi: Do Men Decide, and Women Work?" *Sustainability* 11 (16): 4304. doi:10.3390/su11164304.

[81] See CIA World Factbook: https://www.cia.gov/the-world-factbook/countries/burundi/.

[82] Republic of Burundi, 2015, "Intended Nationally Determined Contribution (NDC)."

[83] Baramburiye et al., 2013, "Burundi."

[84] Plisnier, P.-D. et al. 2018. "Monitoring Climate Change and Anthropogenic Pressure at Lake Tanganyika." Journal of Great Lakes Research 44 (6): 1194–1208. doi:10.1016/j.jglr.2018.05.019.

lake mix with water in the deeper areas. This limits nutrient fluxes to the phototrophic zone,[85] impacting lake productivity and potentially reducing fish yields.

Burundi has already identified several strategies to protect its water bodies in a changing climate. They include improving the management of urban water drainage systems, watersheds and rivers to avoid pollution of Lake Tanganyika; strengthening sustainable fisheries management; protecting critical habitats, including lake buffer zones and spawning grounds; assessing and then monitoring biodiversity in lakes; and adopting and enforcing fisheries legislation.[86] The recent floods caused by exceptionally high water levels in Lake Tanganyika also suggest further work should be done to assess how climate change may affect lake levels.

3.2 Transport, energy systems, and infrastructure

Burundi's infrastructure, which is already inadequate, faces large and growing risks due to climate change and land degradation. As discussed further below, modern energy access is very limited, especially in rural areas; energy production falls far short of demand; and the transmission and distribution networks are obsolete.[87] The country's road network is better than those in many African countries,[88] but the quality of the roads and Burundi's hilly, landslide-prone terrain make the national transport infrastructure unreliable, a barrier to development.[89] Information and communications technology (ICT) infrastructure is also very limited, and much of the public infrastructure, in general, is not robust enough to withstand the shocks that Burundi is already experiencing. There are also significant spatial disparities in infrastructure quality and availability.

In this context, a single extreme event, such as torrential rain, can cause devastating harm and reverse hard-fought development gains. This is particularly the case when there are cascading hazards: rain can trigger landslides and floods and destroy vital infrastructure; disease outbreaks can ensue in affected areas. For example, over two days in February 2014, Burundi received 80 mm of heavy rain, which generated intense runoff, leading to landslides and the bursting of an unauthorized reservoir on the Gasenyi River.[90] That, in turn, caused a violent flash flood that wrecked the densely settled Gatunguru area in Bujumbura and washed away a stretch of the country's main highway. More than 3,000 homes were destroyed and total damage to infrastructure amounted to FBu 6.9 billion, equivalent to US$4.5 million, or 0.18 percent of GDP—60.5 percent for roads and bridges, and 9–10 percent each for schools, agricultural infrastructure, markets, and water supply systems, plus 80 million FBu for the power grid.

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[85] Verburga, P., and R.E. Hecky. 2009. "The Physics of the Warming of Lake Tanganyika by Climate Change." *Limnology and Oceanography* 54 (6part2): 2418–30. doi:10.4319/lo.2009.54.6_part_2.2418.

[86] Republic of Burundi, 2019, "Third National Communication on Climate Change."

[87] AfDB. 2019. "Republic of Burundi: Country Strategy Paper 2019-2023." African Development Bank. https://www.afdb.org/sites/default/files/documents/projects-and-operations/burundi_country_strategy_paper_2019-2023-rev.pdf.

[88] Burundi ranked No. 22 out of 54 countries on the African Development Bank's Transport Index in 2019 and 2020; see AfDB. 2020. "The Africa Infrastructure Development Index (AIDI) 2020." AfDB Statistics Department Economic Brief. African Development Bank. https://www.afdb.org/en/documents/economic-brief-africa-infrastructure-development-index-aidi-2020-july-2020.

[89] AfDB, 2019, "Republic of Burundi: Country Strategy Paper 2019-2023."

[90] This example is adapted from Box A7.1 in World Bank Group, 2017, "Burundi Country Environmental Analysis: Understanding the Environment within the Dynamics of a Complex World—Linkages to Fragility, Conflict, and Climate Change."

Analysis for this report shows that *collines* in Bubanza, Bujumbura Mairie, and Bujumbura, Cibitoke, and Rumonge provinces have the highest density of roads at risk from landslides. Burundi has already identified several strategies to improve the resilience of its transportation infrastructure, including improved road maintenance, upgrades, and budgeting for emergencies, as well as the use of new technologies and materials.[91] In this context, it is crucial to recognize the potential benefits of nature-based solutions, which the analysis presented in Section 2 shows would work well in the highest-risk *collines*. It would thus be valuable to engage the transport sector in designing and coordinating NBS landscape management activities that can mitigate these hazards. Figure 21 Burundi's national transportation network and the *collines* where the largest numbers of roads are increasingly exposed to landslide and runout hazards.

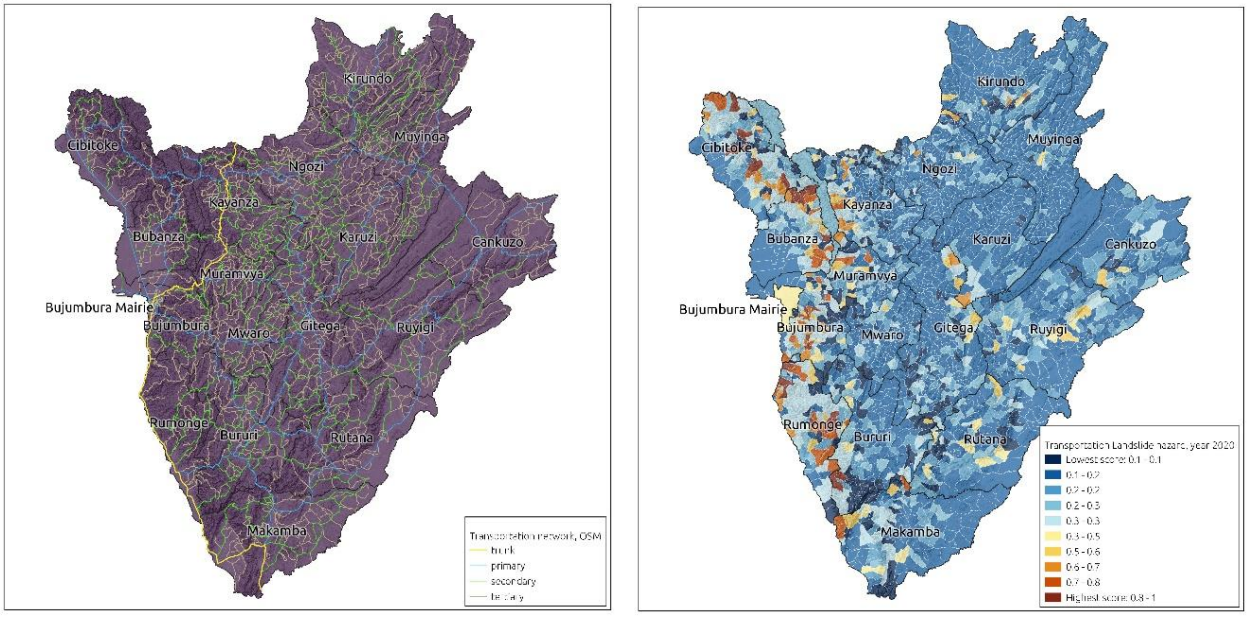

Figure 21. Transport network (left) and landslide risk levels to transportation networks, by colline (right).

Extreme events linked to climate change and land degradation are causing severe and growing harm to a wide range of other infrastructure. As illustrated by the example from 2014 and, more recently, by the 2021 floods in Bujumbura and Rumongo provinces, infrastructure is suffering from extreme weather events.[92] This includes sanitation systems, schools, markets, and other public infrastructure; commercial buildings; agricultural infrastructure; and housing. Without targeted measures to increase the climate resilience of those infrastructures, losses and damages from extreme events are expected to escalate with climate change. Lower-income people living in poor-quality housing and in areas with poor infrastructure, IDPs living in camps, and other vulnerable groups will be particularly hard-hit.

Expanding access to modern energy services is also crucial to mitigating climate and land degradation-related risks and building resilience. Burundi may be roughly on par with many of its African neighbors when it comes to transport infrastructure, but when it comes

[91] Republic of Burundi, 2019, "Third National Communication on Climate Change."
[92] IFRC. 2021. "Emergency Plan of Action (EPoA) Burundi: Floods and Landslides April 2021." International Federation of Red Cross and Red Crescent Societies. https://adore.ifrc.org/Download.aspx?FileId=409103.

to electricity infrastructure, it ranks last.[93] Only an estimated 11.7 percent of Burundians had access to electricity in 2020,[94] mainly in the cities; in rural areas, the share was 3.5 percent.[95] Not only is power generation inadequate, but transmission losses are high, 32.1 percent in 2016.[96] Lack of electricity access limits opportunities to diversify livelihoods; affects the quality of basic services, such as healthcare and education; and hinders communications, including internet access. It also stifles industrial development.

With no better alternatives, most people still rely on solid biomass—firewood or, at best, charcoal—to meet household energy needs. As of 2016, less than 1 percent of people had access to clean fuels and stoves for cooking.[97] This means millions of Burundians have to burn biomass every day just to meet basic needs, putting pressure on the country's already sparse tree cover, and exposing themselves to smoke that harms their health. This accounts for 90 percent of Burundi's energy use.[98] Modern, clean energy options for households would thus have double benefits: improving living standards, and helping to reduce deforestation and land degradation.

Burundi has large untapped hydropower potential, estimated at 1,300 MW,[99] but climate change could complicate its development. The current installed capacity is only 48 MW.[100] The country is actively expanding its hydropower capacity—a prominent feature of its NDC that is reinforced in last year's update.[101] However, the climate projections presented in Section 2 suggest that precautions will need to be taken to ensure that the new infrastructure is resilient to highly variable and increasingly extreme precipitation. While this study shows no clear trend in overall precipitation, another recent study,[102] also using CORDEX simulations, suggested decreases in output of 11 percent and 16 percent by 2050 over the Rwegura catchment under RCP 4.5 and RCP 8.5, respectively. Even if on average, hydropower production remains strong, experience around the world—and within Burundi—shows how sharply the output can drop in the dry years. Burundi has already experienced drought-related power shortages.[103] Landslides and soil erosion also affect hydropower production by accelerating the buildup of sediment in reservoirs, and thus reducing their performance.[104]

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[93] Burundi ranked No. 54 out of 54 on the AfDB's Electricity Index in both 2019 and 2020. See AfDB, 2020, "The Africa Infrastructure Development Index (AIDI) 2020."
[94] For sub-Saharan Africa as a whole, the share was 48.4 percent. See https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=BI-ZG.
[95] For sub-Saharan Africa as a whole, the share was 28.7 percent. See https://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS?locations=BI-ZG.
[96] AfDB, 2019, "Republic of Burundi: Country Strategy Paper 2019-2023."
[97] See Sustainable Development Report indicators database: https://dashboards.sdgindex.org/profiles/burundi/indicators.
[98] AfDB, 2019, "Republic of Burundi: Country Strategy Paper 2019-2023."
[99] AfDB, 2019.
[100] IRENA. 2021. "Renewable Capacity Statistics 2021." Abu Dhabi: International Renewable Energy Agency. https://www.irena.org/publications/2021/March/Renewable-Capacity-Statistics-2021.
[101] Republic of Burundi, 2021, "Contribution Determinée Au Niveau National 2020: Annexe."
[102] Manirakiza, C. et al. 2021. "Hydropower Potential in near Future Climate over Burundi (East Africa) : A Case Study of Rwegura Catchment." *Journal of Energy Research and Reviews*, February, 51–65. doi:10.9734/jenrr/2021/v7i130184.
[103] AfDB, 2019, "Republic of Burundi: Country Strategy Paper 2019-2023."
[104] HydroReview. 2017. "Dealing with Sediment: Effects on Dams and Hydropower Generation." February 22, 2017. https://www.hydroreview.com/world-regions/dealing-with-sediment-effects-on-dams-and-hydropower-generation/.

Burundi has also considered solar and wind power as options for expanding its clean electricity supply and is starting to realize the benefits. In October 2021, the country's first large-scale solar photovoltaic (PV) plant was completed.[105] The 7.5 MW installation, built at a cost of $14 million, with significant international support, increased Burundi's power generation capacity by over 10 percent. Solar power could be a promising option both for utility-scale generation, and for off-grid installations and mini-grids, which have been used effectively to expand electricity access in several African countries.[106] Looking at wind power, it is notable that an upward trend in wind speeds has been detected in recent years, but a recent study found that current mean wind speeds are promising only for small-scale power generation, and are unlikely to support large-scale power generation until the end of the century.[107]

3.3 Health

The Government of Burundi has identified a wide range of concerns about public health in the context of climate change.[108] They include deaths and injuries resulting from extreme events (such as floods and heatwaves); changes in the extent and seasonality of climate-related health hazards (such as decreased water quality); and the incidence of water-borne diseases, such as cholera, and vector-borne diseases, such as malaria. The degradation of source watersheds has been shown to increase the risk of diarrheal disease in children,[109] which points to a role for landscape management and nature-based solutions for supporting healthy drinking water supplies in rural areas. As discussed earlier, climate change also has implications for food security, and Burundi already has very high levels of food insecurity as well as stunting among children. The poorest households and communities, IDPs, people with chronic illness or disabilities, elders, and children are particularly vulnerable to the health impacts of climate change.

The evidence on malaria transmission highlights the seriousness of the threats. The academic literature suggests that malaria transmission in Burundi increases with higher temperatures, especially higher nighttime (minimum) temperatures—which, as discussed in Section 2, are rising particularly fast.[110] Figure 22 shows a malaria risk map produced for one of

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[105] Bellini, E. 2021. "Burundi's First Solar Park Comes Online." *PV Magazine*, October 25, 2021. https://www.pv-magazine.com/2021/10/25/burundis-first-solar-park-comes-online/.

[106] Lawrence, D. 2020. "Investors Forecast Bright Future for Mini-Grids in Africa." *IFC Insights,* International Finance Corporation (blog). June 2020. https://www.ifc.org/wps/wcm/connect/NEWS_EXT_CONTENT/IFC_External_Corporate_Site/News+and+Events/News/Insights/africa-mini-grids.

[107] Célestin, M. et al. 2019. "Spatio-Temporal Analysis of Climate Change Impact on Future Wind Power Potential in Burundi (East Africa)." *American Journal of Climate Change* 08 (02): 237–62. doi:10.4236/ajcc.2019.82014.

[108] Republic of Burundi, 2019, "Third National Communication on Climate Change."

[109] Herrera, D. et al. 2017. "Upstream Watershed Condition Predicts Rural Children's Health across 35 Developing Countries." *Nature Communications* 8 (1). doi:10.1038/s41467-017-00775-2.

[110] Smith, M.W. et al. 2020. "Incorporating Hydrology into Climate Suitability Models Changes Projections of Malaria Transmission in Africa." Nature Communications 11 (1): 1–9. doi:10.1038/s41467-020-18239-5; Nkurunziza, H., and J. Pilz. 2011. "Impact of Increased Temperature on Malaria Transmission in Burundi." *International Journal of Global Warming* 3 (1/2): 77. doi:10.1504/ijgw.2011.038371; Nkurunziza, H., A. Gebhardt, and J. Pilz. 2010. "Bayesian Modelling of the Effect of Climate on Malaria in Burundi." *Malaria Journal* 9: 114. doi:10.1186/1475-2875-9-114; Hassaan, M.A., M.A. Abdrabo, and P. Masabarakiza. 2017. "GIS-Based Model for Mapping Malaria Risk under Climate Change Case Study: Burundi." *Journal of Geoscience and Environment Protection* 05 (11): 102–17. doi:10.4236/gep.2017.511008.

those studies, which identifies large areas in western Burundi, and several places in northern regions, as being at high risk.

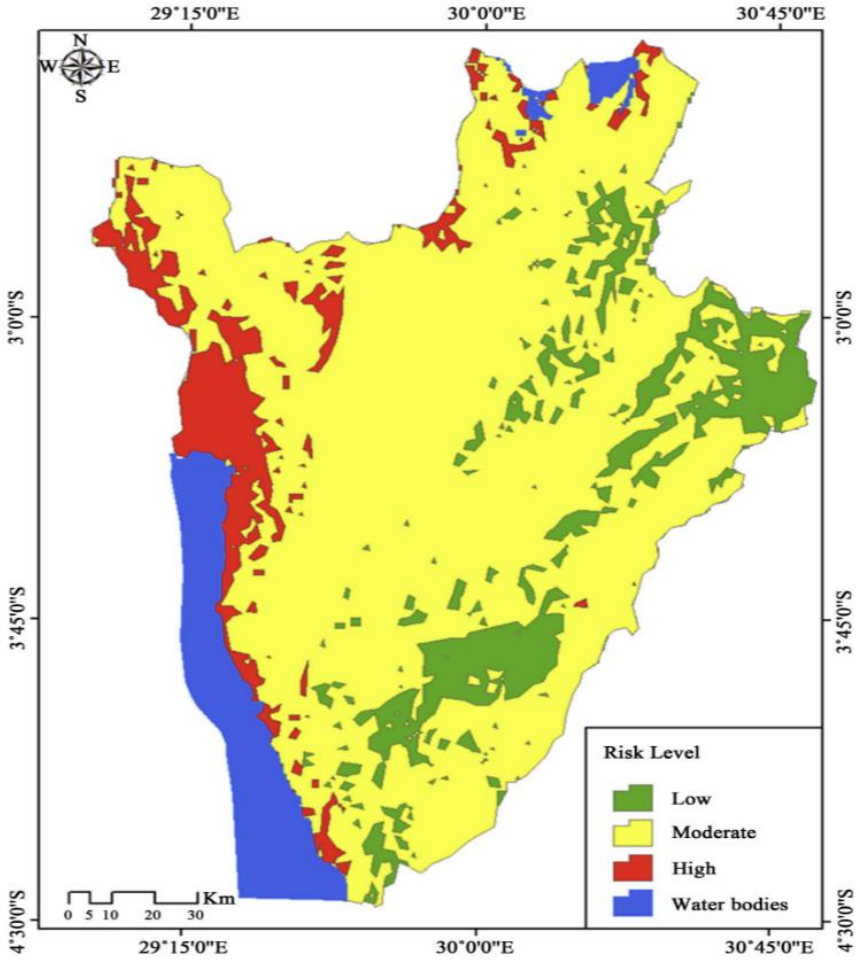

Figure 22. Malaria risk map under climate change using GIS-Based Model. Source: Hassaan et al., 2017.[111]

Heat stress risks could also increase, particularly in the longer term. As discussed in Section 2, the model results show that even in the lower-emissions scenario (RCP 4.5), the average temperature in Burundi could be 0.5°C higher than 1981–2000, and in a higher-emissions scenario (RCP 8.5), warming could reach 1.0°C. A study published in 2018 that looked at exposure to apparent temperature (which takes into account humidity and wind speed as well as temperature) found that under RCP 8.5, Burundi would go from zero days of heat stress a year to 5–10 heat stress days per month in August/September by 2070–2099.[112]

[111] Hassaan, Abdrabo, and Masabarakiza, 2017, "GIS-Based Model for Mapping Malaria Risk under Climate Change Case Study: Burundi."
[112] Asefi-Najafabady, S. et al. 2018. "Climate Change, Population, and Poverty: Vulnerability and Exposure to Heat Stress in Countries Bordering the Great Lakes of Africa." *Climatic Change* 148 (4): 561–73. doi:10.1007/s10584-018-2211-5.

3.4 Implications for Tackling Fragility, Conflict, and Violence (FCV)

The historical impacts of cyclical conflict—and the traumas they induced— exacerbate socioeconomic, physical and environmental vulnerabilities in Burundi. People who fled the violence are still returning from other countries,[113] requiring significant support to restart their lives in Burundi and complicating social dynamics.[114] The legacy of violence and displacement still lingers in the collective consciousness, and households in the areas most affected by conflict continue to be poorer as a result.[115] The impacts of climate change add to all these stresses. While land scarcity is already causing intercommunal conflicts, research for this report suggests that conflicts over land could potentially increase as arable land becomes unproductive due to climate change impacts and land degradation. This is a particular risk if current population growth rates continue in the absence of new livelihood options that do not depend on natural resources. Extreme events are also likely to keep destroying cropland and agricultural infrastructure.

Interviews for this report indicated that Bujumbura Mairie is a hotspot of land ownership-related conflict and violence. Because the capital city has the highest overall population density in Burundi, civilians' vulnerabilities to climate-induced hazards are exacerbated there. We further identified conflict-affected hotspots in the provinces of Cibitoke, Rumonge, Bubanza, and Bujumbura, and those provinces along the border regions with the Democratic Republic of Congo. Those regions have historically seen more conflict due to their ethnic mix or proximity with armed groups and unstable areas, and now they are exposed to climate threats.

Climate change could also act as a threat multiplier by driving displacement, which climate-related extreme events are already causing. As noted in Section 2, in the past four years, the IOM has tracked more than 52,000 people displaced by floods and more than 39,000 displaced by torrential rains.[116] Together, the two closely related hazards account for more than 80 percent of total displacements in that period. Of the 84,373 IDPs tracked by the agency in February 2022, 92 percent had been displaced by climate-related disasters.[117] Rumonge and Kirundo provinces were the top places of origin of IDPs, with 14,350 and 12,336 people displaced at the time, respectively.

Several climate hotspot *collines* also host large numbers of IDPs and refugees, emphasizing the complexity of their risk profiles. It is crucial to understand the underlying vulnerabilities of people in these contexts, as well as how climate change and land degradation might exacerbate them. Displaced persons with no better options can also have a harmful impact on the environment, as they heavily depend on natural resources to meet their survival needs. For example, they cut down trees for firewood and to build shelters; these activities, in turn, impact the soil. Further analysis of the impact of conflict and displacement vis-à-vis natural resource utilization and environmental costs to society is recommended.

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[113] UNHCR. 2021. "More than 60,000 Burundian Refugees Voluntarily Return Home This Year." UN Refugee Agency Briefing Notes. October 26, 2021. https://www.unhcr.org/news/briefing/2021/10/617708884/60000-burundian-refugees-voluntarily-return-home-year.html.

[114] Schwartz, S. 2019. "Home, Again: Refugee Return and Post-Conflict Violence in Burundi." *International Security* 44 (2): 110–45. doi:10.1162/isec_a_00362.

[115] Mercier, M., R.L. Ngenzebuke, and P. Verwimp. 2020. "Violence Exposure and Poverty: Evidence from the Burundi Civil War." *Journal of Comparative Economics* 48 (4): 822–40. doi:10.1016/j.jce.2020.04.005.

[116] IOM, 2022, "Burundi – Emergency Tracking Overview – Natural Disasters: January 2018–March 2022."

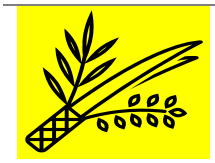
[117] IOM, 2022, "Burundi – Internal Displacement Dashboard."

The vulnerability of women and girls both to climate change impacts and to violence warrants special attention. Burundi has made important strides in improving conditions for women—for instance, providing free prenatal care during pregnancy (though only a third of women receive the recommended four visits),[118] and reducing the maternal mortality rate from 1,010 to 548 per 100,000 live births from 2000 to 2017.[119] Yet gender-based violence rates remain very high: 27.9 percent of women aged 15–49 report having experienced physical or sexual intimate partner violence in the past 12 months, and 48.5 percent have experienced it at some point.[120] As noted earlier, most women farmers lack secure land tenure, and 78.4 percent of employed women (almost all farmers) live below the poverty line.[121] Women also bring important strengths to the table, however: they are likelier than men to be literate, for instance—68.4 percent, compared with 61.2 percent[122]—and as they have been allowed to become more involved in community-based conflict resolution and prevention,[123] they have proven to be creative and effective at the task.[124]

Table 2 provides highlights of the concerns raised by the ASA modeling for different sectors in Burundi.

[118] Rames, Bununagi, and Niyonzima, 2017, "USAID/Burundi Gender Analysis: Final Report."
[119] See Sustainable Development Report indicators database: https://dashboards.sdgindex.org/profiles/burundi/indicators.
[120] See UN Women Global Database on Violence Against Women: https://evaw-global-database.unwomen.org/en/countries/africa/burundi.
[121] See UN Women data: https://data.unwomen.org/country/burundi.
[122] See UN Women data: https://data.unwomen.org/country/burundi.
[123] Rames, Bununagi, and Niyonzima, 2017, "USAID/Burundi Gender Analysis: Final Report."
[124] Féron, É. 2020. "Reinventing Conflict Prevention? Women and the Prevention of the Reemergence of Conflict in Burundi." *Conflict Resolution Quarterly* 37 (3): 239–52. doi:10.1002/crq.21275; Väyrynen, T., É. Féron, and M. Lehti. 2020. "Burundi Women's Grassroots Preventive Mediation." *Peace Review* 32 (3): 367–73. doi:10.1080/10402659.2020.1867354.

Table 2. Sectoral impacts of climate change and land degradation in Burundi

Sector	Projected Climate Impacts
 *Agriculture*	Decline in rainfed crops, without technological improvements Reduce water availability for plant growth Increase in soil erosion leading to agricultural land degradation Increased pest and disease incidences affecting crops and livestock
 *Water*	Intense pluvial and fluvial flooding, causing floods in lowlands and marshlands and exceptionally in Lake Tanganyika basin Increase in sedimentation causing decline water quality Increase in demand on water resources, depleting surface water and groundwater aquifers Increase salinity of groundwater resources near lakes
 *Health*	Increase in malnutrition due to unbalanced nutrition Increase in prevalence of vector-borne diseases such as malaria Increase in number of people at risk to heat stress and its related condition, elderly, chronically ill, and children are especially vulnerable Increase in the prevalence of water-borne communicable and non-communicable diseases such as cholera, dysentery, etc.
 *Infrastructure*	Extreme pluvial and fluvial flooding causing damage to public infrastructure such as roads, bridges, hospitals, electricity networks, schools, and markets etc. Destruction of private properties such houses, hotels, etc. Increase forced displacement of people, especially affecting those in the most vulnerable *collines*
 *Forests*	Increase deforestation fueled by households' economic and domestic needs as well as cutting down trees for firewood, service lumber and timber Land degradation due to increase temperatures Loss of biodiversity, including plants and animals Increase prevalence of conflict over forest resources Increase forest disturbances such as insect outbreaks, invasive species, wildfires, and violent winds
 *Fisheries*	Reduce productivity of fish yields in lakes and river systems Increase pollution of marine ecosystem Overfishing leading to depletion of fisheries resources Loss of fisheries stock due to the migratory nature of certain fishes Degradation of spawning areas
 *Energy*	Decrease in hydropower output Increase in demand for energy uses for household and industrial purposes Siltation of hydroelectric dams

4. Mapping Multi-Risk Hotspots

Adaptation and landscape restoration work best when they are tailored to local conditions, which makes it important to assess climate risks at the *colline* level. Although many hazards, vulnerabilities, and barriers to adaptation are common across Burundi, they are not distributed equally. The maps presented in sections 2 and 3 highlight areas that are particularly affected by specific risks, such as landslides or disruptions to food production. The final step of the analysis combines modeling results and data from key indicators to assign a risk score to each of 2,616 *collines.*[125]

As noted in the introduction, the analysis used an enhanced version of the INFORM index, considering hazards, exposure, vulnerability, and (lack of) coping capacity. Figure 23 shows the indicators used for each dimension of risk. Each *colline* was assigned a score for each dimension, and then the scores were combined and weighted equally to obtain a risk score and identify multi-risk hotspots. For ease of understanding, the scores are grouped into five classes: *very low*, *low*, *medium*, *high*, and *very high*. Figure 31 in Appendix A1.5 shows the range of scores for each class in each dimension.

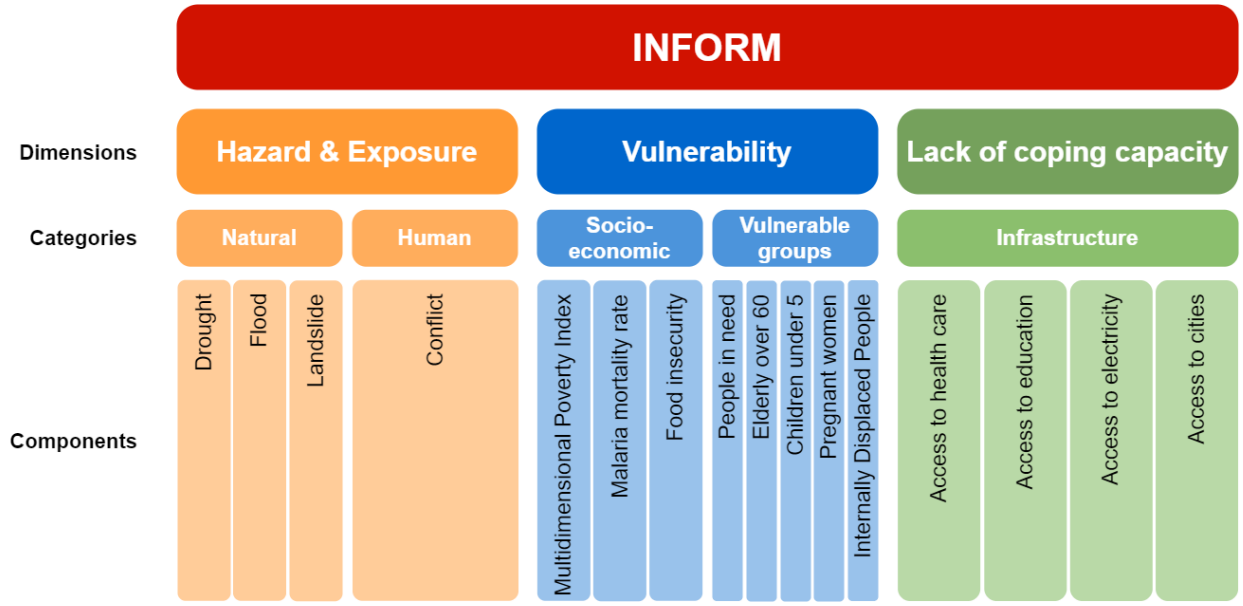


Figure 23. INFORM index indicators used to identify multi-risk hotspots. Source: World Bank, guided by Joint Research Centre et al., 2017.[126]

Two out of every five *collines* have high or very high exposure to climate hazards. This dimension reflects the extent to which *collines* are physically exposed to three types of climate

[125] As also noted in Appendix 1, in the absence of an official database of *collines,* the ASA analysis has relied on a database from the UN Office for the Coordination of Humanitarian Affairs (OCHA), which lists 2,616 *collines*, not 2,638, the number used by the Government. This means a small number of *collines* are apparently merged in the database. However, the 2,616 *collines* in the analysis still cover the entire country; no area is excluded.

[126] Joint Research Centre (European Commission) et al., 2017, *Index for Risk Management - INFORM: Concept and Methodology, Version 2017*.

hazards—droughts, landslides, and floods—as/or to conflict.[127] In total, 178 *collines* were found to have very high exposure; 888, high exposure; 749, medium exposure; and 801, low exposure. None was found to have very low exposure. Most of the highly exposed *collines* are situated along Lake Tanganyika (see Figure 24).

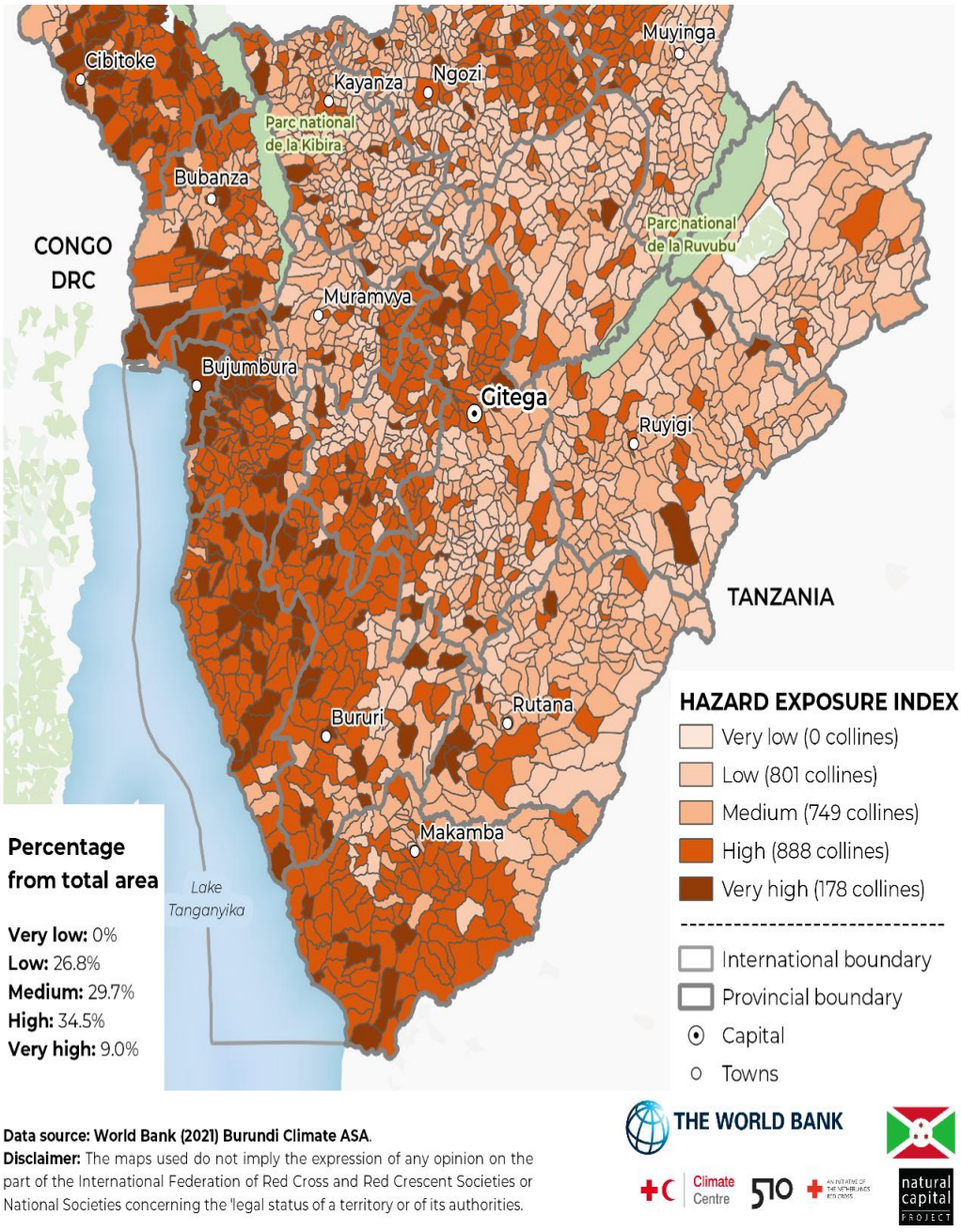


Figure 24. Composite hazard exposure index classification, by colline.

[127] The conflict category is represented by the past conflict fatalities data from the Uppsala Conflict Data Program (see https://ucdp.uu.se), as well as conflict trends described by experts interviewed for Technical Report 1. For details, see Section 8 of Jaime et al., 2021, "Diagnosing Drivers of Climate and Environmental Fragility in Burundi's Colline Landscapes – Climate and Conflict Risks."

All but 120 *collines* feature high or very high vulnerability, underscoring the extent to which tackling climate risk in Burundi requires addressing poverty, food insecurity, displacement, and other socio-economic issues. A total of 1,296 *collines* have very high vulnerability, and 1,200 have high vulnerability; the rest are in the medium class. As shown in Figure 25, the most vulnerable *collines* are concentrated in the north and northwest of the country, while those in the south, the east, and the area around Lake Tanganyika, are somewhat less vulnerable. Note that these scores are completely independent from hazards—they reflect how susceptible someone is to being harmed. A family that has savings, income that is not tied to the land, and a sturdy home may suffer only minor losses if there are torrential rains, for instance. By contrast, a family of subsistence farmers might lose a harvest and go hungry, and their house might be washed away. If they need to evacuate, having children, a pregnant woman, or an elder or person with disabilities in the household could hinder their ability to move quickly.

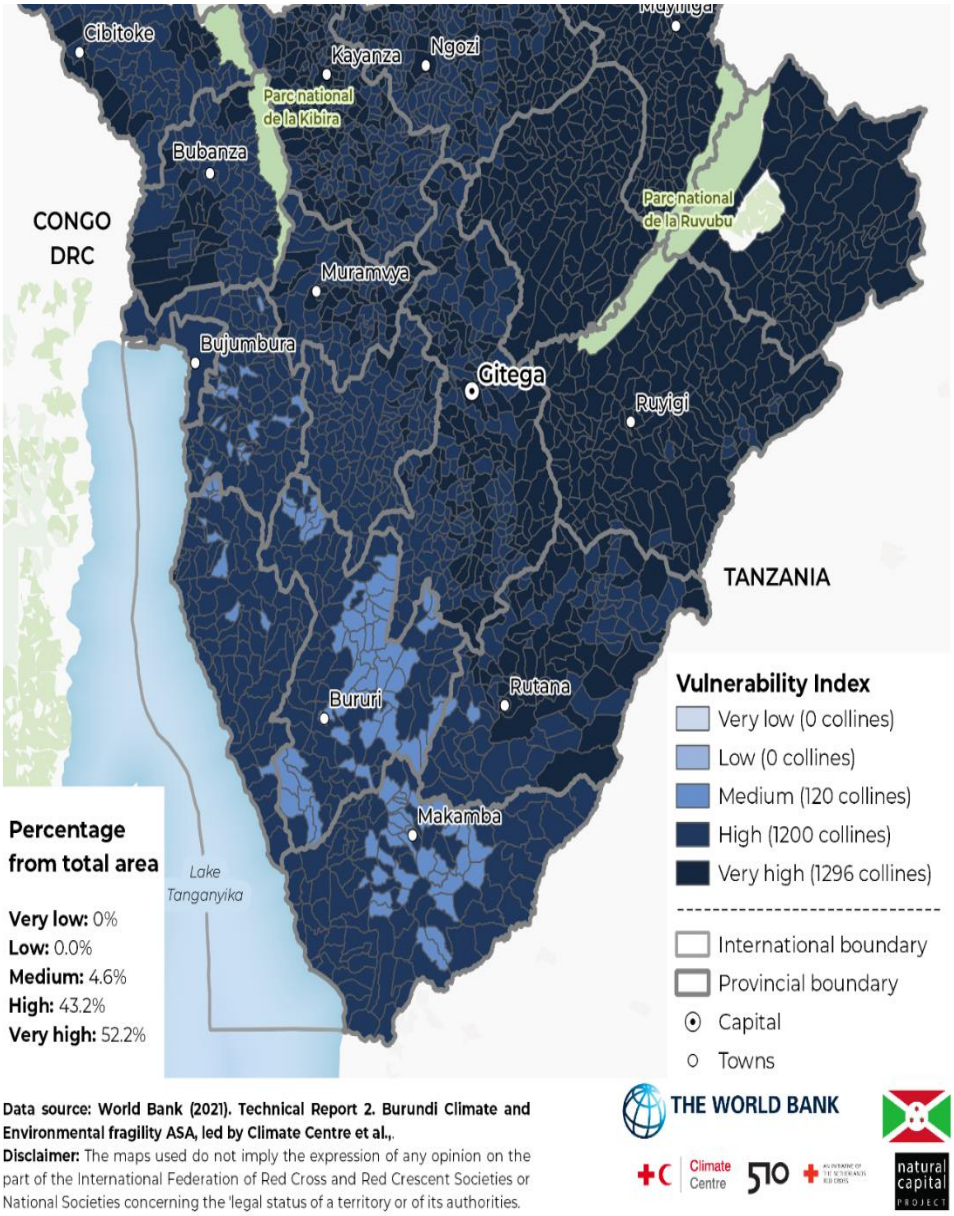


Figure 25. Composite vulnerability index classifications, by colline.

Nine out of 10 *collines* lack coping capacity (that is, very low coping capacity), 2,367 overall; another 216 were classified as high, 27 as medium, five as low, and one in the very low class Figure 26. This reflects the very large gaps in infrastructure and basic services discussed in Section 3, such as the lack of electricity access in most of rural Burundi. Access to health care is also very low, so the capacity to prevent an outbreak of cholera, for instance, or even to control malaria, is limited. Most of the country is simply not equipped to respond adequately to an emergency, or to provide sufficient support to affected people to ensure that they can recover quickly.

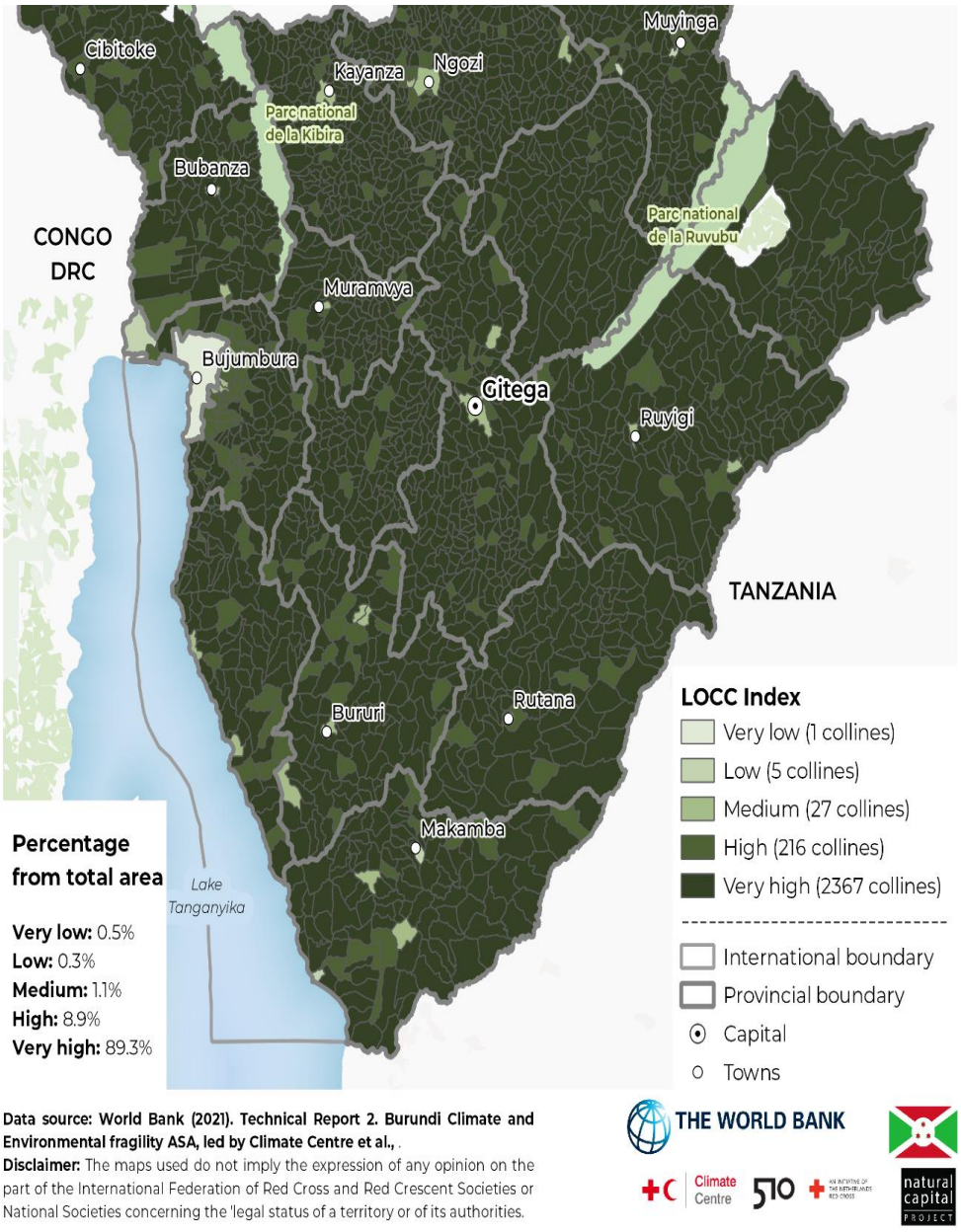


Figure 2627. Composite score for lack of coping capacity, by colline.

When the scores for the three dimensions were combined, 347 *collines* were found to be at very high risk, and 1,780 at high risk. Only 489 were at medium risk, and none was in the low or very low risk classes. The 347 very high risk *collines*, which are listed in Appendix

4, can be considered hotspots of climate and environmental fragility. As much as all of Burundi needs stepped-up efforts to build climate resilience, these *collines* require the most urgent attention. The provinces of Kirundo, Cibitoke, and Gitega have the largest numbers of very high risk *collines*: 91 in Kirundo, 42 in Cibitoke, and 31 in Gitega. Figure 28 presents the overall climate risk scores for all *collines,* and Figure 31 extracts the 347 *collines* with the highest composite risk scores. Table 3 then summarizes the results of the entire analysis.

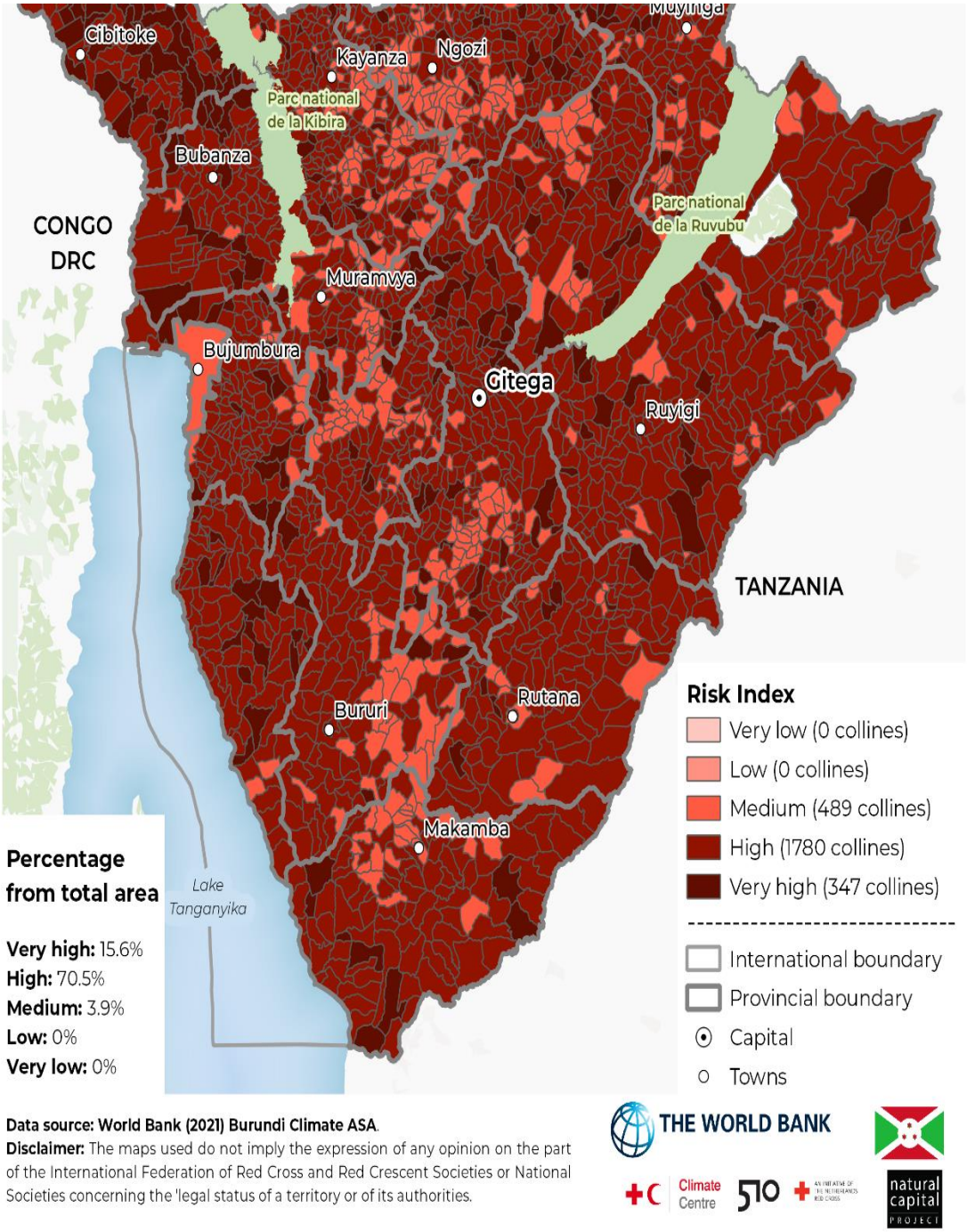


Figure 28. Final composite risk score, combining hazard exposure, vulnerability, and lack of coping capacity, by colline, using the INFORM risk mapping approach.

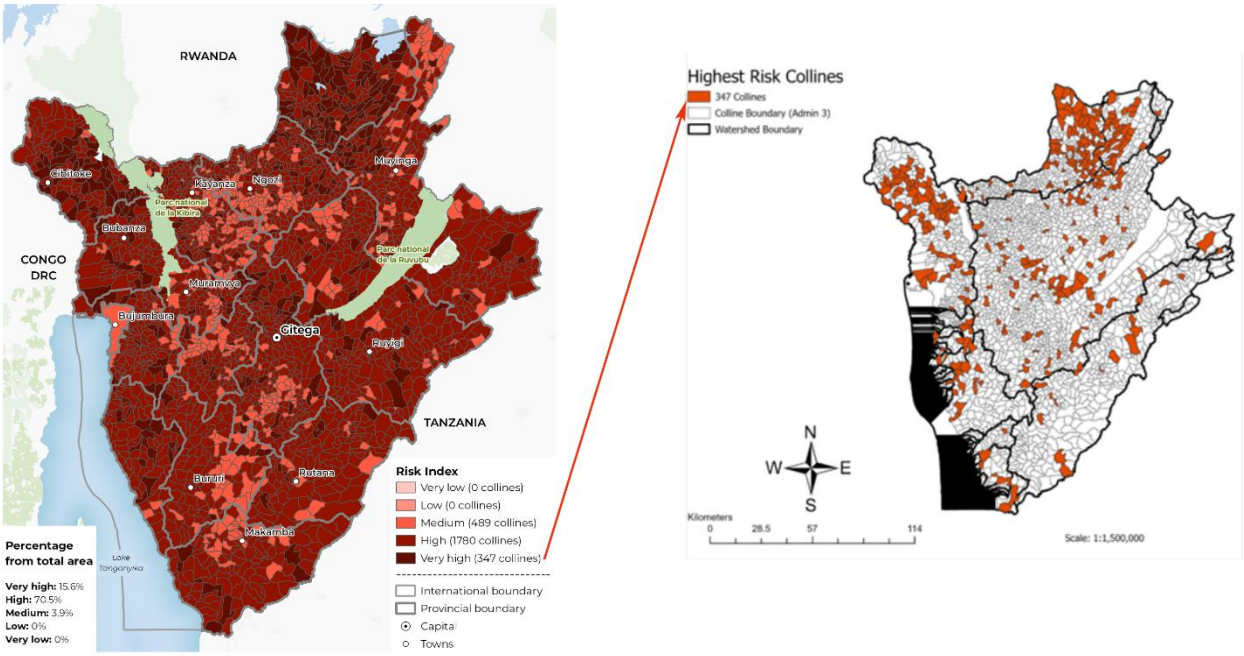


Figure 29. Extracting a map of the highest-risk collines based on the composite INFORM risk score results.

Table 3. Summary of the analysis—number of collines per class per dimension of risk.

Class	Hazard exposure	Vulnerability	Lack of coping capacity	Composite risk
Very high	178	1,296	2,367	347
High	888	1,200	216	1,780
Medium	749	120	27	489
Low	801	0	5	0
Very low	0	0	1	0

5. Recommendations for Addressing Barriers to Climate Resilience in Burundi and Next Steps

This section presents initial recommendations, meant to serve as the basis for additional dialogue with stakeholders in Burundi, with the goal of developing a proposal to scale up World Bank support to build climate resilience in all of Burundi's *collines*.

5.1 Tackling Institutional Barriers

Analysis presented in this report showed there is limited capacity at both the national and local levels to identify and address the impacts of climate change and land degradation, and their complex interactions with pre-existing post-conflict fragility. Burundi urgently needs support to strengthen early warning/early action systems, and to develop multi-sectoral coordination and effective monitoring and evaluation mechanisms. In general, institutions need to be strengthened, capacities need to be built across the Government, and climate change adaptation needs to be mainstreamed in all sectoral policies and plans. Priority actions for addressing institutional barriers to scaling up climate resilience include:

1. **Strengthen institutional capacity to monitor, assess and act on climate and land-related risks and communicate risk information.** A first step is to improve climate forecasting and hydrometeorological monitoring capability within the national met agency *Institut Geographique du Burundi (IGEBU)*, which is a prerequisite for effective data collection, prioritization, and analysis, and for improving Burundi's Early Warning System for land and climate-related risks.
2. **Support institutions to act on early warning information from risk monitoring systems and use them to enhance environmental protection and help rural *colline* communities adapt to climate change.** This builds on the recommendation above. Real-time environmental monitoring can help the Government prioritize interventions across sectors and evaluate their impacts, while building knowledge about climate change and land degradation. Burundi also needs a robust national resource management and monitoring system (ensuring sustainability of land, water and forest resources for generations to come). For farmers, along with weather data, another crucial service is epidemiological monitoring, with effective early warning systems for crop and livestock diseases and pests.

5.2 Tackling Policy Barriers

The Government is taking steps to reduce climate risks, halt land degradation, and restore landscapes for productive uses, but significant policy barriers remain. There are no integrated climate change strategies in sectoral policies, plans, and programs. There is also a lack of land tenure security that might undermine investment at the *colline* level, and there are no *colline*-level contingency plans. Another challenge is the lack of incentives for green jobs and private sector investment in land restoration and climate adaptation. Burundi's 2015 NDC and its 2020 update identify several measures the Government has prioritized, such as developing rural forestry; growing bamboo to protect riverbanks; restoring degraded land in areas such as the Congo Basin and Bugesera; improving livestock feed; installing solar power at 455 health and educational facilities; significantly expanding hydropower and grid-connected solar; promoting the use of biogas digesters to reduce the need for firewood; and improving water resources

management, among other measures.[128] These are steps in the right direction. In order to address key policy barriers to scaling up resilience in Burundi's *collines,* we recommend:

1. **Develop *colline*-level, multisectoral action plans to build climate resilience, as well as local contingency plans**. Such plans could be integrated into local development planning processes to ensure that climate impacts are taken into account across all relevant sectors and embedded within development planning, from local to national. Contingency plans are particularly important for areas that face the highest risk from land degradation, flood, and drought. The analysis presented in this report shows that climate hazards, vulnerabilities, and coping capacities are unevenly distributed across Burundi. Even though many of the intervention types needed are the same—from NBS, to improved disaster preparedness, to poverty alleviation measures—it is important to tailor responses to the needs of each *colline*, and to leave no community behind.
2. **Introduce urban development policies, paying special attention to areas with large concentrations of vulnerable people.** Informal settlements with poor infrastructure and populations are growing fast, driven to a great extent by migration from rural areas. As noted in Section 3, some of these areas are also at heightened risk of conflict. It is crucial to integrate climate resilience in urban design and infrastructure, to mitigate climate-related disaster risks. Develop master plans for the larger cities, with a view to making them engines of inclusive growth, and work to integrate informal settlements.
3. **Prioritize equity, inclusion and social cohesion as essential ingredients for resilience in the face of multi-risk fragility observed in Burundi's *collines.*** Policies will particularly need to be mindful of not reopening old wounds and rekindling conflict risks in designing policies and implementing climate interventions. Put the inclusion of marginalized groups, including women, IDPs, refugees, ethnic minorities, youth, and people with disabilities at the heart of the country's development and resilience-building strategies. Providing space for community dialogue and addressing conflict-related trauma further reduces social conflict risks and fosters inclusion, enhancing social resilience. These measures will help build shared prosperity and reduce multi-risk fragility in Burundi's *colline* landscapes. One of the key areas that creates grievances and increases FCV is exclusion from service delivery, decision-making, and economic and social opportunities. In this context, it is also important to be aware of political economy issues, including the potential for elite capture.
4. **Make climate resilience a priority in land use and infrastructure planning.** Thoroughly consider climate risks in the design of infrastructure—from roads, to sanitation systems, to hydropower plants, schools and health facilities —and build for resilience. Create national and provincial master plans for land use planning, with appropriate risk-informed zoning regulations. Equip health clinics with off-grid solar technologies to ensure their operations are not disrupted by power outages during recurring landslide events, and ensure safe climate-resilient passages to schools to avoid interruptions in school system delivery. In Burundi's rural *collines*, during heavy rainfall events, bridges are often cut off, leaving pupils stranded and unable to access their schools for weeks.

[128] Republic of Burundi, 2015, "Intended Nationally Determined Contribution (NDC)"; 2021, "Contribution Determinée Au Niveau National 2020: Annexe."

5.3 Tackling Financial Barriers

The Government's limited fiscal capacity and limited access to finance grossly undermine climate resilience investment and development in Burundi. This is the case even for the interventions described in the NDC, but the Bank's Burundi Landscape Restoration and Resilience Project has shown that local-scale interventions are most effective. For example, the project has successfully led *colline*-level land certification and registration activities, and digital cash-for-work transfers to local marginalized *barwa* communities for land restoration labor work produced. It has also shown the importance of investing in local capacity building—for example, by employing community members to replant trees, giving them the skills and tools to continue to restore degraded land in their communities for decades to come.

We found that a full package of *colline*-level interventions would cost about US$1.5 million per *colline*, or more than $500 million to cover just the highest-risk *collines*. As noted in the introduction, a final step in the analysis for this report was to create draft Community-Level Climate Action Plans (CCAPs) for a sample of five *collines,* identifying community-designed activities to address physical hazards (through land restoration); reduce vulnerabilities and increase coping capacities and resources; build economic resilience by strengthening and diversifying livelihoods; and build social resilience through community dialogue and activities to build social cohesion in post-conflict contexts. The $1.5 million estimate was derived from community consultations in May 2022 (see Annex 7 for details). Scaled up to cover all of Burundi—the actual need, as shown in Section 4, since the multi-risk analysis found every *colline* is at medium, high, or very high risk—leads to a staggering national resilience investment cost of close to $4 billion. Targeting only the 347 very high risk *collines* listed in Appendix 4 brings the required investment down to at least $535 million.

We recommend convening a multi-donor roundtable for large-scale resource mobilization to tackle drivers of climate fragility in Burundi's *collines*. Given that the Government has very little fiscal capacity to cover the costs of resilience building, it is crucial to mobilize global climate financing and secure development finance from the World Bank Group, UN Agencies, bilateral and multilateral partners, the private sector, and non-governmental organizations operating in Burundi. The mobilized resources should be used to prioritize climate resilience investments in the following areas:

1. **Deploy nature-based solutions (NBS) to address landslide, erosion, and flood risks putting people, food production, livelihoods, and infrastructure at risk:** National-level leadership, technical guidance, and funding are essential, but interventions should be tailored to each *colline*'s needs. Strong stakeholder engagement is key to ensure that NBS activities proposed and modeled are appropriate for the local context and to build local ownership, so the interventions are likelier to be sustained over the long term.
2. **Leverage the power of landscape restoration and climate-smart agriculture to improve and diversify livelihoods,** with special attention to women, who play key roles in farming and food production in rural Burundi. Take a landscape approach,[129] recognizing that environmental interventions will be more effective if they also improve people's lives and build prosperity. Support farmers to enable them to adopt climate-smart agriculture techniques that improve productivity while building resilience and improving soil carbon

[129] See Cordon, S. 2019. "A Brief Explainer of the Landscape Approach." *Landscape News* (blog). August 6, 2019. https://news.globallandscapesforum.org/37802/a-brief-explainer-of-the-landscape-approach/.

storage. Adopt terracing techniques to reduce erosion and landslide risks and protect crops. Some approaches can also create new sources of income. Agroforestry, for example, can help farmers earn cash from selling fruit or nuts from the trees on their land. Create targeted programs for rural women, including opportunities to earn income from planting trees, protecting forests, and restoring degraded land.

3. **Invest in public health and food security.** Significant progress has been made in recent years, but stepped-up efforts are needed to address hunger and malnutrition and to protect from disease outbreaks. The incidence of malaria across Africa declined by 40 percent from 2000 to 2015, but in Burundi, it more than doubled from 2000 to 2019,[130] reaching epidemic levels despite increased testing and treatment. Cholera outbreaks remain common. With climate change increasing the risks of these and other vector- and water-borne diseases, sustained public health interventions and improved infrastructure (especially for water and sanitation) will be crucial.
4. **Protect freshwater resources and collect rainwater for storage and irrigation:** Women in particular walk miles with water buckets on their heads from watersheds at the bottom of the hills back to their farms up to on hillsides. Monitor and manage the quality and levels of water in Lake Tanganyika and invest in the Lake's Integrated Coastal Management Plan. Monitor other lakes and rivers, especially in areas that have experienced water scarcity. Invest in NBS to control erosion and create buffer zones around rivers and lakes to reduce pollution risks. Improve fisheries management and monitoring to help protect these resources from depletion.

5.4 Tackling Knowledge Barriers

Burundi needs to close significant knowledge and data gaps to be able to identify climate and disaster risks and develop appropriate interventions. These gaps include, but are not limited to, lack of technical knowledge about NBS, lack of climate and disaster risk impact data, limited assessment of climate change impacts on sustainable economic growth and poverty reduction, and the absence of a national climate platform for dialogue and knowledge-sharing. To tackle those barriers, we recommend:

1. **Build capacities across national and local Government** to identify climate risks, diagnose their impacts on sector and national development and develop appropriate policy responses. This requires additional training of decision-makers and staff in different ministries to build their knowledge of climate change and locally appropriate strategies, as well as coordination to identify synergies and foster knowledge-sharing and mutual learning. Opportunities to make the most of NBS, for instance, are likelier to be seized if officials in charge of transport or water resources work together with those in charge of landscape restoration and reforestation efforts. Dialogue and knowledge-sharing should also be promoted among communes designing resilience-building interventions. World Bank teams working in Burundi should seek to build synergies as well, including with other regional and international partners.
2. **Establish a national climate database to track climate change impacts, including disasters, at the province and *colline* levels:** Such a database could be

[130] Sinzinkayo, D. et al. 2021. "The Lead-up to Epidemic Transmission: Malaria Trends and Control Interventions in Burundi 2000 to 2019." *Malaria Journal* 20 (1): 298. doi:10.1186/s12936-021-03830-y.

complemented with feedback from focal points in every colline to contextualize quantitative data with more qualitative insights, including on social impacts of climate change such as land conflicts. It is also crucial to invest in climate research and development in Burundi, which requires using the latest technologies, robust scientific methods, and innovative software and tools to regularly collect risk data and analyze them to inform decision-making processes. All this would also provide a solid foundation for climate services, which can translate this knowledge and information for affected communities.

3. **Build strong monitoring, evaluation, and learning systems:** Development partners can provide support to ensure high-quality data gathering and analytics to evaluate the effectiveness of interventions and keep improving them. The World Bank's Geo-Enabling Initiative for Monitoring and Supervision (GEMS)[131] can provide valuable information to increase program responsiveness and real-time learning, especially in the most fragile areas. Robust grievance redress mechanisms (GRMs) are also crucial.

5.5 Next Steps

Burundi urgently needs to scale up investments to build resilience to the combined effects of climate change, land degradation, and fragility, which pose significant threats to the livelihoods and well-being of millions of people in Burundi's *collines*. The modeling done for this report provides a chilling outlook: By 2030, more than 69 percent of soils will experience acute sedimentation relative to 2020 baselines, and by 2060, close to a third of Burundi's territory could be degraded (see Figure 16). Between 2017 and 2020 alone, 1.2 percent of Burundi's land area experienced acute land degradation. Meanwhile, temperatures are rising and precipitation extremes appear to be becoming more common. Drought, flood, and landslide risks are escalating, and soil erosion is stripping the land of nutrients, reducing its fertility. As shown in Section 4, our multi-risk analysis showed 347 *collines* are at very high risk, 1,780 are at high risk; and 489 are at medium risk; none is at low risk. This highlights the importance of investing in resilience all across the country, while prioritizing the most at-risk *collines*.

The World Bank Group will continue to work closely with the Government to hardwire a focus on resilience in all new investments, building on the insights from this ASA and from initial work on the Burundi Landscape Restoration and Resilience Project. Now that workshops have been conducted in sample *collines,* and *colline*-level CCAPs have been developed, the next step will be to develop a proposal with targeted measures to scale up the restoration of degraded landscapes; strengthen community resilience; strengthen institutional resilience; and improve monitoring and evaluation.

Along with this report, the ASA has produced several digital interactive resources, accessible online and today fully owned by the Government of Burundi and national partners:

1. The story map accessible on: https://p-phung.github.io/Burundi_hotspots/
2. The digital e-books: French version https://spatialagent.org/BurundiClimateLandscapeFr/ & English Version: https://spatialagent.org/BurundiClimateLandscapeEn/
3. Knowledge resources: https://spatialagent.org/Burundi/filter.html

[131] See https://www.worldbank.org/en/topic/fragilityconflictviolence/brief/geo-enabling-initiative-for-monitoring-and-supervision-gems.

It is our sincere hope that the findings and recommendations from this report will guide a large-scale financing mobilization effort to save the *collines* of Burundi, in support of the efforts of the Government of Burundi, and protect them for the benefit of future generations, before it is too late. These spectacular hills are a testament to the majesty of nature, and deserve our protection, along with the vibrant and resilient populations who inhabit them.

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Appendix 1. Risk Modeling Methodology

This Appendix provides a brief overview of the risk modeling methodology that underpins the results presented in Section 4. This is only a summary; for more detailed descriptions and more information about data sources, see Technical Reports 1 and 2.[132]

A1.1 Modeling future climate in Burundi: Temperature and precipitation changes

This analysis spanned historical, current, and future primary climate indicators—temperature and precipitation in Burundi. The analysis of historical trends and variability of temperature is based on WATCH forcing data.[133] Climate Hazards Group InfraRed Precipitation with Stations data (CHIRPS) were also used for rainfall analysis.[134] CHIRPS estimates were merged with rain gauge measurements from a wide dataset provided by Burundi Geographical Institute (IGEBU).

In addition, the analysis used IGEBU ground observation data at monthly timescales for the period 1991–2020. Fifteen stations distributed across Burundi were used to assess the trends in annual total precipitation; eight stations were used to assess trends in annual maximum temperature; and seven stations were used to assess trends in annual minimum temperature. The dataset was carefully checked, including controlling for unrealistic precipitation and temperature values, before being used for trend analysis. The list of the stations used is shown in Table A1. The Theil–Sen's slope estimator was used to measure the magnitude of precipitation and temperature change in all stations.

[132] Jaime et al., 2021, "Diagnosing Drivers of Climate and Environmental Fragility in Burundi's Colline Landscapes – Climate and Conflict Risks"; Vogl, Leon, and Dampha, 2021, "Landslide/Soil Erosion Risks and the Potential for Nature-Based Solutions for Burundi's Colline Landscapes."
[133] Weedon, G.P. et al. 2014. "The WFDEI Meteorological Forcing Data Set: WATCH Forcing Data Methodology Applied to ERA-Interim Reanalysis Data." *Water Resources Research* 50 (9): 7505–14. doi:10.1002/2014WR015638.
[134] Funk et al., 2015, "The Climate Hazards Infrared Precipitation with Stations—a New Environmental Record for Monitoring Extremes."

Table A1. Synoptic stations used in the trend analysis of rainfall, maximum and minimum temperature

STATIONS	LON	LAT	PR	Tmaxi	Tmin
BUJUMBURA (Airport)	29,32	-3,32	1991–2020	1991–2020	1991–2020
CANKUZO (Project)	30,38	-3,28	1991–2020	1991–2020	—
GIGOZI	29,68	-3,57	—	1991–2020	1991–2020
GITEGA (Airfield)	29,92	-3,42	1991–2020	1991–2020	1991–2020
KARUZI	30,17	-3,10	1991–2020	1991–2020	1991–2020
KINYINYA	30,33	-3,65	1991–2020	—	1991–2020
KIRUNDO (Project)	30,12	-2,58	1991–2020	1991–2020	1991–2020
MAKAMBA	29,82	-4,13	1991–2020	—	—
MURIZA	30,08	-3,53	1991–2020	—	—
MUSASA	30,10	-4,00	1991–2020	1991–2020	1991–2020
MUYINGA	30,35	-2,85	1991–2020	—	—
NYAMUSWAGA	30,03	-2,88	1991–2020	1991–2020	1991–2020
RUVYIRONZA	30,25	-3,48	1991–2016	—	—
RWEGURA	29,52	-2,92	1991–2020	—	—
TORA	29,53	-3,73	1991–2016	—	—
RWEZA	29,6	-4,1	1991–2016	—	—

The climate change projections are based on the Regional Climate Models (RCMs) from the Coordinated Regional Downscaling Experiment (CORDEX).[135] The models are driven by global climate models (GCMs) used in the IPCC's Fifth Assessment Report. A complete list of the combination of GCMs downscaled and the RCMs used is in Technical Report 1.[136] Two representative concentration pathways (RCPs) were selected—RCP 4.5 and RCP 8.5—to show futures under medium-low and very high emissions pathways. Figure 30 shows the schematic procedure of the downscaling methodology.

Future projections were developed for two time periods, 2020–2040 and 2040–2060, and compared with the historical period 1981–2000. This enables us to provide both near- and mid-term projections, and thus support decision-making processes on different planning horizons.

[135] Giorgi, F., and W.J. Gutowski. 2015. "Regional Dynamical Downscaling and the CORDEX Initiative." *Annual Review of Environment and Resources* 40 (1): 467–90. doi:10.1146/annurev-environ-102014-021217.
[136] Jaime et al., 2021, "Diagnosing Drivers of Climate and Environmental Fragility in Burundi's Colline Landscapes – Climate and Conflict Risks."

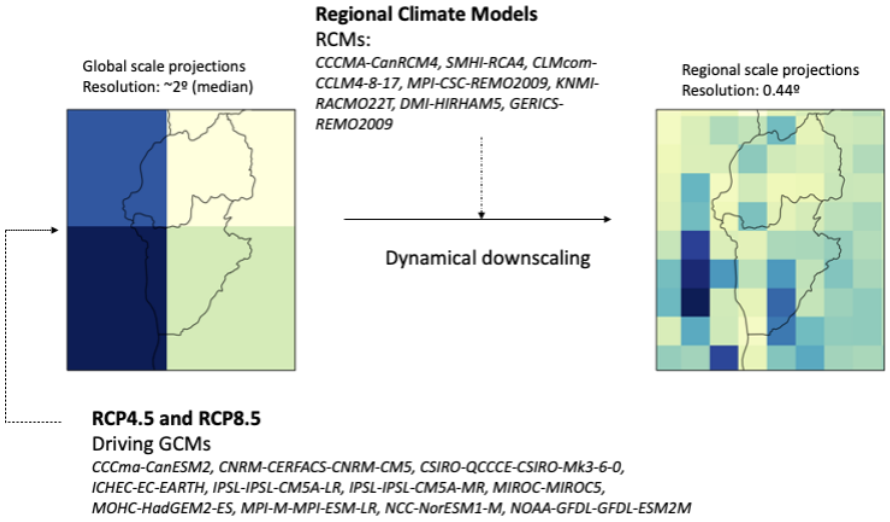

Figure 30. Schematic of the downscaling procedure. Ten GCMs and two RCPs (RCP 4.5 and RCP 8.5) were dynamically downscaled by the CORDEX project and used in this report.

A1.2 Modeling relative flood risk in Burundi

To develop a national-level rapid assessment of flood risk, we applied a spatial multi-criteria evaluation (SMCE) approach based on the analytical hierarchy process method and geographic information system (GIS) techniques. The SMCE method evaluates and integrates multiple layers to inform a flood risk modeling process.[137] The model input layers include digital elevation model, precipitation, potential evapotranspiration, normalized difference vegetation index, compound topographic index, gridded population layer, and accessibility map (representing the distance to major cities); examples are provided in Appendix 3. The input data layers were sourced from globally available earth observation datasets; see Technical Report 2 for details.[138] Table A2 shows flood risk severity and vulnerability levels based on major factors conditioning flood risk.

[137] Feizizadeh, B., and T. Blaschke. 2013. "Land Suitability Analysis for Tabriz County, Iran: A Multi-Criteria Evaluation Approach Using GIS." *Journal of Environmental Planning and Management* 56 (1): 1–23. doi:10.1080/09640568.2011.646964.
[138] Vogl, Leon, and Dampha, 2021, "Landslide/Soil Erosion Risks and the Potential for Nature-Based Solutions for Burundi's Colline Landscapes."

Table A2. Flood risk severity and vulnerability levels, relative to key flood risk conditioning factors

Risk Severity	**Lowest**	**Low**	**Moderate**	**High**	**Highest**
Risk Index	1	2	3	4	5
NDVI (index)	>0,637	0,637–0,527	0,527–0,416	0,416–0,305	<0,305
Elevation (m)	<1155	1155–1543	1543–1931	1931–2319	>2319
Precipitation (mm)	<115,7	115,7–140,8	140,8–165,9	165,9–191,0	>191,0
Potential evapotranspiration (mm)	>119,5	119,5–110,5	110,5–101,6	101,6–92,7	<92,7
Slope (%)	<15	15,2–30,4	30,4–45,6	45,6–60,8	>60,8
Compound Topographic Index	<902,4	902,4–1391,8	1391,8–1881,2	1881,2–2370,6	>2370,6
Travel time (minutes)/ Mobility access	<211,4	211,4–422,8	422,8–634,2	634,2–845,6	>845,6
Population density (people/100m)	<168	168–335	335–502	502–669	>836

These SMCE methods have been widely applied to inform decision-making processes in many developing countries where there are limited or no data on flood extent.[139] This approach aims not to deliver a "final and optimal solution"[140] to flood risk mitigation, but rather to provide high-level details on population, infrastructure, and landscape features' relative exposure and vulnerability to fluvial and pluvial flood risks in order to inform decision-makers on where to prioritize interventions.

A1.3 Modeling land degradation, landslide, and soil erosion risks

This analysis, led by scientists from Stanford University's Natural Capital Project, applied spatially explicit models to estimate Burundi's land degradation, erosion, and landslide risk.[141] First, Landsat data were used to conduct a supervised classification of land-use/land cover change in Burundi from 2000 to 2020. Second, spatially explicit models were applied to estimate erosion and landslide hazards at the *colline* level for the baseline year 2020. This entailed (a) analyzing remote sensing data to identify land degradation hotspots, (b) estimating erosion and sedimentation rates using the InVEST Sediment Delivery Ratio (SDR) model,[142] (c) estimating

[139] Rahmati, O., H. Zeinivand, and M. Besharat. 2016. "Flood Hazard Zoning in Yasooj Region, Iran, Using GIS and Multi-Criteria Decision Analysis." *Geomatics, Natural Hazards and Risk* 7 (3): 1000–1017. doi:10.1080/19475705.2015.1045043.
[140] de Brito, Evers, and Almoradie, 2018, "Participatory Flood Vulnerability Assessment: A Multi-Criteria Approach"; Kowalski, K. et al. 2009. "Sustainable Energy Futures: Methodological Challenges in Combining Scenarios and Participatory Multi-Criteria Analysis." *European Journal of Operational Research* 197 (3): 1063–74. doi:10.1016/j.ejor.2007.12.049.
[141] Vogl, Leon, and Dampha, 2021, "Landslide/Soil Erosion Risks and the Potential for Nature-Based Solutions for Burundi's Colline Landscapes."
[142] Sharp, R. et al. 2020. "InVEST 3.9.0. User's Guide. The Natural Capital Project, Stanford University, University of Minnesota, The Nature Conservancy, and World Wildlife Fund."

rainfall infiltration using the InVEST Seasonal Water Yield (SWY) model,[143] to inform landslide hazard modeling, and (d) generating estimates of landslide hazard using the Factor of Safety[144] and Gravitational Process Path[145] approaches, to identify areas of high, medium, and low landslide risk. For details on each of these steps, as well as data sources, see Technical Report 2.[146]

Evidently, nature-based solutions (NBS) can offset climate-related hazards, including landslide and soil erosion[147]. Step three of the analysis was to perform a screening assessment of NBS, comparing erosion and landslide risks *with* versus *without* investments in improving vegetation cover, to identify areas where these activities would most effectively mitigate such hazards. The approach helps us examine the role of natural vegetation cover in amplifying or diminishing the background level of hazard driven by slope, soil properties, and geology.[148]

Two scenarios were considered to reflect two types of potential nature-based solutions:

1. A degradation scenario that assumes a loss of existing natural vegetation in good condition;
2. A restoration scenario that assumes investments in activities that improve the condition of vegetation and soil cover, such as agroforestry, silvopasture, revegetation, etc.

The first scenario allowed us to determine where the damage costs are highest under continuous land degradation and the second allowed us to examine the potential benefits of nature-based solutions (NBS) involving the restoration or rehabilitation of degraded land. Results for each model were aggregated to the *colline* level, and the differences between the baseline (2020) hazard and the two scenarios were calculated. Potential NBS impacts from the two scenarios were summed in the end to produce a single index per *colline* that reflects the benefits of investing in restoration and protection of natural capital.[149] The output maps, including the multi-hazard layer, were overlaid with other climate risk indicators (rainfall, temperature, floods, droughts) to generate the national multi-risk hotspot map.[150]

A1.4 Modeling climate, land conflict, and forced displacement risks

The analysis of land conflict plays an essential role in the overall understanding of vulnerability across Burundi. There is a complex dynamic between socioeconomic vulnerability, conflict risks, and climatic hazards. All these components need to be explored to draw a holistic picture of the vulnerability of people living in the country. Hence, a conflict risk analysis has been conducted

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[143] Richard Sharp et al., 2020, "InVEST 3.9.0 User's Guide."
[144] Selby, M.J. (Michael J., and A.P.W. Hodder. 1993. "Hillslope Materials and Processes," 451.
[145] Wichmann, V. 2017. "The Gravitational Process Path (GPP) Model (v1.0) - A GIS-Based Simulation Framework for Gravitational Processes." *Geoscientific Model Development* 10 (9): 3309–27. doi:10.5194/gmd-10-3309-2017.
[146] Vogl, Leon, and Dampha, 2021, "Landslide/Soil Erosion Risks and the Potential for Nature-Based Solutions for Burundi's Colline Landscapes."
[147] FEMA. 2021. "Building Community Resilience With Nature-Based Solutions: A Guide for Local Communities," no. June: 1–30; IPCC, 2012, "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D."
[148] Vogl, Leon, and Dampha, 2021, "Landslide/Soil Erosion Risks and the Potential for Nature-Based Solutions for Burundi's Colline Landscapes."
[149] Vogl, Leon, and Dampha, 2021.
[150] Jaime et al., 2021, "Diagnosing Drivers of Climate and Environmental Fragility in Burundi's Colline Landscapes – Climate and Conflict Risks"; Vogl, Leon, and Dampha, 2021, "Landslide/Soil Erosion Risks and the Potential for Nature-Based Solutions for Burundi's Colline Landscapes."

using georeferenced historical conflict event data (UCDP 1989–2020; ACLED 2020–2021).[151] In addition, a literature scan was conducted to identify the drivers of conflicts related to climate-related disaster impacts and conflicts associated with natural resource utilization and population's reactions to their degradation and depletion. Together with the results of the grey literature and six semi-structured interviews, we identify the geographical locations of historical and current land conflict situations as well as potential future conflict trends and locations.[152]

A1.5 Bringing it all together: Mapping climate fragility hotspots in Burundi

To put the various methodological pieces together, we use an **enhanced INFORM index method,** where the risk data is analyzed based on three standard risk dimensions: vulnerability, hazard, and coping capacity.[153] The term "enhanced INFORM index" was coined, as the methodology used to integrate additional pieces of information that is normally not considered in the standard INFORM index, including climate change projection, conflict, and migration data. INFORM is an index method that calculates a composite risk index across three dimensions.[154] It does not consider interactions between hazards but allows for layering other types of hazards than natural hazards. INFORM has been developed by the Joint Research Centre of the European Commission.[155] Technical Report 1 provides details on the INFORM methodological steps, including data sources.[156]

Interpretation and visualization

The INFORM index is scored between 0 and 10, with low values representing low-risk *collines*, and the high values representing high risk (Figure 31). The notion that higher is worse is consistently applied also at dimension, category and component levels. Once the score for each dimension is calculated, *collines* are classified into five classes: very low, low, medium, high, and very high. The purpose of this classification in the form of a hierarchical scale is to systematically identify risk in a consistent manner. Risk classes give users greater ability to monitor, control and even manage risk because it helps identify the root causes of risk in better way. Different dimensions have different threshold classes and coloring. A standard graduated color scheme is used to visualize the data from soft colors representing lower risk classes to darker colors representing the higher-risk ones.

[151] Jaime et al., 2021, "Diagnosing Drivers of Climate and Environmental Fragility in Burundi's Colline Landscapes – Climate and Conflict Risks."
[152] Jaime et al., 2021.
[153] Jaime et al., 2021.
[154] Joint Research Centre (European Commission) et al., 2017, *Index for Risk Management - INFORM: Concept and Methodology, Version 2017*.
[155] Nicholson, S.E. 1999. "Historical and Modern Fluctuations of Lakes Tanganyika and Rukwa and Their Relationship to Rainfall Variability." *Climatic Change* 41 (1): 53–71. doi:10.1023/A:1005424619718.
[156] Jaime et al., 2021, "Diagnosing Drivers of Climate and Environmental Fragility in Burundi's Colline Landscapes – Climate and Conflict Risks."

CLASSES THRESHOLDS IN INFORM			
Dimension	CLASS	MAX	MIN
RISK	very high	10	6.5
	high	6.4	5.0
	medium	4.9	3.5
	low	3.4	2.0
	very low	1.9	0.0
HAZARD & EXPOSURE	very high	10.0	6.1
	high	6.0	4.1
	medium	4.0	2.7
	low	2.6	1.5
	very low	1.4	0.0
VULNERABILITY	very high	10.0	6.4
	high	6.3	4.8
	medium	4.7	3.3
	low	3.2	2.0
	very low	1.9	0.0
LACK OF COPING CAPACITY	very high	10.0	7.4
	high	7.3	6.0
	medium	5.9	4.7
	low	4.6	3.2
	very low	3.1	0.0

Figure 31. Fixed thresholds and colors at the level of dimension. Source: Joint Research Centre et al., 2017.[157]

[157] Joint Research Centre (European Commission) et al., 2017, *Index for Risk Management - INFORM: Concept and Methodology, Version 2017*.

Appendix 2. Weather Station Temperature and Rainfall Trends

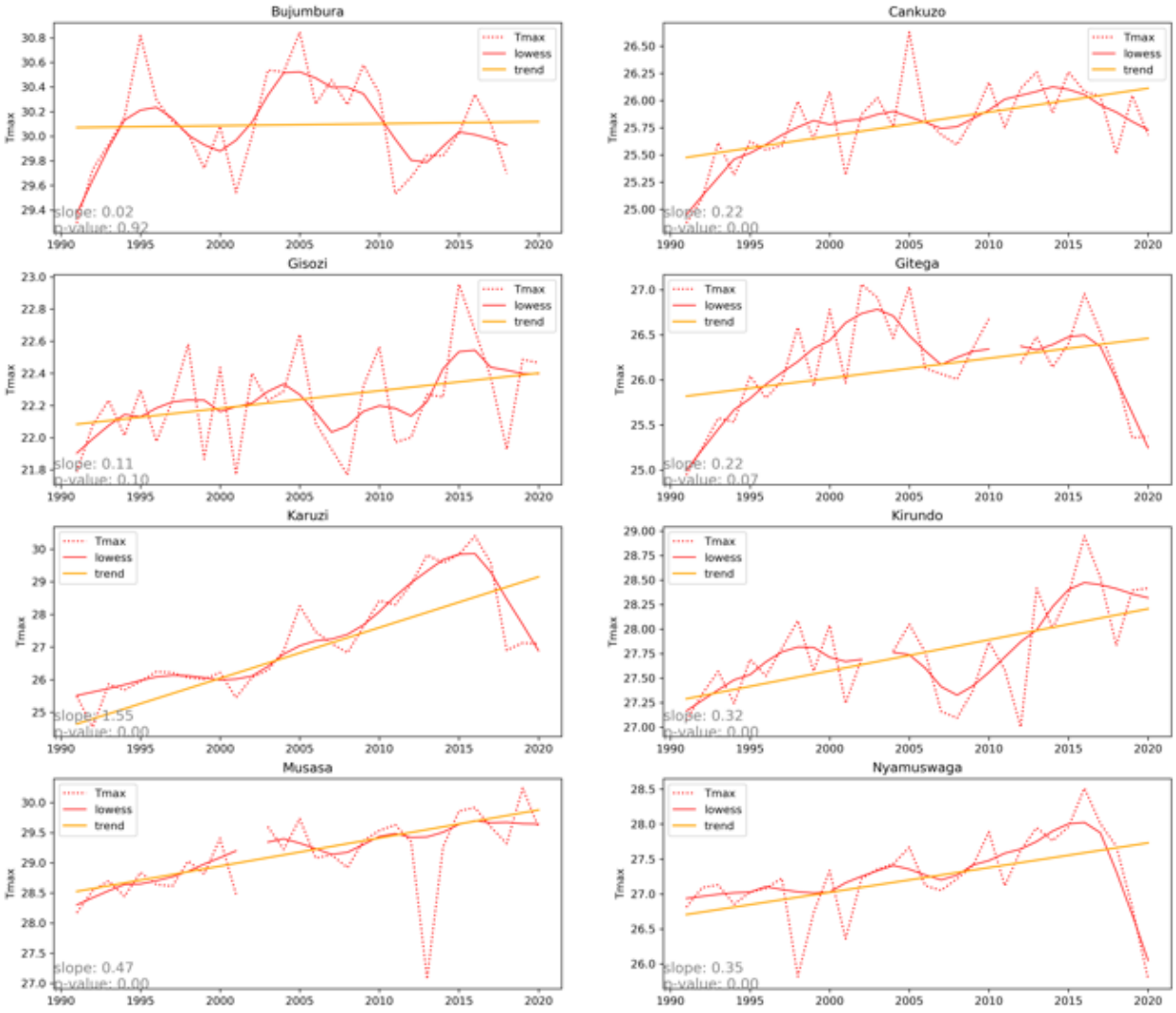


Figure 32. Annual daily maximum temperature trends documented at Burundi weather stations. Data source: IGOBU.

Figure 33. Annual daily maximum temperature trends documented at Burundi weather stations. Data source: IGOBU.

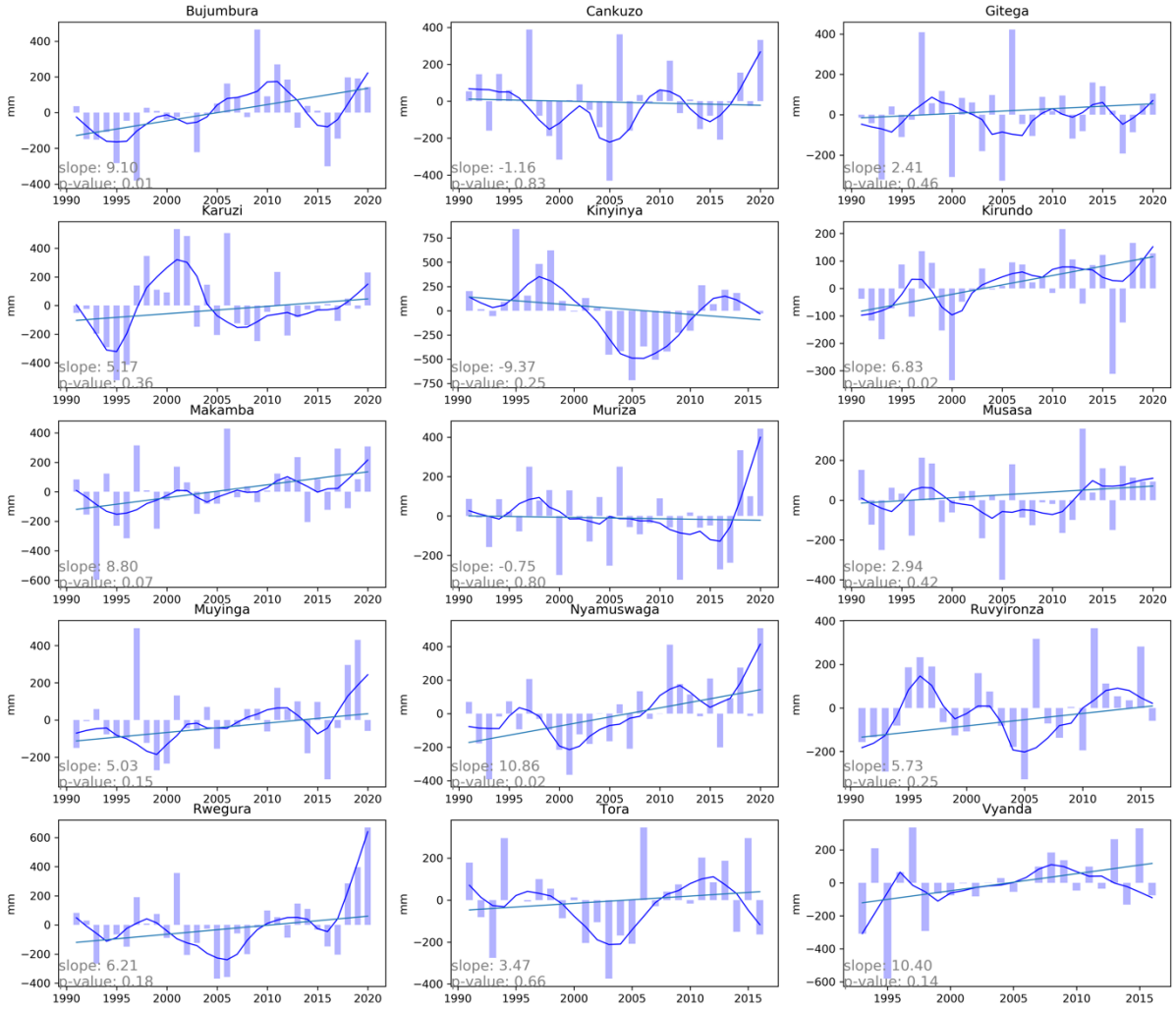
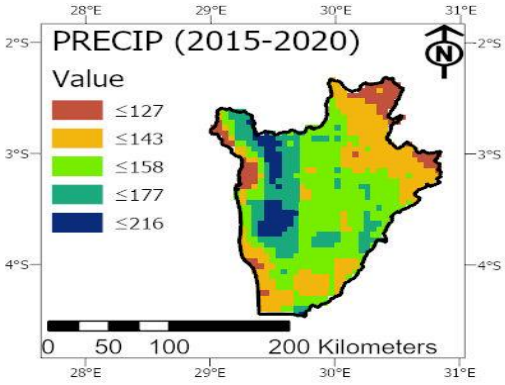
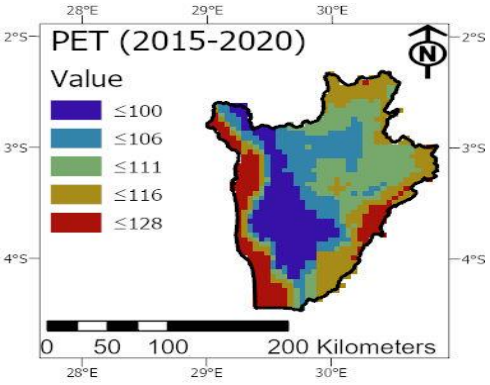
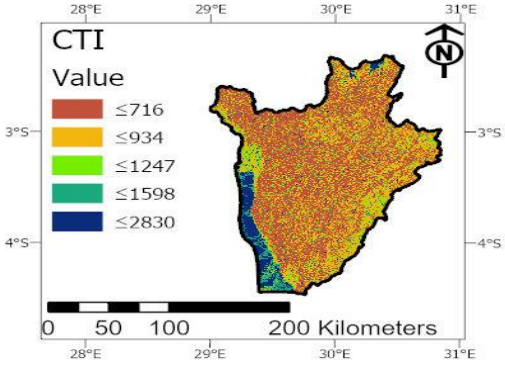


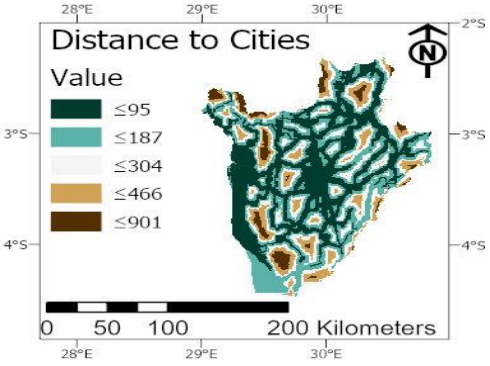
Figure 34. Annual total precipitation anomalies relative to 1991–2020 mean. The annual trend magnitude and the p-value is indicated in the bottom left of each panel. Data source: IGEBU.

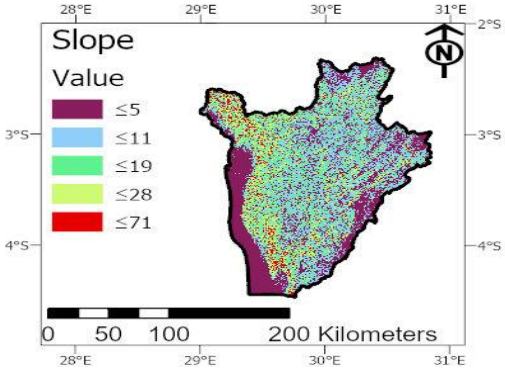
Appendix 3. Flood Risk Conditioning Factors for Flood Risk Mapping

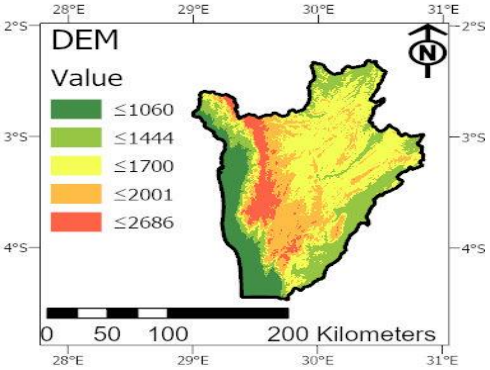












Appendix 4. The 347 *Collines* Ranked as Highest-Risk per the INFORM Index—Hotspots of Multi-Risk Fragility in Burundi

Province	Commune	Colline	INFORM Risk Index Score
Ruyigi	Bweru	Gasenyi	7,52
Karuzi	Buhiga	Gisenyi	7,47
Cibitoke	Bukinanyana	Bukinanyana	7,41
Gitega	Buraza	Ndava	7,40
Cibitoke	Bukinanyana	Rtyazo	7,36
Kirundo	Gitobe	Cumba	7,33
Cankuzo	Mishiha	Kibimba	7,27
Cibitoke	Rugombo	Cibitoke	7,21
Kirundo	Kirundo	Cumva	7,20
Kirundo	Busoni	Buringa	7,20
Kirundo	Kirundo	Kavomo	7,19
Ruyigi	Bweru	Gatwaro	7,18
Ngozi	Tangara	Cumba	7,17
Kirundo	Busoni	Burara	7,16
Kirundo	Vumbi	Vumbi	7,15
Bururi	Bururi	Gasenyi	7,12
Kirundo	Kirundo	Cewe	7,11
Cibitoke	Mabayi	Kabere	7,10
Rutana	Rutana	Musenyi	7,09
Kirundo	Bwambarangwe	Budahunga	7,09
Rumonge	Burambi	Gisenyi	7,08
Gitega	Mutaho	Muyange	7,08
Rutana	Musongati	Kamaramagambo	7,08
Muyinga	Gashoho	Muyange	7,08
Cibitoke	Bukinanyana	Gakomero	7,06
Muyinga	Gasorwe	Buringa	7,04
Kirundo	Busoni	Sigu	7,04
Gitega	Mutaho	Nkongwe	7,00
Kayanza	Butaganzwa	Bumba	6,99
Ngozi	Kiremba	Ruvumu	6,99
Kirundo	Ntega	Kigaga	6,99
Cibitoke	Bukinanyana	Nyarwumba	6,99
Ruyigi	Kinyinya	Kinyinya	6,98
Ngozi	Busiga	Kididiri	6,98
Kayanza	Matongo	Kinyovu	6,98
Gitega	Itaba	Kirambi	6,96
Kayanza	Matongo	Kivumu	6,95
Kayanza	Kabarore	Gikingo	6,95

Province	Commune	Colline	INFORM Risk Index Score
Cibitoke	Rugombo	Ruvumera	6,94
Muyinga	Butihinda	Rushombo	6,94
Cibitoke	Bukinanyana	Nderama	6,94
Cibitoke	Rugombo	Kagazi	6,94
Muramvya	Muramvya	Kirama	6,93
Bubanza	Bubanza	Buhororo	6,92
Ngozi	Gashikanwa	Gatare	6,92
Kirundo	Bugabira	Kiri	6,92
Rumonge	Buyengero	Rubirizi	6,91
Cibitoke	Bukinanyana	Kibati	6,91
Muramvya	Rutegama	Cumba	6,89
Muyinga	Muyinga	Murama	6,89
Cibitoke	Mabayi	Gahoma	6,89
Gitega	Ryansoro	Ndava	6,88
Cibitoke	Rugombo	Karamira	6,88
Ngozi	Nyamurenza	Gikingo	6,88
Karuzi	Mutumba	Kigoma	6,88
Muyinga	Mwakiro	Mukungu	6,88
Cibitoke	Buganda	Ruhagarika	6,88
Bubanza	Bubanza	Muhenga	6,87
Gitega	Gitega	Higiro	6,87
Cibitoke	Murwi	Ngoma	6,86
Ruyigi	Butaganzwa	Nyamugari	6,86
Ruyigi	Ruyigi	Kigamba	6,86
Kirundo	Vumbi	Gahe	6,86
Kirundo	Kirundo	Nyabibugu	6,86
Bubanza	Gihanga	Buramata	6,85
Bubanza	Bubanza	Gitanga	6,85
Cibitoke	Murwi	Butega	6,85
Kirundo	Ntega	Susa	6,85
Kirundo	Busoni	Higiro	6,85
Kirundo	Gitobe	Gihinga	6,85
Kirundo	Kirundo	Runyonza	6,85
Kirundo	Ntega	Murungurira	6,84
Mwaro	Rusaka	Gasenyi	6,83
Ruyigi	Ruyigi	Bunogera	6,82
Kirundo	Bwambarangwe	Mukenke	6,82
Mwaro	Rusaka	Mahonda	6,81
Cibitoke	Mabayi	Mayuki	6,81
Kirundo	Kirundo	Centre-Urbain	6,81
Kirundo	Busoni	Kigoma	6,81

Province	Commune	Colline	INFORM Risk Index Score
Cibitoke	Murwi	Mushanga	6,80
Rumonge	Burambi	Maramvya	6,79
Muramvya	Mbuye	Kabuye	6,79
Ngozi	Nyamurenza	Kigina	6,79
Bubanza	Rugazi	Rugazi	6,78
Gitega	Gitega	Mirama	6,78
Rutana	Giharo	Gitanga	6,78
Muyinga	Gashoho	Gisebeyi	6,78
Rumonge	Muhuta	Gitaza	6,78
Bubanza	Rugazi	Kayange	6,77
Ruyigi	Butaganzwa	Gikwiye	6,77
Kirundo	Ntega	Rushubije	6,77
Kirundo	Kirundo	Karamagi	6,77
Muyinga	Gasorwe	Jani	6,77
Kayanza	Gahombo	Gasave	6,76
Muyinga	Mwakiro	Rurtyazo	6,76
Makamba	Vugizo	Kagege	6,75
Bubanza	Mpanda	Gifurwe	6,75
Cibitoke	Mugina	Marumpu	6,75
Kirundo	Ntega	Bugorora	6,75
Ngozi	Kiremba	Ruhata	6,74
Kirundo	Ntega	Gisitwe	6,74
Makamba	Nyanza-Lac	Mukimba	6,73
Bubanza	Musigati	Ntamba	6,73
Cibitoke	Rugombo	Munyika	6,73
Kayanza	Rango	Gatare	6,73
Gitega	Itaba	Kibogoye	6,73
Karuzi	Shombo	Kiyange	6,73
Karuzi	Nyabikere	Masama	6,73
Gitega	Ryansoro	Kibaya	6,72
Ngozi	Ruhororo	Gitaramuka	6,72
Muyinga	Gasorwe	Karira	6,72
Cibitoke	Buganda	Kaburantwa	6,72
Bujumbura	Mukike	Nyarumanga	6,71
Cibitoke	Buganda	Muremera	6,71
Muramvya	Mbuye	Rwuya	6,71
Cankuzo	Cendajuru	Kibande	6,71
Rumonge	Buyengero	Kirama	6,70
Bururi	Rutovu	Munyinya	6,70
Karuzi	Bugenyuzi	Munyinya	6,70
Kirundo	Kirundo	Rugero	6,70

Province	Commune	Colline	INFORM Risk Index Score
Cibitoke	Bukinanyana	Nyamyeha	6,69
Muramvya	Mbuye	Kigina	6,69
Kirundo	Gitobe	Marembo	6,69
Cibitoke	Bukinanyana	Nyarubugu	6,69
Bujumbura	Isare	Kibuye	6,68
Cibitoke	Mugina	Mwarangao	6,68
Muramvya	Mbuye	Murehe	6,68
Kirundo	Kirundo	Mataka	6,68
Kirundo	Gitobe	Burwana	6,67
Bubanza	Gihanga	Buringa	6,67
Makamba	Mabanda	Musenyi	6,66
Ngozi	Kiremba	Gahororo	6,66
Kayanza	Kabarore	Tondero	6,66
Makamba	Nyanza-Lac	Ruvumera	6,65
Gitega	Bugendana	Carire	6,65
Kirundo	Ntega	Rukore	6,65
Bubanza	Musigati	Rugeyo	6,65
Cibitoke	Murwi	Kivumvu	6,64
Gitega	Giheta	Kibande	6,64
Ruyigi	Kinyinya	Musumba	6,64
Karuzi	Bugenyuzi	Muramba	6,64
Kirundo	Ntega	Gihome	6,64
Mwaro	Kayokwe	Maramvya	6,63
Mwaro	Nyabihanga	Muyange	6,63
Gitega	Ryansoro	Murama	6,63
Karuzi	Bugenyuzi	Rwimbogo	6,63
Kirundo	Kirundo	Mwenya	6,63
Kirundo	Gitobe	Butahana	6,63
Muyinga	Butihinda	Rabiro	6,63
Rumonge	Buyengero	Mujigo	6,62
Gitega	Buraza	Gicumbi	6,62
Gitega	Itaba	Mugitega	6,62
Karuzi	Nyabikere	Nyenzi	6,62
Kirundo	Vumbi	Rugeri	6,62
Karuzi	Buhiga	Ruyaga	6,62
Rumonge	Buyengero	Banda	6,61
Bujumbura	Mukike	Ruhororo	6,61
Muramvya	Muramvya	Gatwaro	6,61
Bubanza	Bubanza	Muhanza	6,61
Makamba	Kayogoro	Sampeke	6,61
Ngozi	Nyamurenza	Shoza	6,61

Province	Commune	Colline	INFORM Risk Index Score
Kirundo	Vumbi	Nyagatovu	6,61
Kirundo	Gitobe	Rungazi	6,61
Makamba	Nyanza-Lac	Mukerezi	6,61
Bujumbura	Isare	Rutegama	6,60
Bujumbura	Mutimbuzi	Rubirizi	6,60
Kayanza	Butaganzwa	Ninga	6,60
Ruyigi	Butaganzwa	Rugongo	6,60
Ruyigi	Nyabitsinda	Mago	6,60
Rumonge	Rumonge	Rumonge	6,60
Makamba	Nyanza-Lac	Muyange	6,59
Gitega	Giheta	Gasunu	6,59
Muyinga	Gashoho	Nkohwa	6,59
Kirundo	Gitobe	Gasuga	6,59
Muyinga	Butihinda	Masaka	6,59
Kirundo	Busoni	Rutabo	6,59
Kirundo	Busoni	Nyagisozi	6,59
Gitega	Gishubi	Yanza	6,58
Cibitoke	Buganda	Nimba	6,58
Cibitoke	Murwi	Kabuye	6,58
Cibitoke	Bukinanyana	Bihembe	6,58
Gitega	Giheta	Kaguhu	6,58
,Rutana	Gitanga	Gisenyi	6,58
Karuzi	Gihogazi	Nyamiyaga	6,58
Ngozi	Marangara	Kigoma	6,58
Kirundo	Vumbi	Gasura	6,58
Ruyigi	Butezi	Muyange	6,58
Gitega	Bugendana	Bitare	6,57
Karuzi	Gitaramuka	Nyarutovu	6,57
Muyinga	Gashoho	Bwisha	6,57
Kirundo	Ntega	Runyankezi	6,57
Kirundo	Vumbi	Gashingwa	6,57
Kirundo	Vumbi	Kirima	6,57
Kirundo	Vumbi	Rwamikore	6,57
Kirundo	Kirundo	Gikuyo	6,57
Kirundo	Kirundo	Kinyangurube	6,57
Kirundo	Vumbi	Kabirizi	6,57
Muyinga	Butihinda	Gahehe	6,57
Muyinga	Gashoho	Buvumbi	6,57
Kirundo	Busoni	Nyabugeni	6,57
Bujumbura	Mukike	Rukina	6,56
Gitega	Giheta	Gishuha	6,56

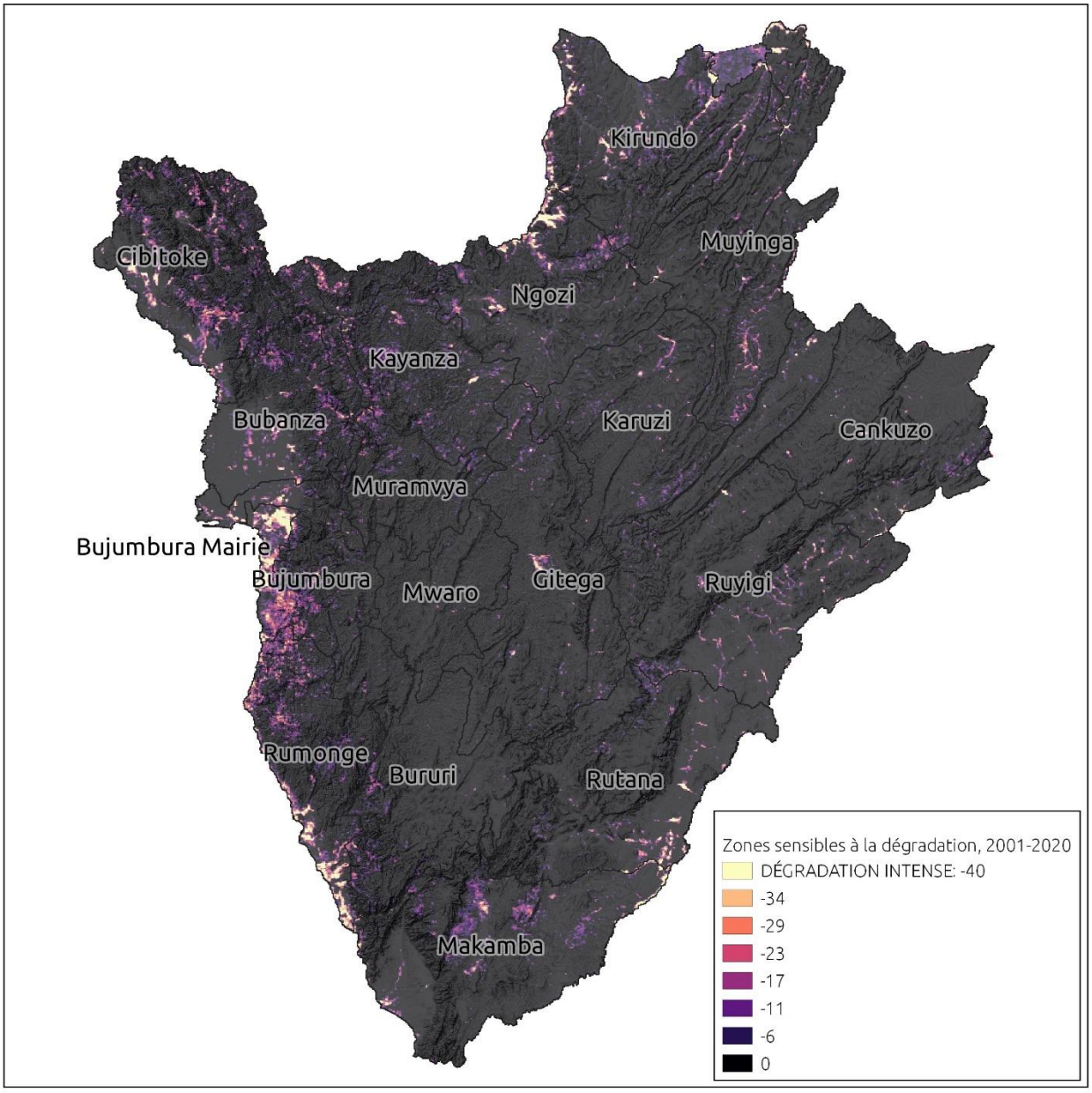
Province	Commune	Colline	INFORM Risk Index Score
Ngozi	Kiremba	Ruhama	6,56
Kirundo	Vumbi	Butsimba	6,56
Kirundo	Vumbi	Canika	6,56
Kirundo	Bwambarangwe	Kibonobono	6,56
Kirundo	Busoni	Nyakizu	6,56
Kirundo	Busoni	Buhimba	6,56
Kirundo	Bugabira	Rugasa	6,56
Rutana	Mpinga-Kayove	Gihinga	6,55
Muyinga	Gasorwe	Kaguhu	6,55
Kirundo	Vumbi	Kiraro	6,55
Kirundo	Vumbi	Rwimanzovu	6,55
Kirundo	Busoni	Kibonde	6,55
Kirundo	Bwambarangwe	Mutarishwa	6,55
Kirundo	Busoni	Kumana	6,55
Kirundo	Busoni	Gatete	6,55
Bujumbura	Mutimbuzi	Maramvya	6,54
Cibitoke	Buganda	Mwunguzi	6,54
Kayanza	Matongo	Murambi	6,54
Gitega	Bugendana	Mirama	6,54
Kirundo	Vumbi	Kabuye-Gitanga	6,54
Muyinga	Gashoho	Mirwa	6,54
Kirundo	Ntega	Mugendo	6,54
Cibitoke	Mabayi	Rutorero	6,54
Makamba	Kayogoro	Mayange	6,54
Bubanza	Bubanza	Karinzi	6,53
Bujumbura	Mubimbi	Kiziba	6,53
Bubanza	Musigati	Rushiha	6,53
Kayanza	Butaganzwa	Muremera	6,53
Gitega	Bukirasazi	Kibuye	6,53
Karuzi	Gihogazi	Kibezi	6,53
Kirundo	Kirundo	Ceru	6,53
Kirundo	Bugabira	Gaturanda	6,53
Bubanza	Bubanza	Zina	6,52
Cibitoke	Murwi	Mahande	6,52
Gitega	Giheta	Gisarara	6,52
Ngozi	Tangara	Musakazi	6,52
Ngozi	Kiremba	Kivoga	6,52
Kirundo	Bugabira	Gitwe	6,52
Kirundo	Kirundo	Yaranda	6,52
Kirundo	Bugabira	Nyamabuye	6,52
Kirundo	Kirundo	Bugera	6,52

Province	Commune	Colline	INFORM Risk Index Score
Bujumbura	Kabezi	Migera	6,52
Rumonge	Burambi	Gishiha	6,51
Bujumbura	Mugongomanga	Centre-Urbain	6,51
Bubanza	Bubanza	Mugimbu	6,51
Kayanza	Kabarore	Nyamisagara	6,51
Gitega	Giheta	Nyarunazi	6,51
Muyinga	Gashoho	Gisanze-Rugerero	6,51
Kirundo	Vumbi	Nyakibanda	6,51
Kirundo	Busoni	Mukerwa	6,51
Kirundo	Busoni	Marembo	6,51
Kayanza	Kabarore	Rukere	6,51
Rumonge	Bugarama	Kagoma	6,50
Bujumbura	Mutimbuzi	Rukaramu	6,50
Bururi	Rutovu	Gihanga	6,50
Mwaro	Gisozi	Gatare	6,50
Cibitoke	Rugombo	Rugeregere	6,50
Ngozi	Tangara	Kigomero	6,50
Kirundo	Vumbi	Bwinyana	6,50
Kirundo	Bugabira	Nyabikenke	6,50
Kirundo	Vumbi	Mbasi	6,50
Karuzi	Gitaramuka	Rubuga	6,49
Kirundo	Vumbi	Rwisuri	6,49
Muyinga	Gashoho	Gisabazuba	6,49
Kirundo	Bugabira	Nyakarama	6,49
Cibitoke	Murwi	Gasheke	6,48
Rutana	Rutana	Maramvya	6,48
Cankuzo	Gisagara	Rabiro	6,48
Kirundo	Ntega	Muyinza	6,48
Kirundo	Gitobe	Gahosha	6,48
Kirundo	Gitobe	Santunda	6,48
Ngozi	Marangara	Kagot	6,48
Bururi	Mugamba	Kivumu	6,47
Cibitoke	Mabayi	Rugongo	6,47
Gitega	Bugendana	Rushanga	6,47
Muyinga	Gashoho	Kagari	6,47
Muyinga	Gashoho	Bubambira	6,47
Kirundo	Kirundo	Gihosha	6,47
Muyinga	Muyinga	Butihinda	6,47
Muyinga	Gashoho	Nyagatovu	6,47
Kirundo	Gitobe	Mirwa	6,47
Kirundo	Busoni	Mugobe	6,47

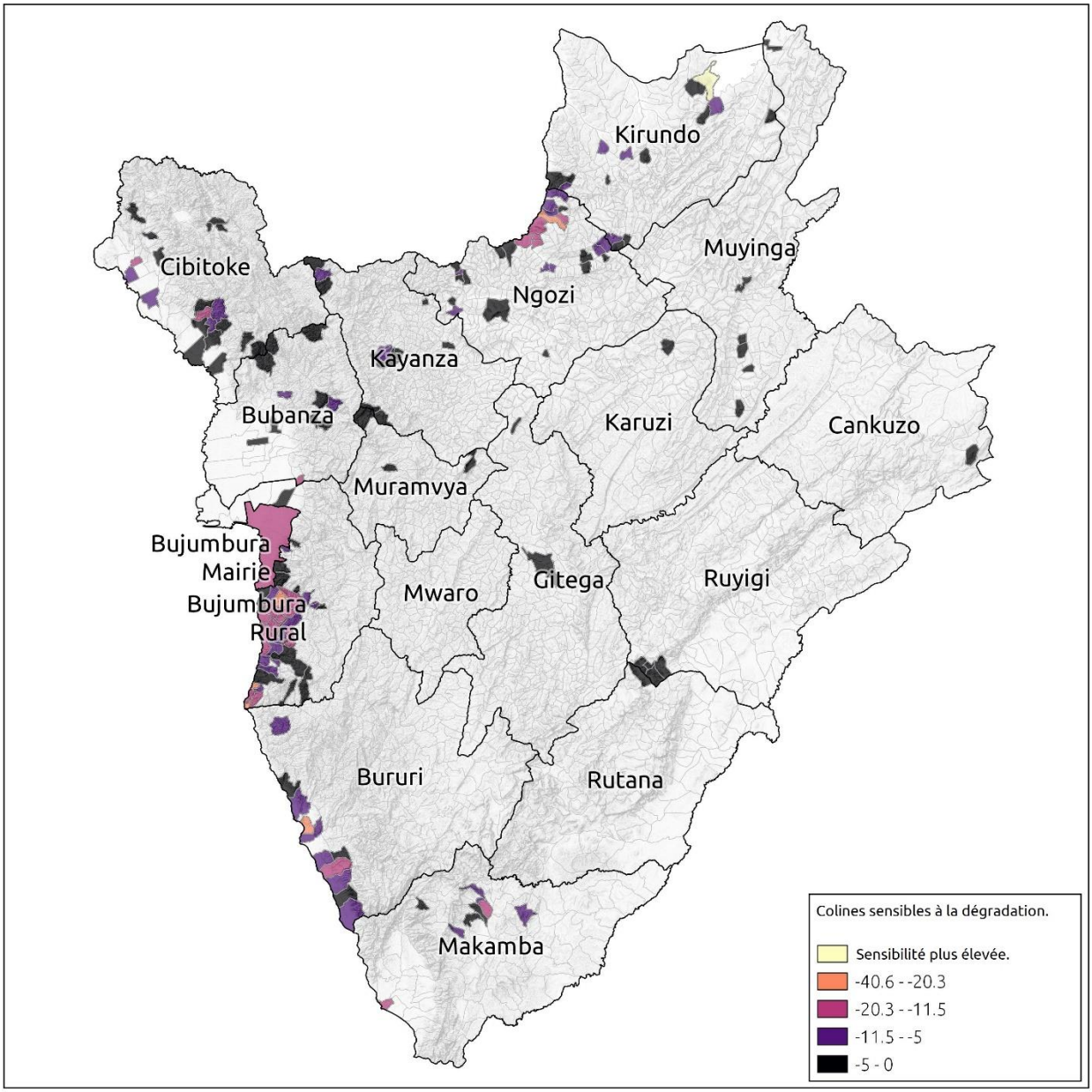
Province	Commune	Colline	INFORM Risk Index Score
Muyinga	Giteranyi	Mihigo	6,47
Kirundo	Bugabira	Kiyonza	6,47
Ngozi	Marangara	Nyamurenge	6,47
Ngozi	Marangara	Nyunzwe	6,47
Cibitoke	Bukinanyana	Rusenda	6,47
Rumonge	Burambi	Murara	6,46
Rumonge	Muhuta	Kinyovu	6,46
Cibitoke	Murwi	Kahirwa	6,46
Gitega	Bugendana	Nyamagana	6,46
Ngozi	Tangara	Mbasi	6,46
Rumonge	Bugarama	Kayombe	6,45
Bujumbura	Mukike	Ruzibazi	6,45
Muramvya	Rutegama	Rutegama	6,45
Gitega	Giheta	Gahuga	6,45
Ngozi	Busiga	Bitambwe	6,45
Ngozi	Tangara	Nkanda	6,45
Ngozi	Tangara	Nyarugati	6,45
Kirundo	Gitobe	Tonga	6,45
Muyinga	Butihinda	Zaga	6,45
Gitega	Giheta	Gisuru	6,44
Bubanza	Mpanda	Nyomvyi	6,44
Cibitoke	Buganda	Cunyu	6,44
Cibitoke	Mugina	Bwayi	6,44
Karuzi	Mutumba	Mutara	6,44
Ngozi	Marangara	Muhu	6,44
Kirundo	Busoni	Rurende	6,44
Ruyigi	Butezi	Nkongwe	6,44
Rumonge	Burambi	Gitaramuka	6,43
Mwaro	Ndava	Higiro	6,43
Gitega	Nyanrusange	Muzima	6,43
Bujumbura	Mutimbuzi	Muyange	6,43
Cibitoke	Mabayi	Nyabungere	6,43
Kayanza	Matongo	Gitwe	6,43
Karuzi	Gihogazi	Gasenyi	6,43
Ruyigi	Nyabitsinda	Muramba	6,43
Ngozi	Kiremba	Cayi	6,43
Kirundo	Vumbi	Kigobe	6,43
Muyinga	Gasorwe	Ngogomo	6,43
Muyinga	Gashoho	Musama	6,43
Kirundo	Gitobe	Shore	6,43
Kirundo	Busoni	Gitete	6,43

Province	Commune	Colline	INFORM Risk Index Score
Rumonge	Burambi	Gitongwe	6,42
Bujumbura	Kanyosha	Ruvumu	6,42
Bujumbura	Mukike	Mutobo	6,42
Cibitoke	Bukinanyana	Gahabura	6,42
Cibitoke	Bukinanyana	Nyangwe	6,42
Gitega	Mutaho	Mwumba	6,42
Muyinga	Gashoho	Gishambusha	6,42
Kirundo	Vumbi	Nyamyumba	6,42
Muyinga	Gasorwe	Karimbi	6,42
Muyinga	Gashoho	Gisanze-Muzingi	6,42
Kirundo	Busoni	Rurira	6,42
Rumonge	Buyengero	Kanyinya	6,41
Bujumbura	Isare	Sagara	6,41
Muramvya	Rutegama	Camumandu	6,41
Gitega	Nyanrusange	Kabimba	6,41
Mwaro	Nyabihanga	Muyebe	6,41
Cibitoke	Bukinanyana	Burimbi	6,41
Kayanza	Rango	Karama	6,41
Kayanza	Kayanza	Kibingo	6,41
Rutana	Musongati	Nyabisindu	6,41
Gitega	Bugendana	Cishwa	6,41
Kirundo	Vumbi	Nyamivuma	6,41

Appendix 5. Map of Degradation Hotspots, 2001–2020



Appendix 6. Map of *Collines* Most at Risk of Land Degradation



Appendix 7. A Model for Developing and Costing Community-Level Climate Action Plans (CCAPs)

The Community-Level Climate Action Plans (CCAPs) for the four sample *collines* identified and prioritized community-designed resilience-building activities intended to reduce vulnerabilities; increase coping capacities and resources; and promote economic empowerment, social cohesion, and inclusion, with special attention to people who are particularly disadvantaged or marginalized, such as women (including widows), children, elders, internally displaced persons, returnees, and people with physical and mental disabilities or illnesses. The activities costed out are meant to address the most pressing climate risk reduction and livelihood strengthening needs/challenges.

For Bugarama *colline*, in Rumonge province, for example, we costed out:

a) Watershed-level landscape restoration through terracing and *colline*-wide tree planting interventions (NBS/ecosystem-based adaptation) to prevent erosion, landslides, and floods during heavy rain;
b) Land certification and registration of all plots in the *colline*, including 100 percent land titling for women-owned plots;
c) Empowering farmer cooperatives to provide competitive grants for investing in diversified livelihood options such as petty trading, renewable charcoal production, and energy-efficient cookstoves;
d) Distribution of livestock (cows, goats, pigs, chickens, etc.) to households with the capacity to enhance breeding, supplement household income, strengthen food security, and generate organic fertilizer (manure) to increase crop yields;
e) Construction of climate-smart infrastructure, including improved housing for the most disadvantaged subgroups, establishment of schools, markets, health centers, and provision of clean energy supplies (community-based solar projects) and improved water, sanitation, and hygiene conditions for all;
f) Distribution of pesticides and deployment of extension workers to support farmers with information on best farming practices and learn from local experiences;
g) Training of farmers, fishers, and pastoralists, including women, people with disabilities, and youth, on climate change impacts and locally appropriate adaptation strategies;
h) Organizing community members into climate and disaster risk management committees—to work with local authorities, national institutions, and international partners to develop and implement *colline*-level plans. We found local residents are willing to provide unpaid labor to lead adaptation and resilience-building activities, including disaster response committees, stockpiling committees, and natural resources management committees.

Table A7.1 summarizes the results of the costing exercise.

Table A7.1. Costing out the sample Bugurama Community-Level Climate Action Plan

Activity	**Community Contribution**	**External Support**	**Geographic Scale**	**Cost ($1,000)**
Organizing and raising awareness (e.g., setting up committees for climate change awareness, natural resources management, safer shelter, and water, sanitation, and hygiene)	Labor (unpaid) and time	Financial, technical, and technology, and communication resources	Colline	283.97
Strengthening social resilience, cohesion, and inclusion (e.g., social solidarity, community dialogue, support to local institutions/cooperatives)	Labor (unpaid) and time	Civil society involvement, counseling,	Colline	153.33
Enhancing *colline*-based economic resilience (e.g., digitized cash-for-work; training on best farming practices, energy-saving stoves; water, land, and forest resources management; and leadership development within cooperatives)	Labor (unpaid) and time	Financial, training, and materials	Colline	229.68
Making farms more productive and resilient for increased economic benefits (e.g., by shifting to drought-resistant crop varieties and breeding resilient livestock breeds, and providing inputs)	Land, labor (unpaid), and time	Financial, tools and technology, inputs, seedlings, extension services	Colline	303.87
Developing *colline*-based contingency plans (e.g., savings, contingency funds, food/seed banking, relief during crises)	Household savings, labor, food banking	Financial, technical, seeds, institutional, and technological	Colline	209.47
Promoting landscape restoration on degraded lands (e.g., terracing and tree planting)	Land, labor (cash for work), and time	Financial, tree nurseries, expert advice, materials	Watershed	310.62
Introducing sustainable watershed management (e.g., developing a *colline*-level watershed plan and protecting water sources—Rubizi I, Rubizi II, Nyamwari, and Rutabibiro-Nyagare) using both gray and green infrastructure for water conservation)	Labor (cash for work) and time	Financial, technical, material, and technological support	Watershed	80.74
Enhancing evidence-based policy formulation for design, implementation, and monitoring of resilience-building interventions, including legal framework for inter-ministerial coordination and reforms	Participation of national & local government, technical institutions, think tanks	Financial, technical, material, technological, etc.	National/ *Colline*	147.50
Land certification and registration on digitized national cadaster, including titling for women-owned plots	Participation of both men and women	Financial, technical, material, technological, etc.	National/ *Colline*	100.00
Total cost				**1,519.18**
With assumption of foreign exchange depreciation at 20% and 16% inflation				1,819.18

A7.1 Methodology for CCAP development

The World Bank and the Government of Burundi, with support from the Red Cross Climate Centre in fieldwork design, developed and tested a step-by-step methodological framework for creating CCAPs. The objective is to promote community-centric resilience-building with the proactive and inclusive participation of all subgroups in the identification of hazards, assessment of vulnerabilities to climate change, and evaluation of existing coping capacities. This approach helps ensure that the adaptation actions prioritized reflect communities' own perception of urgent needs.

Through a series of participatory field activities, facilitated by carefully selected and trained enumerators, *colline* residents are supported in developing a shared understanding of their vulnerabilities as well as their strengths and capacities, and then a shared vision for building resilience, including specific priority interventions.

The materials presented below illustrate the process for the development of the CCAP in Bugarama *colline*, in Rumonge province.

HISTORICAL PROFILING (MEN'S FOCUS GROUP)

HAZARD PRIORITIZATION

SEASONAL CALENDAR (WOMEN'S FOCUS GROUP)

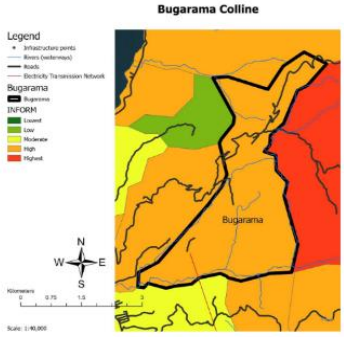
RESILIENCE STAR ASSESSMENT

BUGARAMA COLLINE CLIMATE ACTION PLAN (CCAP)

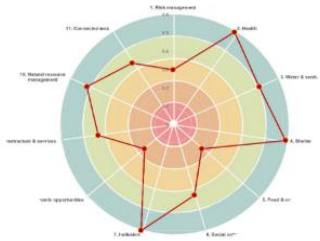
Bugarama Colline is located in Rumonge Province, 3 kilometers from Lake Tanganyika, with nearly 4,000 inhabitants (628 households) – 56% women and 60% under 18 years old. The average elevation of the landscape is 1400 meters above the global mean sea level. According to Burundi climate and fragility ASA results, **Bibare's climate and fragility risk score falls under the "Medium Risk" category relative to colline across Burundi's landscape.**

HAZARD EXPOSURE

Bugarama colline is highly exposed to numerous climate related hazards, including intense precipitation or heavy rains (primary hazards). In Bugarama, community ranked hazard exposure based on severity of impacts on their lives, livelihoods, and properties, including infrastructure and farmland. **Heavy rains was ranked as the top hazard followed by conflict. Heavy rains trigger multiple secondary hazards such as dreadful landslides, frequent floods, and increasing land degradation (soil erosion).**



RESILIENCE STAR



In Bugarama, an assessment of 11 dimensions of resilience reveals very low access to nutritious food and limited economic and employment opportunities. The colline's resilience are highest for social inclusion, availability of shelter (although vulnerable to climate risks), and access to some basic health care services (see Figure above).

OUR RESILIENCE VISION

Bugarama colline envisions a restored landscape with quality crop, livestock, and rich biodiversity, protected from land degradation, less vulnerable to climate change impacts, and enhanced coping capacity, especially for infrastructure provision and resilience. **This proposed CCAP has costed US$1.8 million worth of investment to contribute to strengthening climate resilience and promoting sustainable growth and development in Bugarama.**

VULNERABILITY

About 98% of Bugarama inhabitants are highly vulnerable to climate change impacts, land degradation, and conflict. Poverty and unemployment rates are very high, while the intra-colline inequality gap is relatively low. The most vulnerable subgroups are farmers, women, widows, elders, children, riverside communities, disabled members, internally displaced persons (IDPs), and business owners. Infrastructure vulnerability (houses, schools, health centers, and roads), livestock, farmland, and biodiversity richness are quite high.

COPING CAPACITY

Nearly 99% of inhabitants lack the basic coping ability to withstand and recover from climate change impacts. However, there is enough human capital (unskilled) willing to offer free and paid labor to support resilience development projects. Occasionally, they receive support from government, but social solidarity and support from neighbors are more reliable than external support. Secondly, they also have some available water, and land for crop and livestock production and some trees for protecting their houses.

Access to public services is low, victims of post-traumatic stress disorders (PTSD) have no resources, returnees have limited social and economic support, and farmers have no access to loans, insurances, and farm inputs such as tools, seeds, pesticides, etc.

HISTORICAL PROFILE

YEAR	Months	CLIMATE EVENT AND IMPACTS
1978, 2008, 2014, 2015, 2018,-2022	March/ April	**HEAVY RAINS** in recent years have increased in frequency, intensity, and severity. Heavy downpours trigger more deadly landslides and frequent flooding, which destroys private properties, and public infrastructure in Bugarama.
1972 – 1976, 1993 – 2009, 2015, and 2020	Jan-Dec.	**CONFLICTS** in Bugarama led to chronic economic hardship. Conflict also led environmental degradation, biodiversity loss (wild animals killed and fled) and deforestation. Land related conflict is also escalating in Bugarama as Burundians who fled the country returned home from neighboring countries. Degradation of land by climate change impacts also exacerbate conflict over the remaining arable land. Example, there is an ongoing land conflict between Monge National Reserve and surrounding population.
1989, 2006, 2008-2022	Jan-Dec.	**PEST INFESTATION** incidences have been increasing since 2006 and and from 2008, it has been occurring. Between 1993 – 2000, the Bugarama colline has been severely affected by bean weevil infestation, which contributed to malnutrition, reduced harvests, and household income. Also, in 2005 and 2014, cassava Mozaic affected cassava plantations. Similarly, from 2012 to date, there was another Banana wilt infestation. Additionally, from 2002 to date, maize farms were affected by "Automed Disease."
1991, 1992, 2000, 2008, 2021	Oct, Nov. Dec.	**DROUGHTS** have been variable and less frequent than floods and landslides (droughts events remembered were 1992, 1991, 2000, 2008, 2021). The environmental impacts of droughts led to drying out of trees and vegetation cover , thus, no feed for livestock.
1961, 2015, 2018- 2022	March, April, May	**FLOODING** is a secondary hazard caused by heavy rains. Due to recent rise in heavy downpours, flooding increase in frequency, intensity, and severity in Bugarama. Flooding can also trigger more deadly landslides, destruction of private properties, and public infrastructure (e.g., schools, health centers, markets, roads etc.)

SEASONAL CALENDAR

EVENT	QUARTER 1	QUARTER 2	QUARTER 3	QUARTER 4
Preparing gardens	January, February		August	
Cultivation	February, March		September	November
Irrigation based cultivation		June	July.	
Harvesting	January	June		December
Crop destruction		March, April		November
Bean weevil infestation		April		December
Cassava Mozaic				November
Cassava Mozaic	Jan-March	April-June	July-September	November-December
Maize Pests				
Banana wilt		June	July-September	
Flooding	March	April, May		
Landslides	March	April		